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To identify Chinese university patents´ transferability: Indicators from the perspective of bibliometrics

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ABSTRACT

It is of great significance to study the indicators of university patents' transferability for improving the efficiency of the University Technology Transfer Office and promoting university patent transfer. Based on the in-depth analysis of the existing research, this paper finds that patent quality is the inherent decisive factor of patent transferability. Combining with the evaluation indexes of patent quality and the bibliometrics characteristics of university patents, 9 indicators are proposed to indicate the transferability of university patents. Based on the patent transfer data of 35 Chinese universities, this paper analyzes and verifies the potential indicators of patent transfer using the binary logistic regression method. The results show that the number of inventors and the number of non-patent document citations positively predict the transferability of university patents, while the examination duration negatively predicts transferability. The effects of other indicators on transferability need to be discussed considering the actual situation and specific technology fields.

KEYWORDS

University patent transfer; Patent quality; Transferability characteristics; Patent citation

1 Introduction

Universities play a key role as knowledge creators in the "three-helix structure" of industry-university-research innovation (Etzkowitz & Leydesdorff,1998) and are an important driving force for regional innovation, social development, and economic growth (Luan et al., 2010). With the rapid development of knowledge economy, universities are no longer limited to traditional innovative tasks such as education and fundamental research (Agrawal & Henderson, 2002; Henderson et al., 1998; Rosenberg & Nelson, 1994), but more directly and broadly involved in the process of innovative production. As the basic education and scientific research units, universities do not have the ability to actually manufacture industrial products. University patents mainly realize the transition from innovative achievements to real productivity and from technological value to economic value through patent transfer (Dahlborg et al., 2017).

University patent transfer is a common topic in the world. The United States and Europe witnessed a wave of university patents and transfers in the 1980s and 1990s, especially in medicine and some engineering fields (Sterckx, 2011). According to the AUTM (the Associa-

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tion of University Technology Managers) of the U.S., 198 universities were granted more than 7,600 patents in 2018, and more than 1,000 companies have launched 828 new products based on these patents. From 1991 to 2010, these universities accumulated a commercial income of about $9.56 billion (Hsu et al., 2021).

To promote university patent transfer, the Chinese government has issued a series of policies and regulations, such as Opinions on Improving the Quality of Patents in Colleges/Universities and Promoting Patent Transfer and Application (2020). These "Chinese Bayh-Dole Acts" encouraged and supported 6,841 university patents getting transferred, and the corresponding income was about 2.8 billion yuan in 2020. However, in the same year, the total number of patents granted by Chinese universities reached more than 140,000, and the investment in science and technology was about 245.8 billion yuan. There are still a lot of scientific achievements left untransferred and only circulating among the scientific community without being applied in the industrial world. The number of patents transferred in Chinese universities does not match the huge number of applications, and the economic benefits created by patent transfer do not match the high investment in scientific research. These mismatches have become restricting factors to further improve the innovation level of universities and even the whole society. Insufficient transferability is an important reason for low transfer efficiency, which has led to the inadequate realization of the value of a large number of Chinese universities' innovative resources. As a result, the assessment of patent transferability has become an indispensable part of the innovation management of universities.

The transferability of university patents usually refers to the possibility of university patents being diffused and passed on to enterprises or individuals in the form of patent rights transfer. Transferability is the basis for whether patents could link university innovation resources with industry needs, but from the perspective of innovation management in universities, technology transfer office (hereafter referred as TTO) do not influence patent transfer by directly improving patent transferability or quality through institutional or individual path. However, the assessment of patent transferability made by TTO determines the prospect of patent transfer. In the other word, if TTO believes that a patent is transferable, they will make efforts to find a matching technology market for it, but if they consider a patent is not transferable, even though the patent may be needed in the market, it is likely to be ignored and poorly supported by TTO.

Only by having a clear and definite grasp of the patents held by the university, can TTO effectively find suitable transfer paths for university patents, therefore promote the optimization of institutional and individual factors, and finally realize the ultimate goal of promoting patent transfer. The questions then arise regarding how to define transferability? That is, to select potential transferable patents can be extremely difficult given the huge amount of university patents, the wide technology fields involved and the limited management capability of the TTO. How to evaluate the transferability of university patents, that is, how to identify those patents with transferability potential from the massive amount of university patents? Whether or not do these patents have significant characteristics different from other patents? And how to capture these characteristics? These questions have become the realistic requirements of utilizing university patents, promoting connection between university research and market demand, and realizing innovation-driven development. The answers to the above questions may help us achieve a scientific assessment of transferred patents and improve the accuracy and efficiency of the work of university TTO.

This paper proposes some bibliometric characteristics that can be used to indicate the

transferability of university patents by comparing the transferred patents and those not. It provides objective and reliable patentometrics evidence and workable indicators for university TTO to identify potential transferable patents, promote patent transfer, and formulate or adjust related R&D evaluation strategies.

2 Literature Review

There are many factors that affect the transferability of patents, such as innovation policy (Gong & Peng, 2018), the incentive mechanism of scientific research (Baldini et al., 2007; Macho-stadler et al., 2007), technology transfer management methods (Ismail et al., 2011), university organizational structure and laboratory scale (Bercovitz et al., 2001), and campus atmosphere (Owen-Smith & Powell, 2001) at the institutional level, and the supportive attitude for patent transfer (Wu et al., 2015), relevant background and experience (Bercovitz and Feldman, 2008), and motivation (Daniel & Alves, 2020) at the individual level. Most of the conclusions drawn by these studies are based on the assumption that patents are transferable, that is, when patents have transferability, the university TTO would push forward the transfer process by optimizing management methods and stimulating participation of the patentee(s). In reality, not all university patents have transferability, and in the final analysis, whether a patent can be transferred depends largely on the quality of the patent.

It can be inferred that transferred patents are high quality patents to some extent considering the technical value and economic value of patents. When companies are looking for related technologies, they tend to choose the most novel and practical patents. That is because in the process of patent transfer, company need to pay intellectual property fee to the patentee(s), so for the economic reasons, only when the expected benefits exceed the costs, companies will choose to obtain the right to patents. Therefore, only those high-quality patents will be selected as trading objects and get transferred.

Transferable patents can be considered high-quality patents to some extent. For the evaluation of patent quality, academics and the industry already have mature indicators. For example, Squicciarini et al. (2013) put forward 13 evaluation indicators, such as number of international patent classifications (hereafter referred as IPC), patent scope, number of family patents, number of claims and number of citations. Dialog's Innography analytics tool estimates patent strength based on quantitative metrics such as number of claims, number of backward/forward citations, family size, and litigation data. Putnam (1996) confirmed the impact of the number of inventors, examination duration and the number of family patents on patent quality. Choi et al. (2015) used social network analysis to analyze the correlation between the number of citations, number of family patents, number of inventors, number of claims, number of IPC and patent transfer.

Although there are many evaluation indicators of patent quality, few are used in patent transfer research. The selection of patents for technology transfer is more based on expert opinions than objective criteria (Choi et al, 2015). For university TTO, it is almost impossible to find suitable experts to professionally evaluate the transferability of all patents, and therefore also unrealistic for its personnel to conduct these professional evaluations by themselves. This will, on the other hand, lead to potential transferable patents not receiving enough attention and support, while those without technical potential being falsefully regarded as candidates for transfer. For this situation, it is necessary to construct patent transferability evaluation indicator system based on patent quality. Combining existing research on the evaluation indexes of patent quality and the prediction indexes of patent transfer, as well

as the bibliometrics characteristics of university patents, this research selected 9 indicators as listed in Table 1 as the identification indexes of transferable patents:

Table 1 Indicators of university patents' transferability

Indicator	Abbr.	Reference
Number of inventor	NI	Squicciarini et al., 2013
Number of international patent classifications	NIPC	Squicciarini et al., 2013
Number of claims	NC	Marco et al., 2019
Number of family patents (domestic and foreign)	NFP	Putnam, 1996
Number of backward citations	NBC	Kapoor et al., 2016
Number of non–patent document citations	NNDC	/
Number of forward citations	NFC	Bakker, 2017
Number of family patent forward citations	NFPFC	/
Examination duration	ED	Lanjouw & Schankerman, 2004

The number of inventors reflects the technical characteristics of patentees and the impact of individual factors on patent quality and patent transfer. It is generally believed that the greater the number of inventors, the higher the patent quality and the greater the possibility of transfer.

The number of IPCs, number of claims (technological protection scope), and number of family patents (technological jurisdiction) assess the scope of patent protection. The number of IPCs and the number of claims can indicate the scope of the technical field involved in a patent. The larger the scope of the technology, the more abundant the application scenarios of the patent and therefore the more opportunities to realize the transfer. The number of family patents indicates the geographical protection scope of a patent. The larger the scope of the protection proves that the patentee pays more attention to the patent, and the corresponding patent has higher quality and value. Therefore, the number of IPCs, number of claims and number of family patents should be positively related to the possibility of patent transfer.

For patent quality and value evaluation, backward citation and forward citation indicators are indispensable, as patent backward/forward citations contain rich knowledge logic and have special legal meanings. Backward/forward citations can effectively indicate patent quality (although the specific characteristics of these two indications are uncertain and scholars have debated about this for a long time, for example, if it's positively or negatively affected, whether the correlation is linear or non-linear etc.; conclusions vary from sample data and analysis methods). Therefore, the number of backward citations and the number of forward citations can also be used to indicate patent transfer, but the specific relationship needs to be revealed and verified in empirical experiment.

In particular, patent backward citations include citations to non-patent documents, which reflect the degree of scientific relevance of patents, and therefore should be positively related to patent transfer. In addition, patent forward citations can be extended to the number of family patent forward citations, and the citation situation of patent in the world can better reflect the status of patent in the global technology chain.

For patent transfer, time is a factor that must be considered. The examination duration

affects the time point of patent disclosure and its entry into the technology market, and in turn affects the timeliness and availability of patents for industry application. Therefore, examination duration is negatively correlated with patent transfer.

The above points will be verified by empirical analysis in "Empirical Research" section of this paper based on real patent transfer data of Chinese universities. The "Discussion" section will discuss in depth about the function of above indicators on how they will indicate the patent transfer. The "Conclusion" section puts forward some suggestions for promoting university patent transfer and summarizes the advantages and limitations of this research.

3 Empirical Research

3.1 Research design

The empirical analysis can be roughly divided into two stages: The first stage is to verify the viewpoints proposed in the second section of this paper based on the patent transfer data of some Chinese universities. Research methods in this stage mainly include descriptive statistical analysis, Mann-Whitney test (since each patent bibliometrics characteristic index does not obey a specific distribution and the sample data scale is large, Mann-Whitney test in non-parametric test is used to analyze whether the difference degree of each index is significant), and regression analysis (since patent transfer is a binary variable, binary logistic regression analysis is adopted, the process of which includes correlation analysis, collinearity test and linear fitting judgment). The second stage is confirmatory analysis. Patent transfer data samples different from those in the first stage are selected to test the conclusions drew in stage 1 using the same method, so as to avoid the particularity of conclusions caused by sample limitations.

It is worth noting that it takes a certain time interval from patent application to transfer. Studies have shown that only about 5% of patent transfers occur in the year of application, 30% occur within 3 years, 70% within 5 years, and 90% within 7 years. Over time and technological change and development, the probability of patent transfer will gradually decrease. It was believed that the probability of patent transfer after it has been applied for more than 10 years would approach zero. Therefore, when selecting samples of untrans ferred patents, this study chooses patents for invention of which the authorization year is within 2000 to 2010. On the one hand, it excludes patents that have not been transferred yet but may be transferred in the future. On the other hand, selecting patents authorization at least 10 years ago basically ensures that they don't have the possibility to transfer, avoiding confusion between transferred patents and untransferred patents and guaranteeing the validity of the conclusions.

3.2 Data Sources

In this study, 35 "world-class universities" in China are selected as the analysis objects to discuss the patent transfer of universities, because these universities have the best innovation resources such as funds, scientific research faculty, professional equipment and laboratory, etc. Their technological innovation ability is relatively high, and in consequence, their patent number is much higher than other universities in China. Table 2 shows the situation of patents for invention (unless otherwise specified below, hereafter patents refer to patents for invention) obtained by the above-mentioned 35 universities and their transfer situation from 2010 to 2019. The average transfer rate of these 35 universities is 6.65%, higher than the

average university transfer rate of 4.6%, indicating that the patent transfer situation of these 35 universities is in the leading position of Chinese universities.

Table 2 Patents and its transfer situation of 35 Chinese Universities (2010-2019)

University Name	Number of patents	Number of transferred patents	Transfer rate
ZHEJIANG UNIV	16884	717	4.25%
TSINGHUA UNIV	14431	1197	8.29%
HARBIN INST TECHNOL	20791	1165	5.60%
SOUTHEAST UNIV	10508	795	7.57%
SHANGHAI JIAO TONG UNIV	9834	905	9.20%
BEIJING UNIV AERONAUT ASTRONAUT	9168	740	8.07%
S CHINA UNIV TECHNOL	8686	631	7.26%
XI AN JIAO TONG UNIV	7407	816	11.02%
UNIV ELECT SCI TECHNOL CHINA	7247	417	5.75%
HUAZHONG UNIV SCI TECHNOL	7247	351	4.84%
TIANJIN UNIV	7099	570	8.03%
SHANDONG UNIV	6449	236	3.66%
JILIN UNIV	5785	272	4.70%
CENT S UNIV	5658	351	6.20%
CHONGQING UNIV	5470	768	14.04%
DALIAN UNIV TECHNOL	5127	152	2.96%
BEIJING INST TECHNOL	4934	157	3.18%
TONGJI UNIV	4934	224	4.54%
WUHAN UNIV	4388	442	10.07%
SICHUAN UNIV	4385	184	4.20%
NW POLYTECH UNIV	4368	470	10.76%
PEKING UNIV	4191	355	8.47%
NANJING UNIV	3298	256	7.76%
SUN YAT SEN UNIV	3263	195	5.98%
CHINA AGR UNIV	3247	136	4.19%
XIAMEN UNIV	3195	214	6.70%
FUDAN UNIV	3071	152	4.95%
UNIV SCI TECHNOL CHINA	2270	51	2.25%
NANKAI UNIV	1546	86	5.56%
E CHINA NORMAL UNIV	1372	129	9.40%
OCEAN UNIV CHINA	1328	37	2.79%
BEIJING NORMAL UNIV	1106	25	2.26%
LANZHOU UNIV	819	82	10.01%
RENMIN UNIV CHINA	124	8	6.45%
MINZU UNIV CHINA	52	1	1.92%
Total	199682	13287	6.65%

Note: National University of Defense Technology has no relevant data.

The patents and transferred patents of 35 universities from 2010 to 2019 are divided into different technical fields according to IPC subcategories to better define the appropriate breadth and depth of technical fields. After being categorized, it is discovered that both patents and transferred patents are concentrated in G06F, G01N, A61K and other technical fields. The specific number of patents and transferred patents is shown in Table 3. Therefore, G06F (electrical digital data processing technology), which has the largest number of patents and transferred patents, is selected as the source of sample data to ensure the reliability and representativeness of research results.

Table 3 Technical fields of (transferred) patents of 35 universities (2010-2019)

Technical fields	Number of patents	Number of transferred patents
G06F (electrical digital data processing technology)	14042	1049
G01N (testing or analyzing a material by determining its chemical or physical properties)	13194	799
A61K (medical, dental or cosmetic preparations)	6589	639
H04L (transmission of digital information)	7650	538
G06T (general image data processing or generation)	5817	506

The patent data comes from the PatSnap global patent database, which has complete patent data and fast update speed and can better ensure the accuracy and comprehensiveness of patent search results. During the retrieval process, the original patentees are limited to the 35 selected universities, and the patent technology field was limited to G06F. For the transferred patents, a total of 1,049 patents were found and used as a sample and their authorization date was limited to 2010-01-01 to 2019-12-31. Similarly, a total of 1,648 untransferred patents were found and used as a sample of which the authorization date is limited to 2000-01-01 to 2010-12-31. The data retrieval time is September 15, 2021.

3.3 Descriptive statistics

There are a total of 1,049 transferred patents and 1,648 untransferred patents in the G06F technical field from the selected 35 universities. Independent sample Mann-Whitney test was used to compare the differences of each indicators, and the results showed that the significance values of 7 indicators, namely number of inventors, number of IPCs, number of backward citations, number of non-patent document citations, number of forward citations, number of family patent forward citations and examination duration, were less than 0.05, meaning that there are significant differences between transferred patents and untransferred patents in these 7 indicators. The descriptive statistics and Mann-Whitney test results of all indicators are shown in Table 4.

Table 4 Descriptive statistics and Mann-Whitney test results of transferred/untransferred patents

Indicators	Transferred patents		Untransferred patents		Mann–Whitney test	
	Mean	SD	Mean	SD	Z	Sig.
NI	4.86	2.490	4.17	2.114	–7.364	.000
NIPC	1.77	1.080	2.62	7.150	–12.525	.000
NC	4.37	3.559	4.25	3.891	–1.412	.158

Indicators	Transferred patents		Untransferred patents		Mann–Whitney test	
	Mean	SD	Mean	SD	Z	Sig.
NFP	2.08	0.578	2.10	0.969	–1.339	.181
NBC	2.86	2.063	2.56	2.115	–3.471	.001
NNDC	1.38	1.791	0.68	1.107	–10.792	.000
NFC	0.16	0.572	0.34	0.987	–6.535	.000
NFPFC	11.23	14.650	14.67	15.479	–8.023	.000
ED	943.63	265.195	920.22	324.520	–5.975	.000

Among the 9 indicators, the number of claims and the number of family patents did not pass the Mann-Whitney test, and there was no significant difference between transferred patents and untransferred patents in these two characteristics because their significance values are respectively 0.158 and 0.181, which are bigger than 0.05. The significance values of the other 7 indicators are all less than 0.05. Combined with the mean values of each indicator, it could be seen that the number of inventors, number of backward citations, number of non-patented document citations and examination duration of transferred patents are significantly larger than that of untransferred patents, while the number of IPCs, number of forward citations and number of family patent forward citations are significantly smaller than that of untransferred patents.

3.4 Binary logistic regression analysis

Before regression analysis, correlation analysis and collinearity test should be conducted to check whether there is interaction between indicators. The results of correlation analysis and collinearity test are shown in Table 5. It can be seen that Pearson correlation coefficients of 7 indicators are all less than 0.5, and variance inflation factors (VIF) are all greater than 0.7. There is no obvious interaction and collinearity between indicators, which means these 7 indicators can be incorporated into the regression model.

Table 5 Correlation analysis and collinearity test of 7 indicators

Indicators	NI	NIPC	NBC	NPDC	NFC	NPC	ED
NI	1						
NIPC	–.026	1					
NBC	0.018	0.022	1				
NPDC	0.063**	–0.019	–0.088**	1			
NFC	0.039*	0.006	–0.037	–0.048*	1		
NPC	0.032	0.015	–0.020	–0.047*	0.302**	1	
ED	–0.012	0.015	0.091**	0.055**	–0.025	–0.058**	1
Tolerance	0.983	0.996	0.975	0.974	0.904	0.902	0.955
VIF	1.017	1.004	1.025	1.026	1.107	1.108	1.047

Since the dependent variable patent transfer is a dichotomous variable, binary logistic regression model was used to analyze the correlation between indicators and patent transfer. Logistic regression requires a linear relationship between the independent variable and logit (p), so the following tests were performed on the relationship between each indicator and

the dependent variable: calculate the frequency of occurrence when the indicator is Q1 in transferred patents and in untransferred patents respectively, denoted as N1 and N2; calculate the probability of the indicator is equal to Q1 when the patent is transferred: P1=N1/ (N1+N2), and the probability when the patent is not transferred is 1-P1; finally, calculate logit(p)=ln[P1/(1-P1)], and combine the scatter plot and curve fitting to determine whether the indicator has a linear relationship with logit(p). The results show that there is no linear relationship between the number of backward citations and patent transfer, and the other 6 indicators have the linear relationship with patent transfer. Therefore, the regression model only includes 6 indicators except for the number of backward citations.

Table 6 Regression analysis results (G06F)

Indicators	B	S.E.	Wals	Sig.	Exp (B)
NI	0.131	0.019	46.07	0	1.139
NIPC	–0.372	0.04	87.308	0	0.689
NNDC	0.314	0.032	93.824	0	1.369
NFC	–0.232	0.07	11.068	0.001	0.793
NFPFC	–0.009	0.004	6.005	0.014	0.991
ED			51.321	0	
ED (0–699)	–0.443	0.107	17.174	0	0.642
ED (700–799)	–0.888	0.136	42.649	0	0.411
Constant	–0.654	0.135	23.483	0	0.52
Model fitting	Chi–square	Df	Sig.		
Omniubs	411.040	7	0.000		
Hosmer & Lemeshow	38.316	8	0.072		

It can be seen from Table 6 that the P value of Omnibus test is 0.000, smaller than 0.05, indicating that the OR value of at least one of the indicators included in the regression model is statistically significant, that is, the model was generally meaningful. The P value of Hosmer & Lemeshow test is 0.072, greater than 0.05, indicating that the model fits well and the information in the data is fully extracted. According to the results of binary logistic regression, the number of inventors and the number of non-patent document citations are positively correlated with patent transfer. The probability of patent transfer increases 1.139 times with the increase of 1 inventor. The probability of patent transfer increases 1.369 times with the increase of 1 non-patent document citations. The number of IPC, the number of forward citations, the number of family patent forward citations, and the examination duration are negatively correlated with patent transfer. The probability of patent transfer decreases for 0.689, 0.793 and 0.991 times when the number of IPC, the number of forward citations and the number of family patent forward citations increases by 1 unit respectively. The negative impact of examination duration on patent transfer are different in different phases. When this indicator is within 700 days, the probability of patent transfer for every additional day of examination duration reduces for 0.642, however, when it is within 700 to 799 days, the probability of patent transfer for every additional day of examination duration reduces for 0.411, showing a slower down negative impact of examination duration on patent transfer as time increased.

3.5 Validation analysis

In order to test the adaptability and reliability of regression analysis results, transferred and untransferred patents in A61K technology field, which ranked third in the number of patents and transferred patents, are selected as samples for verification. The selection of A61K technology category, different from G06F technology category, can avoid the particularity of the conclusion caused by the technology field. The process of data collection, analysis and regression is consistent with the above research. Specific regression results are shown in Table 7.

Table 7 Regression analysis results (A61K)

Indicators	B	S.E.	Wals	Sig.	Exp (B)
NI	0.071	0.023	9.632	0.002	1.073
NIPC	0.053	0.017	9.718	0.002	1.054
NFP	0.139	0.030	20.937	0.000	1.150
NBC	0.049	0.020	6.081	0.014	1.051
NNDC	0.231	0.037	39.505	0.000	1.260
ED			70.221	0.000	
ED (0–749)	0.357	0.185	3.705	0.054	1.429
ED (750–1499)	–0.598	0.169	12.451	0.000	0.550
Constant	–1.962	0.165	142.250	0.000	0.141
Model fitting	Chi–square	Df	Sig.		
Omniubs	213.109	7	0.000		
Hosmer & Lemeshow	14.699	8	0.065		

The p value of the Omnibus test and Hosmer & Lemeshow test of the validation model is 0.000 and 0.065, respectively, indicating that the model was statistically significant and had a good fit and sufficient explanatory power. The verification model showed similar conclusions to the regression model of G06F, which are: the number of inventors and the number of non-patent document citations have a positive impact on patent transfer, while the examination duration has a negative impact. However, different from the G06F model, the number of IPCs in the verification model plays a positive role in promoting patent transfer. The verification model includes the number of family patents and the number of backward citations, while the number of forward citations and the number of family patent forward citations in the G06F regression model were not included.

3.6 Empirical results

The conclusions of the empirical analysis are summarized as follows: the number of inventors and the number of non-patented document citations positively indicate patent transfer, while the examination duration negatively indicates patent transfer; the number of IPC has a significant predictive effect on patent transfer, but it varies with different technology fields. The results show that the number of backward/forward citations, the number of family patents and the number of family patent forward citations present differentiated conclusions in different technology fields. The number of claims has nothing to do with the likelihood of patent transfer.

4 Discussion

Based on the correlation between the indicators and patent transfer obtained from empirical analysis, this part mainly conducts an in-depth discussion on the data results and then discovers indicators that can be used in patent transferability assessment of TTO in universities.

4.1 Number of inventors

An inventor is a person who makes a creative contribution to the substantive features of an invention. It is generally believed that the more inventors there are, the richer the intellectual achievements embodied in the patent, and the more likely for the patent to be transferred. The results of the empirical analysis also seem to confirm the view that the number of inventors positively predicts the likelihood of patent transfer. However, it is worth noting that about 52% of all transferred patents in the G06F technology field have inventors less than or equal to 4, and the number of transferred patents starts to decrease as the number of inventors increases. In fact, the strict positive correlation between the number of inventors and patent quality only occurred under the premise that each inventor had basically equal research ability and devoted herself or himself to technology research. In addition, the expansion of the team may also lead to problems such as poor coordination and concept conflicts. The number of inventors positively predicts the probability of patent transfer, but not necessarily the more, the better. According to the results of empirical analysis, when the number of inventors is about 4, the probability of patent transfer is the highest. Therefore, the number of inventors can be used as a reference when university TTO conducts transferability assessment.

4.2 Number of IPCs

IPC defines the functions and application fields of patents. The bigger the number is, the more diversified the technical directions of patents are, the more opportunities they have to be embedded into the technology value chain or the technology chain of production, and thus the greater the possibility of transfer. However, this conclusion is contradictory in the empirical analysis. In the field of G06F, the number of IPCs is negatively correlated with patent transfer, while in the field of A61K, the two are positively correlated. This is determined by the characteristics of the two technical fields. The electrical digital data processing technology represented by G06F is relatively more specialized, so the patent research gives priority to vertical depth. The medical and other configuration products represented by the A61K field are rather compatible since it integrates medical, dental and cosmetic products, so the patent research in this field mainly focus on horizontal expansion. The average IPC numbers of transferred and untransferred patents in G06F were 1.77 and 2.62, respectively, while those of transferred and untransferred patents in A61K were 5.56 and 4.88, respectively. A higher number of IPC does not mean a greater likelihood of transfer, and a lower number may reflect greater technical expertise and depth of research. Therefore, when university TTOs use IPC numbers to evaluate the possibility of patent transfer, they need to further combine the specific features of the patents' technical field by comprehensively considering the depth and breadth of technology, rather than simply using the IPC numbers as the judging criteria.

4.3 Number of claims

Claims include independent claims and dependent claims. Compared with independent claims, dependent claims are often exclusive and limited but sometimes indispensable. Especially when the independent claims of patent are declared invalid, the scope of protection can be reduced by raising dependent claims to ensure that patent authorization is not lost. Therefore, the more claims a patent has, the better the patentee understands and protects the technology. Theoretically, the number of claims can reflect the scope of patent protection, and the more claims there are, the greater the scope of patent protected by law. However, a similar problem with the number of IPC arises again: is it easier to transfer " specialized and precise" patents or "broad and general" patents? The number of claims in this empirical study did not show a significant difference between transferred and untransferred patents. Whether a wider range of patents is easier to transfer (Shane, 2001) or a narrower range of patents is more likely to be commercialized (Lerner, 1994), is still a question worthy of further discussion. Therefore, the number of claims should not simply be included in the assessment of transferability.

4.4 Number of family patents

The number of family patents can be understood as the internationalization level of the patent, which reflects the degree of protection that the patentee seeks for its patent in the international scope. Out of economic rationality, the patentee will choose to bear high maintenance fees to expand the international protection scope of the patent only when the patent has a high value. Therefore, it can be inferred that the number of family patents positively predicts the likelihood of patent transfer, which is well supported by the validation analysis based on A61K technology field. However, while using this indicator, university TTO also needs to consider the specific situations of different technical fields. For example, China has a late start in the field of G06F, and is still in a catch-up situation in the international competition and has not yet carried out a large-scale international layout, so this indicator at this moment has no significant effect on patent transfer in this field. However, in the pharmaceutical field represented by A61K, China has formed certain technological advantages and has occupied a high level of international patent distribution. Therefore, the number of family patents has a significant positive effect on patent transfer. Similar to IPC number, while using the number of family patents as the indicator TTO needs to take the patented technical area into account in the assessment of transferability.

4.5 Number of backward citations and non–patent document citations

The number of backward citations is determined by the examiner. When conducting patent examination, the examiner will cite relevant prior patents to verify or deny the novelty, creativity, and practicality of a patent. For authorized patents, the more patents it cites, the more prior technologies that it supplements, improves, or even replaces. In this situation, the authorized patents have a stronger technical competitive advantage and are more likely to be transferred. In the empirical analysis of this study, the number of backward citations of transferred patents in G06F technology field is significantly more than that of untransferred patents, and the regression analysis based on A61K technology field confirms the positive prediction of the number of backward citations on patent transfer. Therefore, there should be a positive correlation between the number of backward citations and patent transfer.

In addition to citing the prior technologies, that is, the old patents, patents also cite non-patent documents, such as scientific papers, to explain the scientific background of the patents. The number of non-patent documents citation can reflect the correlation between patent and scientific research. The scientific correlation degree of a patent is directly related to its theoretical depth. The technology with a deep theoretical foundation is more scientific and rigorous and often has higher application value. Therefore, the number of non-patent document citations is positively correlated with patent transfer. The empirical analysis of this study confirms this view.

Therefore, university TTO can use the number of backward citations and non-patent document citations as positive indicators to evaluate patent transferability.

4.6 Number of forward citations and family patents forward citations

The effect of the number of forward citations on patent transfer is complex. In this study, in the field of G06F technology, the number of forward citations negatively predicts the probability of patent transfer, while in the validation test, there was no significant difference between transferred and untransferred patents. The reasons are mainly divided into two points: firstly, there are different technical motivations for forward citations. When a patent is used as a comparative document to deny or partly deny the novelty, creativity and practicality of a new patent, the patent may affect the authorization and scope of protection of the new patent. When the applicant wants to implement the new patent in production line, he must first obtain the authorization or license of the cited patent. At this time, forward citation is positively related to patent transfer. When the patent is used as a comparative document to verify the novelty of a new patent, it means that the technical space previously occupied by the cited patent is invaded by the new patent, and the technical competitiveness of the cited patent decreases. At this time, forward citation is negatively related to patent transfer. Secondly, there is a time lag in patent citation. Patents may be cited at any time point after the authorization date, and the transferred and untransferred patents selected in the study may be cited at a certain time point in the future, which is not in the selected time frame of this research. The number of forward citations presented now cannot completely reflect the cited situation of patents. Therefore, the number of cited patents cannot effectively predict the likelihood of patent transfer. The number of family patents forward citations is the sum of citations of patents in the region where they are authorized, and its meaning is close to the number of forward citations, and its effect on patent transfer is also uncertain. Therefore, the number of forward citations and family patents forward citations cannot be used to evaluate patent transferability.

4.7 Examination duration

Examination duration refers to the time lag from application to publication of a patent. The examination duration does not directly explain the novelty, creativity and practicality of a patent, as the examination is affected by many aspects such as the patent text, technical features, examiners, and examination system. However, the length of the examination duration will have a direct impact on the life of the patent. The longer the examination duration, the less time the patent can be put into use after transfer. That is because the longer the examination duration, the more difficult it is for the technology recipient to obtain the specific technical details of the patent in time, which might delay subsequent patent transfer procedures. Taking G06F technology field as an example, the average examination duration of

transferred patents is 943.63 days (about 2.5 years), while the average life of patents at the time of transfer is 1,844.81 days (about 5 years), and the average duration of untransferred patents from the application date to the latest update date of legal status is 2,600.32 days (about 7 years). It can be concluded that the golden period of patent transfer is about 2.5 to 5 years after application, after then the probability of patent transfer decreases. It will be difficult for the patents to transfer 7 years after application, and a long examination duration will take away the golden time window and push patents closer to the 7-year time limit. Therefore, the examination duration negatively predicts the possibility of patent transfer, which can be supported by empirical analysis. University TTO can take the examination duration as an important indicator for patent transferability evaluation. The longer the examination duration, the lower the transferability of a patent.

5 Conclusion

The transferability of patent depends on patent quality and technical and economic value. From the perspective of transferable patent identification, this study focuses on patent quality, combined with the existing evaluation indicators and the bibliometrics characteristics of patents, extracts 9 indicators including technical subject, patent protection scope, patent citation, and examination duration to reveal the transferability of university patents. The transferred and untransferred patent samples from 35 Chinese universities are used for empirical verification, and effective conclusions and inspirations are obtained.

This research provides an objective evaluation basis for university technology transfer offices to evaluate patent transferability, instead of subjective judgment from experienced experts or administrative managers. Through empirical study, it is found that the number of inventors, the number of non-patent document citations and the examination duration can be used in the assessment of patent transferability, while other indicators such as the number of IPCs and backward citations need to be discussed in combination with specific technology fields.

There is a rigorous logical basis for the effective evaluation of transferability by the bibliometrics characteristics of patents. For example, whether patents can be transferred depends on whether patents can help enterprises improve their technological competitiveness, such as forming technical barriers and following technological frontiers, which can be reflected by the number of family patents and the number of backward citations. The number of family patents reflects the international value of patented technology. The number of backward citations is a good indicator of the novelty of the patent and the presentiveness of the technology. University technology transfer office can make professional and accurate evaluation and judgment on the transferability of patents by combining the above indicators with expert opinions and analysis of the specific situation of patents.

For the evaluation of transferable patents in different technology fields, the technology transfer office of universities should not look only at one single evaluation indicator but take the attributes of disciplines and market demand into full consideration to reach a more comprehensive and precise conclusion. For example, the technical breadth and precision of patents can be presented by the number of IPCs and the number of claims. Technical breadth means the richness of application scenarios and practical fields, and precision reflects the degree of patent embedding in the enterprise technology chain. This is compatible with the diversified purpose of enterprises receiving patented technologies. Enterprises may not only want to absorb new technologies (breadth) to expand the competitive market, but

also may want to improve existing technologies (precision) to strengthen their core competitiveness. Therefore, the number of one single indicator cannot be used alone to assess the transferability of patents.

From the perspective of identifying the transferability of university patents, this research proposes a number of evaluation indicators that can be used as references for university technology transfer offices. However, the research still has limitations in data samples and the applicability of various indicators. This research focuses on the analysis of patent bibliometrics characteristics, and for other indicators that may affect the transferability of patents, such as technical subjects and industrial needs, will be verified in follow-up research.

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