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Faculty patent assignment in the Chinese mainland: evidence from the top 35 patent application universities

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Abstract Recent research has explored the issue of university faculty patent assignment in the US, Europe and Japan from the individual or organization perspectives. However, there is limited empirical research that examines the real picture of faculty patent assignment in China's universities. This paper aimed to fill this gap by creating a special dataset including 18,435 faculty/patent pairs. The investigation indicated that 13.16 % of pairs were not solely assigned to universities in 35 top patent application Chinese universities from 2002 to 2012. The empirical study correlates types of patent assignment to invention characteristics, university intellectual eminence and licensing policies, and illustrates that patent assignment changes depending on the research field, that university assignment is positively related to patent claims but negatively related to patent validity, patent maintenance time, and number of co-inventors, and that university intellectual eminence has a weak impact. Through controlling the influence of inventor characteristics, university royalty and equality policies play different roles in faculty patent assignment. This paper provides new insights as well as operational policy implications for China's university policy makers.

Keywords Patent assignment · Invention disclosure · University-industry technology transfer · Chinese Mainland

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1 Introduction

In the past few decades, university-industry technology transfer (UITT) has become a hot topic for academics, industry practitioners, and policy-makers. Most of the discussions have been based on assumptions that university-owned inventions have been disclosed by faculties to university administrations and patented by universities' technology transfer offices (TTOs) (Henderson et al. 1998; Thursby and Thursby 2002, Mowery and Shane 2002). There is evidence, however, to illustrate that many faculty inventions have not been solely assigned to universities in the US, Europe or Japan (Thursby et al. 2007, 2009; Link et al. 2007; Bekkers and Bodas-Freitas 2008; Fini et al. 2010). This implies that university-owned patents do not reveal a complete picture of universities' involvement in the process of UITT: a considerable proportion of academic patents invented by faculty are not owned by universities but, in most cases, by private firms or individuals (Lissoni et al. 2008, 2009).

The reasons for this non-university assignment are affected by a number of factors. First, the institutional and legal system for university inventions differs depending on whether an invention is university-owned versus university-invented (Crespi et al. 2006). Some European countries, including Finland, Hungary, Sweden, and Slovenia, have adopted an intellectual property system centered on inventor ownership (professor privilege), so the fact that faculty members assign their patents to outside entities rather than within their universities is both reasonable and legal (Mowery and Sampat 2005; Geuna and Nesta 2006; Lissoni and Montobbio 2012; Damsgaard and Thursby 2013). In addition, Thursby et al. (2007, 2009), Thursby and Thursby (2011) have pointed out that outside assignment of faculty patents (26.83 %) in US research universities is due to technology consulting projects that are funded by private firms, although faculty's patented inventions should normally be owned by the universities that employ the academic inventors in accordance with the Bayh–Dole Act (1980) and university employment contracts. Third, Czarnitzki et al. (2012)found that faculty patents assigned to non-university assignees are rather applied and associated with short-run profits in German universities. They concluded that corporations cannot identify and exploit basic university inventions because of the lack of absorptive capacity. In summary, the existing literature analyzes faculty patent assignment and factors that might explain outside patent assignment in different countries. However, to our surprise, there is still very limited research on faculty patent assignment in the context of mainland China. We have little knowledge of faculty patent assignment situations in Chinese universities.

Chinese universities have achieved tremendous success in patent creation and become a significant case because their patent applications have increased 7.89 times in the last ten years. In year 2012 alone, China became the top patent application country, while her (Patent Cooperation Treaty) PCT international patent applications also ranked third in the world. However, the performance of Chinese university technology transfer was not viewed as good as its patent application. According to a survey conducted by Tsinghua and Fudan universities, only about 10–15 % of faculty patents from Chinese universities are transferred to industrial settings (State Intellectual Property Office of CHINA 2005). We consider that one possible reason is non-university assignment, which causes the quality of university-owned patents to be too low to be commercialized. This is especially so when high-quality patents are assigned to non-university assignees by faculty inventors.

The objective of this paper is to conduct a more comprehensive investigation of faculty patent assignment in China's universities. For this purpose, we have developed a unique dataset addressing faculty inventor individuals from Chinese universities and explored empirically how many faculty assign academic patents outside of their universities. We found that 13.16 % faculty/patent pairs are not solely assigned to China's universities (5.28 % are assigned to private firms, 5.73 % are jointly owned by universities and firms, and 2.15 % are owned by faculty individuals). We next examined faculty patent assignment as the function of invention characteristics, university licensing policies and intellectual eminence, and then applied the binary and multinomial logit regression models to patent assignment, including four types: (1) university assignment, (2) firm assignment, (3) university-firm assignment, and (4) individual assignment. We found that Chinese faculty inventors assigned their high-quality patents outside but disclosed their low-quality patents to their universities, indicating that non-university assignment depends mainly on a patent's higher quality. We also provided a more comprehensive understanding of Chinese university policies and intellectual eminence.

The rest of this paper is organized as follows. In the next section, previous research and propositions are introduced. Section 3 describes the research design, data collection, and methodology. Section 4 presents the logit regression model and empirical results. In Sect. 5, the main findings of this paper are discussed. Lastly, conclusions and limitations are shown in Sect. 6.

2 Determinants of patent assignment and proposition development

This section describes the main determinants of university faculty patent assignment based on previous research, and makes three propositions. To facilitate the discussion, we classify the determinants into three categories: (1) invention characteristics, (2) university intellectual eminence, and (3) university licensing policies.

2.1 Invention characteristics

The first argument for invention characteristics in faculty assignment activities is patent quality. The fact that high-quality inventions are less likely to be reported to university administrators has been confirmed by previous studies (Jensen et al. 2003; Markman et al. 2007). This is not surprising because it enables faculty inventors to keep 100 % of the licensing revenue rather than about 30 % via disclosing the high-quality patent. From another aspect, in recent years, most of China's universities have focused their efforts on a smaller number but higher-quality faculty patents, in order to balance the numerous patents and limited experience of technology transfer managers (Liu and Jiang 2001). In this case, although meeting with great interest, it seems that it is not easy for faculty to sell or license their high-quality patents directly by bypassing the universities' monitoring systems. Therefore, it is hard to say whether the patent quality has a positive or negative influence on invention disclosure and university assignment.

Second, to link academic inventions with potential interested firms, faculty inventors have to pay search costs and rely on all their co-inventors' contact networks, which are indicated by the number of co-inventors. The assumption of university assignment is that TTOs have lower search costs and larger networks than all faculty listed on a given academic invention (Hellmann 2007; Crespi et al. 2006). This implies that TTOs can make a larger marginal contribution to the success of transferring a given technology than faculty inventors. For the same reason, when faculty inventors have a closer and richer contact network with private firms (for example, some of the co-inventors are from firms), they may not choose university assignment but instead search for interested firms by themselves, commercializing their inventions directly.

Third, several studies have provided empirical evidence of different patent assignment in different research fields (Geuna and Nesta 2006; Thursby et al. 2007, 2009; Fuller 2008; Jensen et al. 2008; Fini et al. 2010). In particular, pharmaceutical, biotechnology, and semi-conductor firms rely more closely on university patents since technology-intensive firms need more advanced technologies and know-how from university laboratories (Kim et al. 2005; Boardman and Ponomatiow 2014). Compared with other research fields, such as life science or telecommunications, university faculties in these research fields can find potential firms with lower search costs and have more opportunities to assign their patents to these firms. Thus, in our initial test, we proposed that:

Proposition 1a *The patent quality has a significant influence on faculty patent assignment activities in China's universities.*

Proposition 1b *The number of inventors has a negative impact on university patent assignment in China's universities.*

Proposition 1c *Faculty patent assignment differs by research field in China's universities.*

2.2 Intellectual eminence

The second argument for faculty patent assignment is university intellectual eminence. Two explanations of university intellectual eminence have been given in previous literature. The first is that more competent researchers have more opportunities to sell their inventions or patents to private firms than less competent researchers (Gregorio and Shane 2003). This is because eminent universities usually employ more top researchers than less eminent universities. In addition, eminent universities are well known and their inventions can easily be tracked. Therefore, private firms prefer to find more competent researchers in more eminent universities, which is helpful in enabling faculty to decrease search costs at the same time. The second explanation is that universities' reputations make it easier for researchers from more eminent universities to create enterprises and commercialize their inventions than researchers from less eminent universities (Humberstone 2009). Because of information asymmetry and uncertainty, venture capitalists tend to believe that more eminent universities produce more technology that is worthy of funding than less eminent universities (Jensen and Thursby 2001; Etzkowitz 2003; Lowe 2006). That is why spin-offs of famous universities always perform better (Gregorio and Shane 2003; Pedro and Ferran 2014). Therefore, we proposed that:

Proposition 2 *Better intellectual eminence increases the likelihood of outside patent assignment in China's universities.*

2.3 Universities policies

The third argument for faculty patent assignment is that universities differ in their patent policies towards revenue management. Specifically, extant literature has suggested the importance of three policies: one type of royalty policy and two types of equity policies. First, the share of licensing revenue between faculty inventors and universities has a crucial impact on patent assignment, and has drawn the most attention from researchers in the last two decades (Aghion and Tirole 1994; Friedman and Silberman 2003; Siegel et al. 2003a, b; Crespi et al. 2006; Crama et al. 2008; Thursby et al. 2009; Panagopoulos and Carayannis 2013; González-Pernía et al. 2013). When faculty inventors disclose patents to their universities, they can earn profits from their inventions by selling or licensing technologies through royalty fees. In general, university policies require that profits should be distributed among faculty inventors, the university administration, departments, and TTO staff. This revenue distribution, reasonable or not, means that faculty inventors can earn part of the profit from their inventions immediately, and that it increases with their share of royalty fees.

Second, when universities seek to make a technology investment, technology appraisal as capital stock is a common business practice. Non-university investors are also more likely to invest in companies in which universities are the major stockholders, as this tie will reduce the information asymmetry between inventors and investors (Jensen and Thursby 2001; Gregorio and Shane 2003, Chang et al. 2015). What is more, the use of equity policies will not influence the marginal profit of new products, which is good for the product yield decision. Equity policies give faculty share options that could ask for more future profit instead of present profit, and stimulate them to put more energy into the commercialization of their technologies (Dechenaux et al. 2009; Savva and Taneri 2011). Therefore, if faculty inventors and TTOs are not cash-constrained or risk-averted aversion, higher equity could also encourage faculty to disclose patents and take part in technology transfer involving universities.

Third, when universities would like to help faculty inventors create new start-ups based on their inventions, an increase in faculty's stock proportion of new start-ups could improve their disclosure rate (Hellmann 2007). Unlike established firms, new start-ups are always cash-constrained. Universities' willingness to take equity stocks in exchange for up-front licensing fees could reduce the cash expenditures of faculty's new firms; prevent them from hiding or shrinking their inventions and start-ups (Gregorio and Shane 2003). Therefore, increasing faculty's equity in new start-ups could improve their disclosure rate.

In short, although these three university patent policies are positively related to university assignment, understanding their differences is a more important task for university administrations in mainland China, because different types of licensing policies require different levels of faculty involvement and effort. This is why university administrators prefer to give faculty inventors more choices in order to promote university assignment and UITT (Savva and Taneri 2011). Hence:

Proposition 3a *University-employed faculty inventors are more likely to assign their patents to the university if they receive a higher share of the royalties or equities.*

Proposition 3b *University royalty policy and equity policy clearly have different influences on faculty patent assignment.*

3 Data and research design

3.1 The sample

In order to investigate the distribution of faculty patent assignment and its influencing factors, we selected 2002 professors from schools of mechanical engineering, telecommunications and life science in the top 35 Chinese patent application universities as our research sample. Specifically, these 35 universities, under the "985 Project" or "211 Project" governed by China's Ministry of Education, owned a large number of patents accounting for 51.01 % of total university patents during the period from 2002 to 2012. In this research, academic invention characteristics, university eminence, university policies, and faculty individual information are needed. However, there is no single database that is able to provide enough data to meet our requirements. Therefore, this research combined three data sources to establish a unique dataset following the steps below.

To begin with, the university faculty curriculum vitae (CVs) dataset was collected from universities' websites, which contain faculty's self-introductions including age, gender, current status, administrative position, and research field. Next, we obtained information about faculty patent applications from the China National Knowledge Infrastructure (CNKI) patent database, which provides detailed information of Chinese patents granted to university faculty inventors. In addition, we used a series of university open documents and Education Statistical Yearbooks (2002–2012) to collect university intellectual eminence and university policies. For the whole process of data collection and some possible bias, please see the Supplementary Description under Data Collection.

3.2 Descriptive analysis

Our data collection produced 18,435 faculty/patent pairs, with 2002 different inventors surveyed in the period from 2002 to 2012. Specifically, 4.12 % of pairs had only one inventor, 13.70 % had two inventors, 19.64 % had three inventors, 21.77 % had four inventors and the rest had five or more inventors. All the faculty/patent pairs were collected according to application dates, rather than authorization dates. This is because faculty inventors always make the assignment decision first and then apply for their patents. This explains why some of the patent applications from 2012 have still not been granted. The distribution of patent assignment by research field was categorized as follows.

Table 1 Assignment of faculty/patent pairs by research field

	Faculty	Total pairs	Patent assignment[a] (%)			
			UNIV	FIRM	UNIV&FIRM	UNASSIGN
Life science	357	3308	79.32	10.61	7.89	2.18
Mechanical engineering	809	7233	88.84	2.72	5.90	2.50
Telecommunication	836	7894	88.12	5.38	4.66	1.82
Total	2002	18,435	86.84	5.28	5.73	2.15

[a] *UNIV* university assignment, *FIRM* firm assignment; *UNIV&FIRM* university-firm assignment, *NASSIGN* individual assignment

Table 1 describes the distribution of faculty/patent pairs classified according to research fields (i.e. life science, mechanical engineering, and telecommunications). 17.83 % of pairs are from faculty inventors who are employed in the life science discipline. 40.41 % are from faculty inventors in mechanical engineering, and the remaining pairs are from telecommunications. It seems that faculty inventors from life sciences tend to assign fewer patents to universities than faculty in mechanical engineering and telecommunications. What is not shown in Table 1 is the fact that the annual growth rates of firm assignment in life science, mechanical engineering, and telecommunications are 10.43, 35.12 and 24.98 %, respectively. This indicates that the growth rates of firm assignment in mechanical engineering and telecommunications far exceed that in life science.

Figure 1 shows the percentage of faculty/patent pairs that were solely assigned to universities in three research fields from 2002 to 2012. Prior to 2005, it is clear that university assignment remained at a low level (except in mechanical engineering). During the period from 2006 to 2012, university patent assignment in mechanical engineering and telecommunications increased steadily, with annual growth rates of 3.06 and 6.58 % respectively. By contrast, university patent assignment in life science fluctuated considerably during this period, because patents in life science are easier for universities and enterprises to commercialize than those in other research fields. For instance, Nankai University established a university-owned biotech company and transferred 88 life science patents to this company in 2004 (the lowest point in Fig. 1).

Table 2 shows the average patent claims in the four different types of patent assignment. University assignment has the most patent claims at 5.26 %, followed by university-firm assignment at 4.53 %. Patents owned by faculty individuals have the fewest patent claims at 3.54 %. This may imply that patents disclosed to universities by faculty are of higher quality than those assigned outside of their universities.

As shown in Fig. 2, we chose those faculty patents whose application year is 2002 to compare the patent maintenance time of university versus non-university assignment. First, faculty patents disclosed to universities have shorter patent life as their maintenance time is less than seven years. Meanwhile, up to June 30th 2014, 32.50 % of patents assigned to outside entities is still in force. It suggests that non-university assignment patents have a

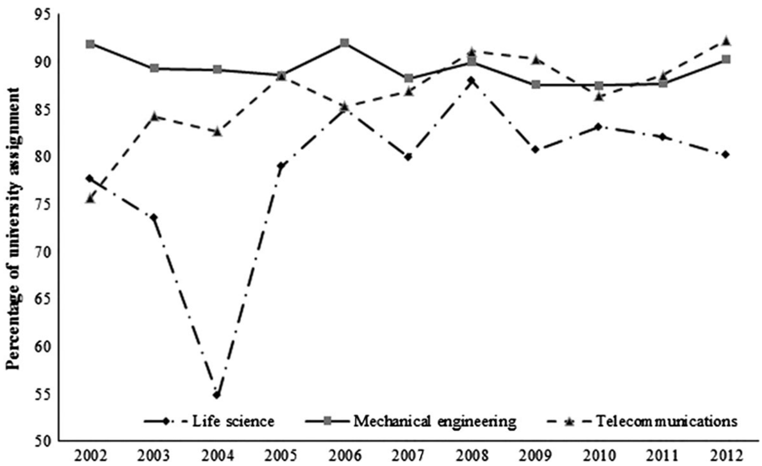

Fig. 1 Faculty-patent pairs solely assigned to universities in three research fields (by year)

Table 2 Patent claims vary by patent assignment

	Patent assignee			
	UNIV	FIRM	UNIV&FIRM	UNASSIGN
Average patent claims	5.26	4.00	4.53	3.54
Proportion (%)	86.84	5.28	5.73	2.15

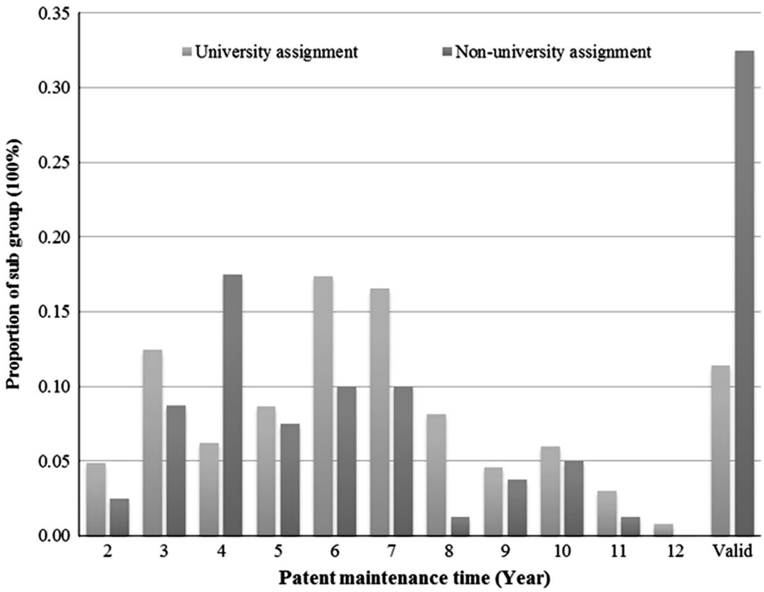

Fig. 2 Comparison of university-owned and university-invented patent on maintenance time

longer economic life and perhaps implies that Chinese faculties disclosed high quality inventions to non-university organizations or individuals more often than to their universities.

Table 3 gives the distribution of faculty's patent assignment in the 35 top patent application universities. The mean number of faculty/patent pairs is 527. Tsinghua University has the largest number of faculty/patent pairs at 2140, accounting for 11.61 % of the total, followed by Shanghai Jiaotong University with 1039 pairs. Jiangnan University has the fewest pairs (78) in our sample. In terms of university assignment, the percentage in these top 35 universities is over 80 %, except for Sun Yat-Sen University (77.64 %), Peking University (73.67 %), the East China University of Science and Technology (76.83), and Nankai University (66.01 %).

Of all the 18,435 faculty/patent pairs in our sample, 2426 were not solely assigned to universities by faculty inventors. We further examined whether there is a correlation between faculty inventors and private firms, it was found that only 158 pairs of outside assignment, accounting for 6.51 %, had the same name as the start-ups' legal persons or stakeholders. However, we believe that the truth is higher than this figure, since it is easy

Table 3 Faculty patent assignment by university from 2002 to 2012

University	Patent pairs	Assignment (%)			
		UNIV	FIRM	UNIV&FIRM	UNASSIGN
1 Tsinghua University	2140	90.09	2.57	4.77	2.57
2 Beijing University of Aeronautics and Astronautics	923	88.30	2.17	6.18	3.36
3 Huazhong University of Science and Technology	1011	85.95	5.44	6.03	2.57
4 University of Science and Technology of China	154	90.91	5.19	1.95	1.95
5 Tongji University	304	80.26	12.17	5.59	1.97
6 Harbin Institute of Technology	774	91.99	0.78	5.68	1.55
7 South China University of Technology	853	88.51	3.87	4.45	3.17
8 Dalian University of Technology	414	91.55	3.14	3.86	1.45
9 Tianjin University	538	92.75	3.90	1.67	1.67
10 Northwestern Polytechnical University	332	91.87	6.93	0.60	0.60
11 Shanghai Jiaotong University	1039	84.02	6.16	9.34	0.48
12 Shanghai University[a]	418	84.45	8.85	6.22	0.48
13 Donghua University[a]	391	88.75	0.77	10.23	0.26
14 Southeast University	784	88.14	3.83	6.51	1.53
15 Central South University	221	83.26	1.36	3.62	11.76
16 Ocean University of China	136	89.71	2.94	3.68	3.68
17 Sun Yat-Sen University	662	77.64	9.37	10.57	2.42
18 Peking University	509	73.67	21.02	3.14	2.16
19 Beijing University of Technology[a]	331	87.01	1.21	6.95	4.83
20 East China University of Science and Technology[a]	164	76.83	14.02	6.10	3.05
21 Nanjing University	408	92.65	2.21	3.43	1.72
22 Nankai University	506	66.01	31.82	1.19	0.99
23 Xiamen University	225	84.44	2.22	12.00	1.33
24 Jilin University	221	88.69	1.36	0.00	9.95
25 Sichuan University	385	81.04	10.13	6.23	2.60
26 Fudan University	796	85.80	3.27	9.17	1.76
27 Shandong University	466	92.92	3.43	1.29	2.36
28 Wuhan University	359	84.68	11.98	2.51	0.84
29 Jiangnan University[a]	78	87.18	6.41	3.85	2.56
30 Zhejiang University	753	87.25	2.52	9.96	0.27
31 Zhejiang University of Technology[a]	287	86.41	2.44	6.62	4.53
32 Hunan University	404	90.35	4.46	2.97	2.23
33 University of Electronic Science and Technology of China	108	93.52	0.93	5.56	0.00
34 Xi'an Jiaotong University	820	91.95	0.98	5.85	1.22
35 Chongqing University	518	89.58	0.97	7.53	1.93

Table 3 continued

University	Patent pairs	Assignment (%)			
		UNIV	FIRM	UNIV&FIRM	UNASSIGN
Total/average	18,435	86.84	5.28	5.73	2.15

[a] In Table 3, universities marked with an asterisk are not part of the "985 Project" but the "211 Project". The "985 Project" and "211 Project" are China's two biggest education projects aimed at developing world-level research universities. All universities in these projects qualify for more research funding and preferential policies. In addition, Shanghai University, Donghua University, Beijing University of Technology, and Zhejiang University of Technology are governed by local governments rather than by China's Ministry of Education (MoE)

for faculty to hide their start-ups in order to avoid contingent payments to university administration in Chinese universities. We also checked the links between universities and private firms since many new start-ups are established in universities' incubators or science parks. We found that 248 firms had close relationships with China's universities. Even so, we have to admit that we could not cover all the links among faculty inventors, universities and private firms. It was also hard to collect information on whether the faculty (or the university) was the principal or shareholder in a firm. Thus we are convinced that all the data about outside assignment in our dataset is at the lower bound of reality. Lastly, after accounting for those university-private firm links, we inferred that external private firms had to appear in the co-applicant list if they allowed employees to take part in those faculty creative activities. As a result, we determined that there were at most 1624 faculty/patent pairs involving private firm employees as co-inventors.

3.3 Dependent variables and model specification

In this paper, in order to investigate the determinants of patent assignment, we correlated faculty patent assignment to invention characteristics, intellectual eminence, and university licensing policies. Thus, the assignment equation is regarded as the function of explanatory and control variables. In most previous studies, the binary and multinomial logit regression models have been considered the most appropriate technique for the analysis of dichotomous/multi-value variables (Thursby et al. 2007, 2009; Fini et al. 2010). In this paper, first, when the dependent variable was coded as 0 (non-university assignment) or 1 (university assignment), the binary logit regression model was used to find the correlation between the probability of assignment to a particular type of organization and a set of influencing factors. Second, a more comprehensive assignment was studied, while patent assignment as a dependent variable has four values (coded as 1 if assigned to the university, 2 if assigned to a private firm, 3 if assigned to the university and a private firm jointly, and 4 if assigned to the individual). Under this scenario, the multinomial logit regression model was employed. Third, following Thursby's (2007) study, we also conducted research on outside assignment, with firm assignment including established firm assignment and start-up assignment (coded as 0 if assigned to a start-up, 1 if assigned to an established firm, 2 if assigned to the university and firms jointly, and 3 if assigned to the individual). The start-up assignment was considered as the reference assignment, and the analysis approach was also the multinomial logit regression model. In summary, this model specification allows us to find the overall effect of each influencing factor through binary logit analysis, and the specific effect on each patent assignment through pairwise comparison judgement in multinomial logit analysis.

3.4 Explanatory variables

3.4.1 Characteristics of inventions: patent quality

In order to measure the quality of academic patents invented by university faculty, patent citation, claim, and maintenance time are considered as three of the most representative indicators (Thursby et al. 2007, 2009; Ho et al. 2014). However, Chinese patent applications do not require citation documents. Thus, in this paper, we use the number of patent claims as measures of patent quality which is also the approach employed in Thursby's (2009) research. In addition, we use the patent maintenance time variable to re-examine the relationship between patent quality and their assignments.

3.4.2 Characteristic of inventions: research field

In this paper, university faculty inventors are from three research fields: life science, mechanical engineering, and telecommunications. Dummy variables are used to indicate these three research fields (Mechanical engineering = 1 if faculty inventors come from schools of mechanical engineering, Telecommunications = 1 for faculty inventors in schools of telecommunication, and life science is regarded as the reference research field in this paper).

3.4.3 Characteristic of inventions: number of inventors

To measure whether faculty inventors' contact networks influence their disclosure willingness, we defined a social contact network as the number of co-inventors who take part in the invention activities. This variable can be extracted from patent documents in the CNKI database.

3.4.4 Intellectual eminence

To measure whether university eminence affects faculty's disclosure rate, we examined the average discipline assessment score of all first-level disciplines in these three research fields among the 35 universities. Because all research fields were assessed by China's Ministry of Education (MoE) every 5 years (i.e. Discipline Evaluation Report of MoE 2002, 2007, 2012), we updated the scores three times in our dataset.

3.4.5 University licensing policies: the inventors' share of royalties

In order to reveal the relationship between university royalty policies and faculty disclosure rates, we examined inventors' share of royalties from their licensing profits. Inventors whose technologies are licensed by TTOs can receive royalty revenues based on a rate stated in published university policies. The royalty rate may be a fixed sum or perhaps a decreasing function of the amount of royalties received by the university. Under most circumstances, the rate of inventors' share of royalties is affected by the yield of new products, thus inventors cannot be sure of the exact share of royalties that they will receive.

Therefore, like Gregorio and Shane (2003), we use the minimum share of royalties as an independent variable. In addition, because some universities use a monotonically decreasing function to distribute the inventor's share according to the total licensing revenues, we use the amount of royalties that an inventor would receive from a patent valued at RMB 1 million as the benchmark for the inventor's share of royalties.

3.4.6 University licensing policies: equity policies

In order to measure whether university equity policies influence the faculty disclosure rate when university administrations adopt a technology investment, we examined the rate of inventors' share of equities received from universities. Unlike inventors' share of royalties, equity policies do not generate a cash flow, and this influences the marginal profit of new products. Faculty inventors receive a continuous future licensing profit, which may encourage their participation. Meanwhile, private firms do not need to pay up-front or annual fees. This is why equity policies are considered the most effective way. We obtained the exact rates of inventors' share of equity from universities' published policies, which are included in information disclosure on the universities' websites. For universities that do not have information disclosure policies, we emailed the leaders of their TTOs to obtain values for this variable.

Universities sometimes prefer to invest more in capital, not limited to technology investment, to help faculty to establish new start-ups. We examined inventors' equity in the new start-ups. Most evidence suggests that in this case, faculty inventors get less equity in start-ups because there are capital constraints. Finally, we also tested an alternative measure of equity policies, in which inventors receive a share of after-tax profit in new start-ups. In our dataset, nine universities, including Shanghai Jiaotong University and Peking University, share the after-tax profit of new start-ups with faculty inventors.

3.5 Control variables

3.5.1 Number of inventions

Because we expect that faculty inventors with more inventions are more likely to assign their patents to private firms, we examined the exact number of inventions while faculty inventors make each patent assignment decision. In our dataset, when the number of inventions is lower than five, the ratio of university assignment versus outside assignment is 6.89, and then decreases to 6.09 when the number of inventions increases to 10. Therefore, we infer that productive faculty inventor is more attractive to private firms than other faculty with lower output. The number of inventions can be obtained by calculating all faculty-invented patents in the CNKI database.

3.5.2 Length of time as professors

Since our sample is related to a faculty's career life, it is hard to use a static indicator variable to control the impact of professorship in every year. Therefore, we use the length of time as professors as an alternative variable. This variable is equal to patent application year minus the year when the faculty got the title of professor. For example, for a given patent, the number "3" implies that on the date of patent application the faculty inventor had been a university professor for 3 years, while "−3" means the faculty inventor will become a university professor 3 years hence. By doing this, we can find differences in patent assignment with different faculty status.

3.5.3 Administrative position

We are convinced that faculty's administrative position plays both an advantageous and a disadvantageous role in patent university assignment. First, faculties, as leaders in their respective departments, have to comply with their schools' invention reporting systems to set a good example. On the other hand, their administrative position always provides faculty with more research resources and social connections, which are helpful in enabling them to commercialize their patents by themselves. In our sample, faculty's experience of administrative position can be collected from universities' websites and faculties' CVs. We used a dichotomous variable to control the influence of faculty position by coding a dean (or vice-dean) as "1", and the rest as "0".

3.5.4 Year of application

From 2006, China's universities have been considered as one of the most important areas in the national innovation system. A number of favorable policies have been introduced by central and local governments to improve Chinese universities' UITT performance. In order to control the influence of policy development, a year of application variable is employed in our dataset. This data can also be collected from the CNKI database.

Table 4 Descriptive statistics for all independent variables

Variable	Observations	Mean	SD	Minimum	Maximum
Research field	18,435.000	1.249	0.739	0.000	2.000
Number of inventors	18,435.000	3.372	2.127	0.000	20.000
Patent claims	18,435.000	5.117	6.328	1.000	106.000
Patent maintenance time	449.000	8.127	5.414	2.000	12.000
Intellectual eminence	18,435.000	77.651	9.793	62.470	97.500
Minimum inventor share of royalty	18,435.000	0.356	0.183	0.200	0.800
Inventor royalty revenue per 1 million	18,435.000	36.116	18.748	20.000	80.000
Minimum inventor share of equity	18,435.000	0.309	0.136	0.200	0.700
Inventor equity of the start-up	18,435.000	0.064	0.182	0.000	0.900
Inventor share of after-tax profit	18,435.000	0.018	0.083	0.000	1.000
Number of inventions	18,435.000	16.171	31.054	0.000	280.000
Length of time as a professor	18,435.000	6.027	5.271	-10.000	57.000
Administrative position	18,435.000	0.308	0.461	0.000	1.000
Year of application	18,435.000	2008.369	2.773	2002.000	2012.000
Age	18,435.000	45.658	6.660	26.000	87.000
Gender	18,435.000	0.894	0.308	0.000	1.000

Table 5 Results of the binary logit regression analysis

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Characteristic of invention										
Mechanical engineering	0.536***	0.538***	0.526***	0.534***	0.507***	0.538***	0.548***	0.567***	0.566***	0.546***
Telecommunications	0.491***	0.489***	0.488***	0.488***	0.474***	0.491***	0.481***	0.515***	0.481***	0.533***
Life science	Reference research field									
Number of inventors	−0.218***	−0.214***	−0.212***	−0.217***	−0.215***	−0.213***	−0.216***	−0.208***	−0.220***	−0.210***
Patent claims	0.028***	0.028***	0.028***	0.028***	0.028***	0.028***	0.029***	0.030***	0.029***	
Intellectual eminence										
MOE discipline evaluation score	0.005**	0.005*	0.005*	0.005**	0.005*	0.005**	0.004	0.005*		0.006**
University licensing policies										
Minimum inventor share of royalty	0.330***	0.297***	0.268***	0.331***	0.335***	0.323***	0.299***	0.302***	0.346***	0.344***
Inventor royalty revenue per 1 million	−0.022***	−0.020***	−0.019***	−0.021***	−0.022***	−0.021***	−0.020***	−0.019***	−0.022***	−0.022***
Minimum inventor share of equity	1.039***	1.07***	1.102***	1.038***	1.002***	1.011***	1.121***	1.09***	1.092***	1.071***
Inventor equity of a start-up	0.313**	0.071		0.309**	0.307**	0.310**	0.296**	0.279**	0.268**	0.264**
Inventor share of after-tax profit	0.195		0.044	0.197	0.208	0.151	0.200	0.249	0.131	0.181
Control variables										
Age	0.023	0.021	0.018		−0.008**	0.095***	−0.007*	−0.006	−0.008**	−0.008**
Gender	−0.362***	−0.363***	−0.364***	−0.363***		−0.341***	−0.374***	−0.386***	−0.357***	−0.359***
Length of time as professor	0.116***	0.116***	0.116***	0.124***	0.146***		0.129***	0.188***	0.156***	0.152***
Administrative position	−0.225***	−0.221***	−0.219***	−0.225***	−0.236***	−0.206***		−0.251***	−0.228***	−0.232***
Number of inventions	−0.067***	−0.068***	−0.067***	−0.068***	−0.074***	−0.045*	−0.247***	−0.049***	−0.066***	−0.070***
Year of application	0.044***	0.043***	0.043***	0.044***	0.049***	0.051***	0.041***		0.046***	0.050***

Table 5 continued

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Observations	18,435	18,435	18,435	18,435	18,435	18,435	18,435	18,435	18,435	18,435
ROC	0.6221	0.6223	0.6224	0.6220	0.6203	0.6232	0.6250	0.6212	0.6236	0.6129

* Significant at 10 %; ** Significant at 5 %; *** Significant at 1 %

3.5.5 Age and gender

It is clear that outside assignment is significantly higher when faculty's ages are between 35 and 55 in our dataset. To account for this variation, we include the faculty age variable for all patents. Meanwhile, we want to control the impact of gender by employing a dichotomous variable (men coded as "1", and women coded as "0").

In summary, Table 4 presents concise statistics for all independent variables included in this paper.

4 Empirical results

4.1 Binary logit regression model

The results of the binary logit regression analysis presented in Table 5 indicates the overall influence of explanatory variables on invention disclosure by testing all propositions. Model 1 provides the principal model that covers all independent variables. Models 2–10 provide a series of robustness checks of explanatory and control variables. In summary, invention characteristics and university licensing policies (except for the inventor's share of after-tax profit) have significant impacts on faculty invention disclosure. University intellectual eminence has a weak influence on faculty's disclosure decisions. For the control variables set, we found that all factors excluding age had significant influences on invention disclosure.

Models 1–10 show that the patent claim is positively related to university assignment at the significance level of 1 %. This is in line with Proposition 1a. Our findings also provide adequate support for the conclusion that patents with more co-inventors are more likely to be assigned to non-university assignees at the significance level of 1 %, among models 1–10. For a given patent, the inventor's social network is very important for invention distribution. More inventors could greatly reduce faculty's search costs, and increase their marginal powers of owning patent right. This is why the number of inventors is negatively related to university assignment. Another explanation is that in many cases, part of the co-inventors are from private firms because of R&D cooperation or technology consulting projects between universities and industry. Academic patents are always assigned to private firms as a result of prior contractual agreements.

In terms of Proposition 1c, the research field significantly predicts the invention disclosure. The estimated coefficient for this factor, shown in Model 1, implies that invention disclosure varies as a result of different research fields. Specifically, the probability of non-university assignment in mechanical engineering and telecommunications is 0.536 and 0.491 times less than that in life science. These results reflect the fact that faculty inventors in mechanical engineering and telecommunications perhaps cannot transfer their inventions without disclosure because of some uncertain reasons, such as weaker connection with private firms. These results suggest that China's university administrators should pay more attention to faculty in life science if they wish to manage faculty's patents and safeguard the interests of their universities effectively.

In the binary logit regression model, our findings provide little evidence that higher intellectual eminence increases the probability of non-university assignment. The coefficient on the variable of MoE's discipline evaluation score is positive, but is close to zero at

Table 6 Results of the multinomial logit regression with the university/start-up as the reference

Variables	Model 11 (RRR, UNIV as the reference assignment)			Model 12 (RRR, START.UP as the reference assignment)		
	FIRM/ UNIV	UNIV&FIRM/ UNIV	UNASSIGN/ UNIV	ESTAB.F/ START.UP	UNIV&FIRM/ START.UP	UNASSIGN/ START.UP
Characteristic of invention						
Mechanical engineering	0.335***	0.677***	1.165	1.361	2.360***	3.755***
Telecommunications	0.551***	0.612***	0.946	0.978	1.156	1.644***
Life science	Reference research field			Reference research field		
Number of inventors	0.855***	2.034***	0.523***	1.408***	2.413***	0.620***
Patent claims	0.971***	0.984***	0.931***	0.945**	1.011	0.974
Intellectual eminence						
MOE discipline evaluation score	0.977***	1.012***	0.993	0.982*	1.029***	1.012*
University licensing policies						
Minimum inventor share of royalty	0.622***	0.650***	2.121***	1.458	1.254	5.650***
Inventor royalty revenue per 1 million	1.025***	1.028***	0.979*	0.971**	0.989	0.937***
Minimum inventor share of equity	0.372***	0.420**	0.123***	4.598	1.939	0.133**
Inventor equity of a start-up	0.886	0.480***	1.519	0.979	0.597	1.954
Inventor share of after-tax profit	0.817	0.735	1.349	1.505	1.346	2.161
Control variables						
Age	1.002	1.002	1.034***	1.002	1.009	1.040***
Gender	1.995***	1.069	1.782***	1.003	0.602**	1.071
Length of time as the professor	0.956***	0.996	0.954***	1.005	1.034**	0.989
Administrative position	1.726***	0.956	1.338***	0.604	0.541***	0.746**
Number of inventions	1.004***	1.000	0.985***	0.985***	0.995**	0.978***
Year of application	1.033**	0.904***	0.974***	1.055***	0.880***	0.917***

Table 6 continued

Variables	Model 11 (RRR, UNIV as the reference assignment)			Model 12 (RRR, START.UP as the reference assignment)		
	FIRM/ UNIV	UNIV&FIRM/ UNIV	UNASSIGN/ UNIV	ESTAB.F/ START.UP	UNIV&FIRM/ START.UP	UNASSIGN/ START.UP
Observations	18,535			2429		
κ^2	1178.69 (48)			766.43 (48)		

* Significant at 10 %; ** Significant at 5 %; *** Significant at 1 %

the significance levels of 5 or 10 %. It seems that the academic research level has a weak relationship with faculty's entrepreneurship in China's universities in our dataset.

Our findings also tested Proposition 3a and suggest that two sets of university royalty policies—minimum inventor share of royalty and inventor royalty revenue per RMB 1 million—appear to influence invention disclosure significantly. The coefficient on the minimum inventor share of royalties is significant at 1 % among Models 1–10. This implies that an increase in the inventor's share of royalties per unit leads to the probability of a university assignment increase 0.3 more or less. The surprising fact is that the coefficient becomes weak negative when royalties are measured by the amount accrued to faculty inventors on a patent valued RMB 1 million. This implies that invention disclosure varies with different calculation methods, and that increasing the inventor's share of royalty per RMB 1 million does not effectively improve the overall faculty disclosure rate.

The other university policies that appear to influence invention disclosure are equity policies. First, when we consider patents assigned to third parties as a technology investment, an increase in the minimum inventor's share of equities will raise the probability of university assignment 1.039 times. Second, when a university is involved in developing new start-ups as company founders, increasing the inventor's share of equities in new start-ups only raises the probability of university assignment 0.313 times at the 5 % significance level. Lastly, we found that the inventor's share of after-tax profit as alternative variable has no impact on invention disclosure in any of the models.

4.2 Result of multinomial logit regression model

The binary logit analysis has resolved the issue of invention disclosure (i.e. university vs. non-university assignment). In this section, we consider faculty inventors' decisions to assign their patents to universities, private firms, jointly to both universities and firms, or to themselves in greater detail. The multinomial logit regression model is employed to investigate the influence of explanatory variables on each specific patent assignment by comparing the target patent assignment and the reference patent assignment. In these models, private firms are divided into start-ups and established firms. We followed Thursby et al. (2007) definition of an established firm as ten years or older at the time of patent application, while the rest are classified as start-ups.

The multinomial logit regression model has the assumption "Independence of Irrelevant Alternatives" (IIA), which requires each type of patent assignment to be independent from others. We test whether this assumption is valid for our data by using the conditional logit regression model and Hausman Test (Hausman 1978; Hausman and McFadden 1984). The result shows that there is no significant difference among outputs, and that some of values have been excluded from the dependent variable. We also employed the nested logit regression model, which is more general than multinomial logit regression. The *p* value also supports the IIA assumption. Therefore, we think that the multinomial logit regression model is appropriate in this paper.

Through the pairwise comparison, the results of the multinomial logit regression model are presented in Table 6. All coefficients are shown as relative risk ratios (RRR). If the RRR of any independent variable is greater (or smaller) than one, an increase in the given independent variable will lead to an increase (or decrease) in the risk ratio of the target assignment versus the reference assignment. In model 11, university assignment is considered as the reference assignment to illustrate the empirical results of patents assigned to a university versus to a private firm (FIRM/UNIV), to a university versus to both the university and a private firm (UNIV&FIRM/UNIV), and to a university versus to an individual (UNASSIGN/UNIV). Meanwhile, model 12 gives the empirical results, where start-up assignment is the reference assignment. In order to uncover more details about outside assignment, university assignment was excluded in model 12.

Regarding the patent claims in Table 6, the RRR is smaller than one at the 1 % level in FIRM versus UNIV, UNIV&FIRM versus UNIV, and UNASSIGN versus UNIV in model 11. This suggests that university-owned inventions have higher quality than university-invented ones from the perspective of protection scope. This finding is in line with the results in Table 5. An interesting thing is that the number of claims has little influence in model 12. This indicates that there is little difference in patent claims among three different types of patent assignment when faculty inventors make non-university assignment decisions.

Our findings also provide significant evidence that the number of co-inventors influences patent assignment. First, having more co-inventors increased the probability of university assignment in the comparison of FIRM versus UNIV and UNASSIGN versus UNIV, but decreased the probability in UNIV&FIRM/UNIV in model 11. This implies that only when inventors find interested firms before the time of patent application or some co-inventors come from private firms because of R&D cooperation or technology consulting projects will they choose university-firm assignment instead of university assignment. In model 12, we also find that increasing the number of co-inventors could increase the likelihood of established firm assignment and university-firm assignment. Meanwhile, the RRR of UNASSIGN versus START-UP is smaller than one, which indicates that much more faculty inventors prefer start-up assignment to individual assignment. Therefore, we can infer that the faculty preference regarding assignment under the impact of the number of co-inventors is as follows: university-firm assignment → university assignment → established firm assignment → start-up assignment → individual assignment.

Considering the effect of research fields, Table 6 shows its significance in the comparison of FIRM/UNIV, UNIV&FIRM/UNIV, and UNASSIGN/START-UP at the 1 % level. Compared with faculty in life science, those in mechanical engineering and telecommunications prefer university assignment. They are also less likely to choose start-up assignment than faculty in life science at the 1 % level of significance. These results, although not significant across all comparisons in Table 6, may indicate that more faculty in mechanical engineering and telecommunications prefer university or individual assignment than those in life science, which tested Proposition 1c directly. This result is of great importance because it suggests that universities and policymakers should focus their efforts on life science in order to avoid the loss of invention. In addition, it suggests that a single policy applicable to all disciplines may not be a viable option for university administrations.

Regarding the university's intellectual eminence, Sect. 4.1 shows that it is positively related to university assignment but with weak significance. In Table 6, the empirical results provide more evidence. More specifically, in the comparison related to university assignment in model 11, the RRR of intellectual eminence is smaller than one in FIRM/UNIV, but larger than one in UNIV&FIRM/UNIV at the 1 % level of significance, as well as that in UNIV&FIRM/START-UP in model 12. However, university intellectual eminence plays little influence in the rest of the comparisons. It seems that universities with greater intellectual eminence wholly or partly owned more faculty patents than private firms and individuals.

Regarding university royalty policies, our findings suggest that this is the only factor that has an impact in the comparisons related to universities in model 11, but that it has little influence in model 12. Increasing the minimum inventor share of royalties could persuade more faculty to assign their patents to universities. Similarly, we find that three types of university equity policies also have a weak impact on faculty patent assignment, except for the variable of minimum inventor share of equity. In terms of the comparison of UNASSIGN/UNIV, the RRR related to royalty payment is greater than one (2.121, significant at 1 %), indicates that higher inventor share of royalty may not encourage university assignment since increasing this share rate can promote faculties to disclose more inventions but come with an added licensing fee for faculties' enterprises. Meanwhile, the RRR related to equity payment is less than one (0.123) indicates that higher inventor share of equity will increase the university assignments without added cost. This result is in line with Proposition 3b.

5 Discussions

5.1 Faculty's real strategy of patent assignment in Chinese universities

In Sect. 4, the empirical results suggest that China's faculties are tended to assign high-quality inventions to universities since patents disclosed to universities have more claims. In order to re-examine this claim, in this section, we consider patent validity and maintenance time as the other two indicators of patent quality. As shown in Table 7, by using

Table 7 Results of the patent claims and maintenance time

Variable	Model 13	Model 14	Model 15	Model 16
Characteristic of invention				
Mechanical engineering		0.442	0.127	0.430
Telecommunications		1.542***	1.136***	1.421***
Life science	Reference research field			
Number of inventors		0.140*	0.100	0.143*
Patent claims	0.113**	0.163		0.157***
Patent validity	−0.457***		−0.418***	−0.416**
Patent maintenance time	−0.087***		−0.074***	−0.073***
Intellectual eminence				
MOE discipline evaluation score		0.033**	0.031**	0.027*
University licensing policies				
Minimum inventor share of royalty		4.145**	3.594**	3.851*
Minimum inventor share of equity		−4.219*	−3.265	−3.392
Control variables				
Age		−0.017	−0.003	−0.010
Gender		0.062	0.094	0.009
Length of time as professor		0.060*	0.031	0.033
Administrative position		−0.603**	−0.476	−0.446
Number of inventions		0.026*	0.027*	0.031*
Observations	451			
R^2	0.113	0.200	0.205	0.245

* Significant at 10 %; ** Significant at 5 %, *** Significant at 1 %

binary logit regression model, the variable of patent claims is positively related to university assignment in models 13, 15 and 16 at the significance levels of 1 or 5 %. However, patent validity and maintenance time have negative relationship with university assignment. Since all these three variables are indicators of patent quality, the opposing results in Table 7 generate a crucial question as to whether China's faculty assigns high quality patents to non-university assignees.

In order to analyze this question, first, most of the patents disclosed to universities by faculty are developed from their basic or original research (Czarnitzki et al. 2012), so they have more justification for their claim to protect a wider technology scope. On the other hand, when faculty decide to choose non-university assignees, negotiation is needed on the issue of protection scope, in order to ensure that their future studies will not infringe the assignees' license, and to reserve the right to apply for related patents. This is why university assignment patents have more claims.

According to Thursby's research (2007), most non-university patent assignments in US research universities are the result of faculty consulting projects. Their decisions, reached through investigating the backward and forward citations, are that non university-assigned patents are less basic than university-owned patents. However, Chinese patent data does not provide further citation information as in the US. As a limitation, we were also unable to obtain details about each faculty's research and consulting projects for our study sample. Therefore, in this study, we could not arrive at a conclusion as to whether non-university assignment is due to consulting arrangements or not. In addition, we could only collect patent information which listed faculty as the first inventor. This has the disadvantage that many patents resulting from Chinese universities' consulting projects were excluded because the faculty was not listed as the first inventor.

Compared with patent claims and citation information, patent validity and maintenance time are the more appropriate measurements of patent quality from an economic perspective. Patents disclosed to universities have less economic life means that universities do not renew patent right because of their limited commercial value and the expenses for patent maintenance. The non-university assignees will tend to keep the patent right longer as a result of economic profit produced by faculty patents. Meanwhile, the variable of patent validity also tests this conclusion and shows in Table 7. We also checked patents randomly and found that most of them were not conducted in collaboration with private companies or in relation to consultancy assignments. Thus, we believe that this explains why faculty prefer to disclose high-quality inventions to non-university assignees before patent application.

5.2 Chinese institutional and legal system

China's education and technology systems were all introduced from the former Soviet Union in the middle of last century. A university is a public corporation, so university-owned patents are under the control of the government's "State-owned Assets Management Office". On the other hand, China's university employment contracts normally specify that faculty's on-duty inventions belong to the university. China's Science and Technology Law, similar to the Bayh-Dole Act of 1980, also rules that inventions funded by the government belong to the university. In addition, the patent licensing income has to be turned over to the state treasury in China. The government then redistributes this income between the university, faculty, and TTO in the form of the fiscal budget.

In China's complex institutional and legal system, faculty have limited freedom to apply, own, sell or license their academic patents independently. Therefore, the IPR policies must be correlated with faculty propensity to patent assignment. It is not surprising that faculty prefer to assign high quality patents to non-university assignees in order to keep 100 % of the licensing revenue, even though this is inappropriate. More seriously, faculty's arrangement for non-university patent assignment decreases the quality of university-owned patents and partly contributes to the poor performance of Chinese UITT. On the other hand, there may be issues of simultaneity here. From the perspective of university administrations, considering those non-university assignments, they have to keep their IPR policies current to prevent the loss of high-quality patents. In this situation, it is better for universities to give concessions to faculty inventors because of their information disadvantage. Thus, in order to control high-quality patents, universities have to improve their institutional and legal ecosystem to suit, e.g. giving faculty more IP rights.

6 Conclusion

According to the requirements of "China's National Medium and Long Term Science and Technology Development Planning (2006–2020)", improving the performance of university technology transfer is considered as one of the most significant strategies. Although this study was limited to examining China's top 35 patent application universities from 2002 to 2012, we have revealed how many university-invented patents have not been solely assigned to the university, as well as showing the related determinants by developing a unique faculty/patent dataset.

Compared with the prior work that focused on faculty patenting by searching for patents assigned to universities, this research concluded that there are four types of faculty patent assignment. We created a unique dataset based on the faculty individual level to account for faculty patent assignment in China's top 35 patent-application universities. This allowed us to find out that 13.16 % of faculty/patent pairs in our dataset are not solely assigned to universities. In addition, we revealed that Chinese faculty prefer to assign high-quality patents to non-university assignees, and gave a more plausible explanation for non-university assignment by using the binary and multinomial logit regression models. Lastly, we paid more attention to university licensing policies, such as inventor share of royalties/equity and related alternative policies, in order to offer more useful and operational policy implications.

Like many studies, ours has limitations. First, our empirical analysis is based on the faculty and university level, which has limitations. Ideally, other determinants, such as public funding, regional characteristics, and co-inventors' background, should be taken into account. Therefore, the empirical results may be subject to some bias. Further research should pay attention to these factors, for instance, how public funding influences faculty patenting.

Second, data is a common limitation. This research mainly focused on China's top 35 patent application universities, but China has over 2300 universities. In addition, whether the schools of mechanical engineering, telecommunications and life science can represent the whole university is subject to further tests. We were unable to collect each patent's forward and backward citations as a significant measurement of applied/basic inventions, and we were unable to judge whether non-university assignment in China is due to technology consulting projects or not.

Lastly, we ignored the influence of university incubators and TTOs among the sampled universities. For further empirical work, we will improve the data collection process, perhaps selecting a faculty patent sample randomly from a specific university and continuing to use the logit regression model to explore relationships among influencing factors at faculty individual, university, and technology market levels.

The main contribution of this paper was to analyze the determinants of faculty patent assignment. Specifically, Tables 5, 6, and 7 show overall research findings from different perspectives, namely invention characteristics, inventor characteristics, university policies and intellectual eminence. Based on these results, the main implication for university managers is that increasing faculty's share of royalties/equity and other economic incentives is an effective way to increase university assignment. In addition, TTOs should pay attention to faculty patenting across different research fields. For instance, more care should be taken over patents in life science. For Chinese universities, although the entrepreneurship infrastructure has developed in recent years, they need to implement flexible approaches to encourage faculty inventors to choose appropriate assignment. Indirectly, this implies a significant change for policy-makers, who will need to establish institutional and legal systems that allow faculty to manage their scientific findings independently.

Appendix: Data collection and screening method

Figure 3 gives details about data collection in this paper. First, we collected all professors' individual information from their CVs in websites on three research fields in the 35 Chinese universities in our sample. The individual information includes date of birth,

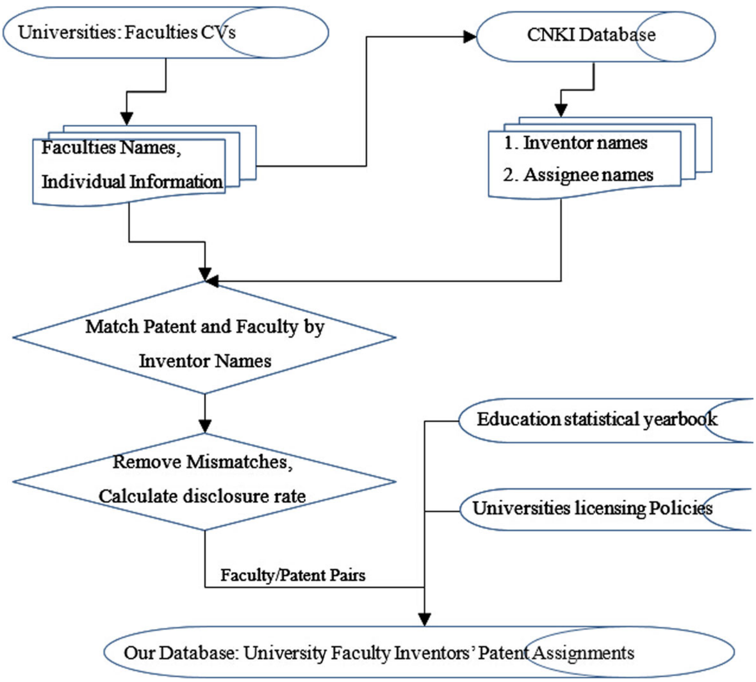

Fig. 3 Process of data collection

gender, research field, work experience, the date when they acquired the title of professor, and their experience of administrative position. Note that in this paper we classify research field according to the titles of the university departments (e.g. schools of mechanical engineering, schools of telecommunications, or schools of life science).

Second, we collected patent documents from the CNKI database by faculty names, and then matched faculty names with first-inventor names. To ensure that the sample included only patents with faculty who were truly employed by universities on the dates of their patent applications, a screening method was adopted that aimed at eliminating inventors who were not true faculty inventors: (1) in our dataset, faculty with no patents were eliminated. In order to avoid name repetition in two or more universities, we excluded patent/faculty pairs if the faculty names appeared in different universities but in the same city; (2) we excluded patent/faculty pairs if name repetition occurred in two or more departments, regardless of whether the faculty had a part-time job in another department; (3) when a faculty name appeared in both the university and an external enterprise, and the first four figures of the zip code in the patent document was not the same as that of the university, the patent/faculty pair was excluded. Finally, (4) for a given faculty inventor, we checked every one of his/her patents according to the patent classification code. We excluded those patents that were significantly different from others. In the end, 18,435 faculty/patent pairs were created in our tailor-made dataset.

It is worth noting that our dataset is at the patent/inventor level. Because a single patent often has more than one inventor, we define a specific patent as the “faculty patent” only where the university faculty is the first inventor, and thus collect faculty patents according to the faculty name when faculty inventor is the first inventor in the patent document. This means that each patent appears only once in our dataset. In this way, patents in which the university faculty inventor takes part in R&D activities and is the second or third inventor will be excluded. Thus, we admit that our study has neglected some of the R&D collaboration activities between faculty and private firms. Perhaps the real proportion of university-firm assignment is higher than we claimed in our paper. In addition, due to the limited information on faculty patents, we do not have information about co-inventors. An obvious limitation of this data presentation method is that we cannot calculate how many industrial firm employees are listed in faculty patent documents.

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