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Patent statistics: A good indicator for innovation in China? Patent subsidy program impacts on patent quality

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Abstract

This study investigates whether patent subsidy programs to promote regional innovations have generated a large volume of low-quality applications in China, resulting in biased patent statistics as an indicator for innovations. We find that subsidies on patent filing fees encouraged the filing of low-quality patents, resulting in a decreased grant rate. Although grant-contingent rewards increased the patent grant rate, they also encouraged patents with narrow claim breadth. Our empirical results confirm a general concern that patent subsidies have side effects of encouraging patent applications of low quality or value. However, patent subsidy programs do not affect granted patent trends, particularly for those requested by businesses. Therefore, while the surge of patent applications exhibits upward biases as an innovation indicator, increases in granted patents can be explained by the increase of technological capability in China's business sector.

Keywords: patent, subsidy, quality, China

JEL codes: O32 O34 O38

1 Introduction

A recent surge of patent applications in China has aroused significant research interest to investigate whether the surge indicates the essential growth of innovative capabilities of Chinese industries and a change from "imitation" to "innovation." Although the rapid increase of Chinese patent applications can be explained by the nation's technological catching up with international players in developed economies, patent quality concerns arise as studies have suggested that such applications are largely supported by local government patent subsidy programs (Li, 2012). Thus, can we rely on patent statistics as an indicator of innovation in China? Several studies have analyzed the determinants of patent application growth, but few have provided empirical evidence on the quality of these patents. It remains especially unclear whether patent subsidy programs have resulted in the deterioration of quality of Chinese patent applications. This study contributes to the literature from a "quantitative" to a "qualitative" perspective.

Despite a surge of patent applications by domestic players in China, a natural concern is whether patent subsidy programs have generated a surge of low-quality patent applications, thus making patent statistics an exaggerated indicator of China's innovative capability. Li (2012) suggests preliminary clues that patent quality was not affected as the grant rates of patent applications have not recently decreased. A recent increase pattern can be observed in not only patent filing data but also in the number of grants. Several studies demonstrate that Chinese granted patents have lower value than patents by foreign players (Thoma, 2013; Zhang & Chen, 2012). However, to the best of our knowledge, whether this low quality can be explained by patent subsidy programs initiated in the early 2000's remains unstudied.

Another question is whether subsidy programs affect different types of applicants. Li (2012) showed that subsidy programs have generally boosted applications from firms, universities, research institutes, and individual inventors. However, differences may exist among firms of different ownerships as studies have suggested that ownership is an important factor in Chinese firms' innovation activities. Subsidy programs were originally established to promote "endogenous innovations," favoring domestic firms; however, the policy itself does not exclude foreign funded enterprises (FFEs) from receiving subsidies.

Therefore, this study investigates whether patent subsidy programs generate "strategic behavior" by domestic applicants and result in deteriorated patent quality and biased patent statistics. We extend the pioneering research of Li (2012) in several directions by answering whether patent subsidy programs encourage excessive filing of low-quality patent applications, reflected in a low grant rate and narrow claim scope. Moreover, we investigate the effect of different policy designs on the timing and condition of subsidies, and using firm level data, we identify whether the policies differently affect state-owned enterprises (SOEs), privately owned enterprises (POEs), and FFEs.

We classify patent subsidies into three categories reflecting their timing and conditions: filing fee, examination fee, and patent grant contingent rewards (hereinafter grant-contingent rewards), and empirically investigate their effects in the patenting process. Filing fee subsidies generated excessive applications that ended without examination requests, and examination fee subsidies increased the propensity of examination requests. Contrary to general observations that the patent grant rate should not be affected by subsidy programs, grant-contingent rewards generally increased the patent grant rate. Further investigation revealed that grant-contingent rewards encouraged strategies to narrow patent claims to obtain patents more easily. This policy effect is generally consistent among firms, non-business organizations (NBOs), such as universities and public research institutes; and individuals.

This study contributes to innovation literature on studies in China. First, we provide solid evidence that patent subsidies generally generate excessive filing of low-quality applications and biased statistics, which must be addressed properly in innovation studies about China. Second, by detailed classification of patent subsidies, we empirically demonstrate the effects of different policy designs, findings that may provide useful policy insights. Most importantly, we find that although grant-contingent rewards help prevent low patentability applications, they encourage strategic patenting with narrow claims and low economic value, a trend which is undesirable for policy makers.

The study proceeds as follows. Section 2 briefly introduces the background and theory. Section 3 describes the data and variables. Section 4 presents our econometric results. Section 5 discusses implications for policy and academic research. Section 6 concludes.

2 Background and theory

2.1 Discussion of Chinese patent statistics as an innovation indicator

China established its patent law in 1985, and patent applications had been growing rather modestly until the end of the 1990s. Since 2000, volumes of patent applications have surged dramatically. Applications from domestic inventors, in particular, surged at an annual rate of 30% from 1999 to 2009 (Fig. 1). The growing patent application numbers suggest stronger endogenous innovative capabilities. However, this surge is unexpected because China is still widely considered as a weak intellectual property regime (Keupp, Friesike, & von Zedtwitz, 2012; Zhao, 2006). Studies suggest that R&D intensification is unlikely to be the primary cause of this surge (Hu & Jefferson, 2009); however, subsidy programs are important factors behind it (Li, 2012).

(Fig. 1)

Rapid growth of patent applications in China is obvious given the technological production and market perspectives: Chinese firms' quick catch-up of technological development and a more attractive market enhances patenting benefits. Successful Chinese companies, such as Huawei and ZTE, have grown rapidly in technological capabilities and market share (Motohashi, 2009), and patent aggressively in both the domestic and global markets[1]. However, studies reveal that the overall patent surge is unlikely to have resulted from R&D intensification (Hu & Jefferson, 2009). Several scholars list foreign direct investment (FDI) as a contributor to patent growth from the market perspective and assert that patenting by foreign firms increases the propensity among domestic innovators, who need larger patent portfolios, to create market barriers or achieve better positions in cross-licensing negotiations (Hu, 2010; Thoma, 2013)

Studies have examined other hypotheses, including pro-patent legal changes and the exit of low-patenting-propensity SOEs (Hu & Jefferson, 2009). Li (2012) confirms with empirical data that subsidy programs established by local governments stimulate patent applications. Whether patent subsidy programs have caused Chinese applicants to file low-quality patents remains to be answered. Li (2012) finds that the grant rate of patent applications did not decrease in recent years and draws a preliminary conclusion that subsidy programs did not generate patent bubbles. However, various controls are needed to reach a solid conclusion.

Several studies take another approach by comparing the economic value or quality of Chinese patents with those requested by foreign firms. Using patent renewal information in the Chinese patent office (SIPO), Zhang and Chen (2012) estimate that patents requested by domestic applicants have a lower value than those requested by foreign applicants, and argue that Chinese firms may patent under local policy

[1] Huawei Technologies Co. Ltd topped the list of PCT applicants in 2008 according to the World Intellectual Property Organization (WIPO, 2009).

demand rather than market competition (Zhang & Chen, 2012). However, a time trend analysis has not been performed to verify whether the lower value of domestic patents is a new phenomenon accompanied by the recent explosive growth of patenting. Thoma (2013) assesses the quality of Chinese patent applications in the European Patent Office (EPO), concluding that applications have shorter renewal life cycles. However, because of the high cost of patenting abroad, firms may patent only inventions with high economic value in the EPO or USPTO. Firms that actively patent abroad are generally larger, younger, and more export-oriented than those that patent solely in the domestic market(Eberhardt, Helmers, & Yu, 2011).

One limitation of using patent renewal data is the inadequate timeliness because of the uncertainty of the life of newly granted patents. A widely used patent value indicator is the number of forward citations, reflecting patents' technological importance (Harhoff, Scherer, & Vopel, 2003; Nagaoka, Motohashi, & Goto, 2010). Studies also use citation-weighted patent counts as a more precise indicator of innovation output (Bloom & Van Reenen, 2002; Hall, Thoma, & Torrisi, 2007). Unfortunately, SIPO does not document this information.

Another approach is to quantify the breadth of patent claims by counting either the number of claims (Lanjouw & Schankerman, 2004) or the length of the primary independent claim. Although the number of claims is more widely used in the literature, it has not been well documented in the Chinese context, making it inappropriate for research with large datasets. Malackowski and Barney (2008) propose patent claim length (count of words) as a rough measurement of claim breadth and state the logic as follows:

> *While claim breadth cannot be precisely measured mechanically or statistically, counting the average number of words per independent claim in an issued patent can serve as rough proxy if taken from a sufficiently large, statistically relevant sample. That is because each word in a claim introduces a further legal limitation upon its scope.*

Meeks and Eldering (2010) also propose that claim length can serve as an initial measurement in determining the scope of claims. Because this method is free of the untimeliness limitation, we apply it to Chinese patent statistics to track the impact of patent subsidy programs on the patent quality.

2.2 Patent subsidy programs and their impact on patent-based innovation indicators

Patent subsidy programs were launched at the end of the 1990s in response to a strong governmental concern about domestic firms' technological competiveness after becoming a WTO member. To strengthen the awareness of intellectual property rights and encourage domestic firms' "endogenous innovation," the central government issued policy guidelines titled "Strengthen Technology Innovation, Develop High-Tech Industries, and Promote Industrialization (of Inventions)". In response to this guideline, relatively developed regions, such as Shanghai, started promoting patenting activities of local enterprises in 1999. Other provinces followed, and 29 of 30 provinces launched similar programs by 2007 (Li, 2012).

Although the goals are the same, policy design varies among regions, and several governments have made considerable revisions to their policies. Li (2012) describes differences in budget constraints and subsidy amounts among regions. A more subtle difference is the timing and condition of subsidies for invention patents, which are more highly valued and are considered as being a better indicator of technological capabilities. Subsidy amounts for invention patents are significantly higher than for utility models or design patents.

Applying an invention patent includes three processes: filing, requesting examination, and examination by the patent office (Yang, 2008; Zheng & Lan, 2010). The examination request can be submitted within three years after filing. However, an early request is encouraged as applicants must otherwise pay an application maintenance fee two years after filing. Renewal fees are charged to maintain a granted patent's validity. Fig.2 illustrates the filing and granting procedure for invention patents and relative costs.

(Fig. 2)

Fig. 2 depicts a typical case, and costs may vary slightly. For example, if a patent has more than 10 claims, the fee includes an additional 150 yuan for each extra claim. However, the examination and registration fees do not change with the number of claims.

Local governments differ in their detailed subsidy conditions. Some governments subsidize only granted patents, intending to promote applications with a good probability of passing the examination. However, such programs may not provide strong incentives for patent filing because three to four years elapse between filing and granting patents, and the examination results are uncertain. Therefore, some governments provide subsidies in filing and examination stages, allowing the applicants to obtain subsidies immediately after patent filing or examination request. Applicants are not required to return the subsidies if the applications are rejected by examiners. Another difference is the amount of subsidies. Some governments fully subsidize the filing and/or examination fee whereas others provide subsidies covering only 50%–80% of the fees. Grant-contingent reward can vary from 500 yuan (Hebei) to 15, 000 yuan (Tibet). Some provinces set no rigid amount and provide subsidies on a case by case basis. Li (2012) first collected information on regional patent subsidy programs and identified the starting year of those programs. On the basis of this information, we checked the policy details in official documents published on local government websites and news reports or by telephone interviews of local officials and categorized the types and amounts of subsidies, as summarized in Table 1.

(Table 1)

Table 1 reports the classification of filing and examination fee subsidy as “Fully” if the amount is equal to the fees charged by SIPO, and as “Partly” if the amount is unclear or less than the fee charged. Grant-contingent reward is classified as “High” if the amount is no less than 2000 yuan, and as “Low” if unclear or less than 2000 yuan. Some governments subsidize the filing or examination fee only after a patent is granted. As such compensations are contingent on patent granting, we classify them as “grant-contingent rewards” though policy documents identify them as “filing fee subsidy” or “examination fee subsidy.”

The effect of subsidy programs on the quality of patent applications can be analyzed from two perspectives, patent grant rate (number of granted patents divided by number of total filed applications) and the value of granted patents. An application may not be granted in two cases: the applicant does not request an examination within three years after filing, or the invention does not meet the criteria of patentability, including utility, novelty, and non-obviousness. Therefore, a low patent grant rate may result from a lower rate of examination requests after filing and a higher probability of patent denial by examiners. For simplicity, we define the patent grant rate as the number of granted patents divided by number of examined patents. Thus, patent grant rate = examination request rate × patent allowance rate. Correspondingly, for one application, we have probability of grant = probability of examination request × probability of allowance.

The effect of filing fee subsidies should be the simplest as they reduce patenting costs from the outset. One may attempt to patent a technology with a lower patentability when subsidies are available. Such applications have a higher probability of being rejected by the examiner, resulting in a decreased rate of patent grants. Moreover, filing fee subsidies may encourage filings of inventions with great market uncertainties. After filing, the applicant may drop the filed applications before requesting examination if it is clear that the economic value of the patent is lower than the subsequent costs for examination and registration. Thus, filing fee subsidies can result in a lower examination request rate, and finally a lower patent grant rate.

The effect of examination fee subsidies can be complex. On one hand, it decreases the total patenting cost and increases the patenting propensity, which may decrease the patent grant rate as more low-quality patents may be filed. On the other hand, examination fee subsidies may encourage applicants to request examination for patents that would have been abandoned because of low patentability or low economic value, resulting in a higher examination request rate. The total effect depends on which effect is dominant.

Grant-contingent reward gives patent assignees economic benefits in addition to exclusive rights. Similar to filing fee and examination fee subsidies, it can increase the trend of patent filing, but it will not encourage filing inventions with low patentability as the reward is contingent on patent grants. Therefore, grant-contingent rewards should not affect the patent granting rate. However, grant-contingent rewards can encourage applicants to submit examination requests for inventions with good patentability, but low value. Although applicants may not benefit greatly from the exclusive rights of patents, they can benefit from the subsidy programs. The increased examination request rate results in a higher grant rate. One characteristic of low-value patents is a narrow independent claim because competitors can easily bypass the protected scope and develop similar products. If grant-contingent rewards encourage the filing of low-value patents, we observe narrowed claims.

As described by Li (2012), individuals, universities, research institutes, and businesses receive essentially the same supports. The subsidy programs make no explicit discrimination between different types of businesses, except for Anhui province, which excludes foreign-owned and -controlled companies from receiving subsidies. However, subsidy programs' implicit barriers may exclude foreign funded businesses because recent Chinese government science and technology development policies emphasize promoting "endogenous innovation" or "self-dependent innovation" (Liu, Simon, Sun, & Cao, 2011). Further, patenting by FFEs is more likely to be determined by their headquarters' R&D output and marketing strategies, rather than local policy incentives.

3 Data and variables

3.1 Data

This study uses a combined dataset of patent information from SIPO and Chinese firm data provided by GTA Information Technology Company, Limited (GTA).

Chinese patent data

Patent data in China is available on the SIPO website (http://www.sipo.gov.cn/); however, it provides formatted data only with a subscription whose data covers all patent applications since 1985, when China established its patent system, and provides following information (Motohashi, 2008).

(1) Patent application information of invention patents, utility models, and design patents, including application number, applying date, IPC classification, patent number of priority applications, applicants' names and addresses, inventors' names, and patent attorney's name and address. For invention patents and utility models, the title, abstract, and primary independent claim are available; for design patents, the title and a short description are available. There is a time lag of 18 months between filing and publication of patent applications.

(2) Examination information of invention patents, including examination request date and issue date of granted patents. Because patent examination generally takes three to four years after filing, a time lag exists in obtaining the result of the final examination decision.

(3) Patent renewal information indicating whether a patent has expired because of unpaid maintenance fees. If the applicant pays past-due maintenance and late fees within six months, the terminated patent rights can be revived and the revival records are also available.

The most important drawback of China's patent data is inadequate citation information, a widely used patent quality indicator. Another limitation is that full claim information and patent descriptions are not currently available for automatic processing.

This study uses domestic invention applications from 1998 to 2008 as the base dataset (Dataset A), including 592,547 applications. We limit our research to invention patents because they represent the major investment target of all regions' patent subsidy programs, whereas some regions, such as Zhejiang and Anhui provinces, do not subsidize utility models and design patents. We truncate old applications before 1998 to match firm data, which is available only since 1998. Patents requested after 2008 are also truncated because their examination information is not available by the end of 2012. The time span is suitable for testing the subsidy programs as those programs were initiated between 1999 and 2007. By text mining applicant names, we categorize applications by three types of applicants: businesses, NBOs (universities, public research institute, and government agencies), and individuals.

<u>GTA firm data</u>

GTA's non-listed enterprise database is a rare data source for Chinese firms. It is based on investigations by the National Bureau of Statistics of China. The data covers roughly 150,000 businesses from 1998 to 2002. More businesses were then added, and since 2009, it covers roughly 380,000 businesses. It includes firm profiles, such as name, ownership, location, established year, and industry, and financial information on assets, revenue, profit, and cash flow. The data covers 31 provinces in Mainland China. Shares of covered businesses in each province are proportional to their shares in China's GDP. Thus, the data does not have a severe regional bias. The major limitation of this data is that information on R&D expenditures is generally absent, which may limit its usage in innovation studies.

We matched patent data with enterprise information by names of applicants, enabling us to identify the ownership of the applicant. The matched dataset (Dataset B) includes 126,386 applications from 12,208 businesses, which accounts for 44.6% of domestic businesses' invention applications filed from 1998 to 2008. However, those applications are highly concentrated, with the top 10 applicants contributing 46.4% of the total applications. Those applicants include Huawei and ZTE, which are known as aggressive patent applicants globally, and Hongfujin Precision Industry Co., Ltd. which is a subsidiary of Foxconn Technology Group. The firm-specific effects may cause bias in estimations, especially as sub datasets grouped by applicant ownerships are needed in this study. Thus, we exclude applications from the 12 large applicants which with large portfolios of more than 1,000 patents, and get a smaller dataset (Dataset B) of 60,244 applications from 12,197 businesses. We divide those applications according to the ownership of applicants: SOEs, POEs, and FFEs (including Hongkong-Macau-Taiwan invested businesses).

3.2 Methodology and variables

We use three steps to estimate the effect of patent subsidy programs. First, we use a probit model to estimate the aggregate effects of filing fee subsidies, examination fee subsidies, and grant-contingent rewards on the patent grant rate. We assume that before filing, the applicants have considered all available subsidies provided by local governments, including grant-contingent rewards. Second, we test whether grant-contingent rewards affect the claim breadth using ordinary least squares (OLS) estimations. Finally, we use the Heckman two-step model to analyze whether the effect of grant-contingent rewards is reflected in the allowance rate. In all the three steps, we use both Datasets A and B.

Dependent variables:

Granted: dummy variable; equals 1 if an application is granted within four years of filing.

Examined: dummy variable; equals 1 if the applicant files an examination request for a patent application.

ClaimScope: inverse of logarithm of noun counts in a patent's primary independent claim. We use the inverse because the number of nouns indicates a narrower claim scope.

Patent granting takes 3.87 years on average after filing with SIPO. The examination process may last longer for some patents because of delays on both applicant and examiner sides. Thus, for a recently filed patent, we cannot obtain accurate information whether it will be granted. Thus, we use a time window of four years after filing, within which granting decisions have been made for 83% of domestic applications. The result is consistent when we extend the time window to five years. This study therefore sets a time window of four years to include more recent observations in the regression.

Our measurement of claim breadth is based on Malackowski and Barney (2012), but with modifications. We count only the number of nouns, rather than all the words in the claims, because nouns represent more substantial technology factors and are a better proxy of "legal limitation." As the Chinese language does not use spaces to separate words in a sentence, we use the ICTCLAS Chinese lexical analysis program developed by the China Academy of Science to separate and tag nouns. We separate process and usage patents from device patents by text mining of abstracts and control this in our regressions because the two types of patents have significantly different conventions in claim drafting.

Independent variables:

FileSub: category variable; 1 if filing fee is fully subsidized in the province where the applicant is located, 0.5 if partly, 0 if not.

ExamSub: category variable; 1 if examination fee is fully subsidized, 0.5 if partly, 0 if not.

GrantSub: category variable; 1 if grant-contingent rewards are no less than 2000 yuan, 0.5 if less than 2000 yuan, 0 if none.

Non-device: dummy; 1 if the application is for a product or a device, 0 if it is about a method, process, or new usage.

Experience: years between the current application and the applicant's first application. The literature suggests that experienced applicants may be skilled in assessing the patentability of technologies, drafting strong application documents, and communicating with examiners (Thoma, 2013). Thus, we use this as a control in our models.

The models include technology and year dummies. Technology dummies are generated from the NBER patent classification based on the IPC, including 33 categories. Moreover, we include five regional dummies indicating whether the applicants are located in Guangdong, Beijing, Shanghai, Jiangsu, or Zhejiang. These top five regions contributed 59% of domestic applications from 1998 to 2008. When using Dataset B, we use the logarithm of the number of employees (logEMP) to control for firm size effect.

3.3 Descriptive trends

(1) Patents examination request rate

(Fig. 3)

Fig. 3 illustrates the trend of the patent examination request rate. Both domestic and foreign applications have exhibited a higher examination request rate since 2001. Foreign applicants and domestic NBOs have requested examination for most of their filed patents in recent years, whereas individuals more often let their filed application lapse without requesting examination, reflecting their budget constraints. The examination request rate of applications from individuals has decreased since 2004, despite the general growth trend, illustrating possible excessive filing.

(2) Patent allowance rate

(Fig. 4)

Fig. 4 depicts the allowance rate of examined patents. Except for the year effect of the patent law amendment in 2000, patent allowance rate has been generally steady in recent years. The allowance rate of patent applications from NBOs has been decreasing gradually in recent years.

4 Empirical results

4.1 Effect of patent subsidy programs on probability of patent granting

Using Granted as the dependent variable, we estimate the effects of three kinds of subsidies on the granting probability with probit models. Table 2 reports that FileSub is negatively significant whereas ExamSub and GrantSub are positively significant in the estimations. The results are generally consistent in estimations with the sub-datasets of applications from businesses, NBOs, and individuals, except that ExamSub is not significant in the estimation using the sub-dataset of applications from NBOs. The results suggest that filing fee subsidies cause excessive applications that are dropped before examination or rejected by examiners. The positive significance of ExamSub reveals that the effect of examination fee subsidies on increasing the trend for requesting examination is more significant than its effect on encouraging low-quality applications. Grant-contingent rewards have a similar effect on increasing the examination rate. However, the positive significance of GrantSub may also result from its effect on increasing the probability of allowance. Table 2 reports a negative significance of ClaimScope, suggesting that applications with narrower claim scope are more likely to be granted. In Section 4.2, we test whether grant-contingent rewards encourage applicants to file applications with a narrow claims scope to more easily obtain patent grants.

(Table 2) and (Table 3)

Table 3 reports the results using Dataset B. Estimations using all applications in Dataset B produce consistent results with those reported in Table 2. However, in estimations using sub-datasets, the effects of examination fee subsidies and grant-contingent rewards vary across the categories of applicants. ExamSub significantly increased the probability of grants for applications filed by POEs, but decreased it for SOEs and FFEs, suggesting that the effect of examination fee subsidies on increasing the propensity of requesting examination is less significant than its effect on encouraging low-quality applications from SOEs and FFEs. GrantSub is positively significant for POEs, but is not significant for SOEs and FFEs, suggesting that grant-contingent rewards may increase the propensity of examination requests for POEs, but not for SOEs and FFEs.

4.2 Effect of grant-contingent rewards on breadth of patent claims

We estimate whether grant-contingent rewards encourage applicants to file patents with narrower claims using OLS models. The dependent variable is ClaimScope. Table 4 reports that GrantSub is negatively significant and the results are consistent across the categories of applicants. The results suggest that grant-contingent rewards encourage more patents with a narrow claim scope, and thus low economic value.

(Table 4) and (Table 5)

Table 5 reports the results of estimations using Dataset B. The result is generally consistent with that reported in Table 4. Although GrantSub is not significant in estimations with applications from SOEs and POEs, the coefficient is negative. GrantSub is significantly negative in estimations using applications from FFEs, suggesting that FFEs are also affected by patent subsidy programs.

4. 3 Effects of patent subsidies on probability of patent allowance

(Table 6) and (Table 7)

Our probit estimation results in Section 4.1 demonstrate that grant-contingent rewards increase the probability of patent granting. However, it is unclear whether the effect results only from a similar effect to that of examination subsidies on increasing the propensity of examination requests, or whether grant-contingent rewards also increase the probability of patent allowance in the examination process. Results in Section 4.2 demonstrate that grant-contingent rewards encourage the filing of patent applications with narrow claim scope, which may result from a strategy to increase the probability of allowance.

Direct estimation of the probability of patent allowance with examined patent applications has a self-selection problem (Heckman, 1979): applicants are more likely to select patents with higher grant probability. The allowance rate of examined applications does not provide a good estimation of the allowance rate of applications dropped before examination if those applications have been examined Bias can be significant because filing and examination fee subsidies can affect the decision about requesting examination. To test whether grant-contingent rewards increase the probability of patent allowance, we use Heckman two-step selection models. We use all applications as observations rather than using only examined patents and controlled for the selection effect in examination requests. Cross production terms between GrantSub and ClaimScope are included to test the interaction effects.

Table 6 reports the results. GrantSub is positively significant in estimations without cross production terms between GrantSub and ClaimScope, suggesting that

GrantSub generally increases the probability of patent allowance when the selection effect in examination requests is controlled. An institutional perspective is that patent examination results are not affected by any types of subsidy programs because examiners make the decision of approval or rejection. However, the applicant's actions can affect the outcomes of examination. First, applicants may make greater efforts in drafting better patent descriptions and responding to Office action (a document of reasons for possible rejection) from examiners if grant-contingent rewards exist. Second, applicants may narrow the breadth of claims to more easily obtain a patent grant. Our results in Section 4.2 suggest greater probability for the second scenario.

When we include a cross term of GrantSub and claim scope in the models, the results vary across different types of applicants. For NBOs and individuals, the cross term is significantly negative, suggesting that the effect of narrower claims becomes stronger when grant-contingent rewards exist. However, the cross production term in estimations using applications from businesses produce a less significant, but positive correlation. Further testing demonstrates that the significance may result from specific effects of the two largest patent applicants, Huawei and ZTE, which contribute 36,457 applications among the 264,696 from businesses. When we exclude applications from these two applicants, the cross production term becomes insignificant and the other coefficients change only slightly. One explanation of this difference is that businesses are less likely to sacrifice claim breadth for a patent grant because they need broader patents to protect their products from imitation.

Table 7 reports the estimation results using Dataset B. GrantSub is positively significant for POEs, suggesting that grant-contingent rewards increase the allowance rate of patent applications from POEs. However, GrantSub is not significant for SOEs and FFEs, which is consistent with the results in Table 3. The cross production terms show a slightly negative significance, suggesting that grant-contingent rewards may encourage some businesses to strategically narrow patent claim scope to more easily obtain the patent. However, this effect is not as significant for POEs as it is for NBOs and individuals.

5 Discussion

5.1 Patent statistics as a biased innovation indicator

Our empirical results demonstrate that patent statistics are biased as a result of "strategic patenting" motivated by patent subsidy programs. This bias causes difficulties for studies on innovations in China.

An explicit bias lies in the increased low-quality patent applications, which are dropped without examination or rejected by examiners, thus distorting the correlation between statistics based on patent applications and granted patents. Li (2012) made a simple tabulation and found that, though many provinces have recently launched subsidy programs, the recent patent grant rate has increased (excluding the time window effects). However, the increased grant rate is more likely an effect of the examination fee subsidy, which increases the examination request rate. When investigating the allowance rate of examined patents, we observe a different outcome: widely adopted patent filing fee subsidies have decreased the patent allowance rate, and that effect is especially significant for NBOs. Although statistics based on applications have their merits in timeliness, it should be used with care for Chinese patents because of the policy bias. One difficulty in making adjustments is that the bias is unsystematic because different regions enacted different policies, and several regions have made substantial policy changes.

An implicit bias lies in the quality of granted patents. Our results revealed that applicants strategically file patents with narrow claim scopes to obtain patents more easily after examinations. The quality bias between patents filed with/without grant-contingent rewards makes patent counts unreliable as an indicator for innovations. Although adjusting patent statistics using citation data is highly recommended in the literature, it is not practical for Chinese patents where citation data is not available. Patent count weighted by claim scope presents another practical option.

However, it is noteworthy that the patent grant data is not as biased as the patent applications data. For NBOs and individuals, we have found the complementarity of grant subsidy and narrower patent claim to increase the probability of patent granting. However, businesses exhibit the opposite pattern. In samples including Huawei and ZTE, we found a positive and statistically significant cross term of GrantSub and patent scope. That is, a broader scope of patents is granted more often with the existence of a patent grant subsidy. This outcome suggests that the grant subsidy policy intent for indigenous innovation seems to work for the enterprise sector.

Since 2000, when the patent subsidy program began, the share of enterprise patents has steadily increased to more than 50% of all patents in both filing and granting statistics. Therefore, the recent surge in granting patents may not be especially biased by the patent subsidy program, but can rather be explained by the enterprise sector's increasing R&D expenditure. Table 8 reports the trend of R&D expenditure, adjusted by GDP deflator, and patent statistics from 2000 to 2008. When we divide the entire period into two halves, 2000–2004 and 2004–2008, we find that the increasing speed of the patent propensity (patent/R&D) declines in the latter period. Therefore, we can conclude that patent granting data is not as greatly biased as patent filing data by strategic patenting behavior motivated by patent subsidy programs.

(Table 8)

5.2 Toward a better subsidy policy design

Patent subsidy programs enacted by local governments have contributed to the surge of patenting in China. These programs have a positive influence in promoting recognition of intellectual property (IP) value, easing financially constrained SMEs' burden of obtaining patents and encouraging inventions. These influences have significant meaning in a weak intellectual property environment such as China, which is transforming from "imitation" to "innovation." However, our empirical study confirms a general concern that patent subsidies have side effects in encouraging low-quality applications.

Policy makers should consider these side effects as we observe differentiated policy incentive designs in different regions, and several provinces have changed their policy from subsidizing the filing fee to giving grant-contingent rewards. The variety of practices allows us to analyze their effects and suggest implications for future policy modifications.

The first question is whether subsidies should be contingent on grants. Our study provides evidence that subsidies before grants decrease the patent allowance rate, indicating that these subsidies encourage filing of inventions lacking novelty or non-obviousness. From the perspective of policy efficiency, grant-contingent subsidy or reward is a better choice for increasing granted patents, which is a policy target as many provinces treat the number of granted patents as an assessment of local innovative capability. Our results demonstrate that grant-contingent rewards improve the grant rate as well as the allowance rate.

However, grant-contingent rewards are not perfect. They can prevent applicants from filing patents of low patentability, but cannot prevent them from filing patents of low value. Our empirical results revealed that grant-contingent rewards encourage filing of patents with narrow claim scope, which is a sign of low economic value. One incentive to do so is to increase the grant probability by sacrificing breadth of claims.

This reaction is more implicit and difficult to identify. This form of strategic reaction to policies is especially significant for NBOs and individuals, who may not use patents to protect real products. However, we should note that grant subsidy programs are beneficial to innovation incentives for the enterprise sector.

A more complex issue is whether the examination fee should be subsidized. Examination fee subsidies have the same function as filing fee subsidies in encouraging more patent filings. It also has a similar effect to that of grant-contingent rewards in increasing the examination request rate and grant rate, as our empirical results demonstrate. However, it disables the filtering effect of the examination fee system. The examination fee requires an applicant to reconsider the patentability and economic value of its application after filing. For example, an applicant may discover a prior art making the patent unlikely to be granted, or he may become less optimistic about appropriation potential after filing. Requesting examination would not be economically beneficial in these cases. Dropped applications before examination can decrease patent examiner workload, but subsidizing the examination fee may weaken the motivation to make a careful assessment before requesting examination.

Although a complete economic assessment of patent subsidy programs is beyond the scope of this study, our results provide empirical evidence of "strategic patenting" driven by various subsidies, which may represent an undesirable policy effect, thus necessitating continuing policy modification.

6 Conclusions

This study investigates whether patent subsidy programs promoting regional innovations have generated a large number of low-quality applications, and thus biased patent statistics as an indicator of innovation in China. Using patent application and examination data, we estimated the effects of filing fee subsidies, examination fee subsidies, and grant-contingent rewards. We find that filing subsidies have encouraged applications with low patentability, reflected in a lower examination request rate and lower patent grant rate. Although examination fee subsidies generally increase the patent grant rate, the effect results from a high examination request rate due to the lower financial burden for applicants. Although grant-contingent rewards do not have the limitation of encouraging filing applications of low patentability, they encourage applicants to strategically file patents with narrow claims, which indicate low economic value. This effect is especially significant for NBOs and individuals who usually do not need strong patents to protect real products. However, it should be noted that this bias is not found in the business sector; thus, overall patent grant statistics suffer less upward bias as a consequence of patent subsidy programs.

Our study makes several contributions to the literature on innovation studies in China. We extend the current literature on the effect of patent subsidy policies from a “quantitative view” to a “qualitative view.” We identified the bias in different stages due to strategic patent filing in response to policy incentives. We make the first investigation of how different subsidy designs affect the outcomes of patenting behavior.

Moreover, our study suggests policy implications and questions. We provide solid evidence that subsidizing the filing fee generates low-quality applications. More local governments seem to have identified this problem recently as we observe that certain governments, such as Zhejiang and Hunan, have suspended the filing fee and examination fee subsidy and replaced it with grant-contingent rewards. However, the policy shift cannot prevent applicants from strategic filing of low value patents, which waste the government budget for promoting innovations. We observed a more complex effect for examination fee subsidies. Although these subsidies have increased the patent grant rate, the increase results from more examination requests for low quality or low value patents. That is, the subsidies hindered the filtering effect of examination fees and generated an excessive workload for patent examiners.

We extend current studies on patent subsidy policies from the “quantitative” to the “qualitative” aspect of patents. Further research is needed to identify how these subsidy programs have affected R&D activities and intellectual property management, and whether they have achieved the goal of promoting “real” innovation output. As the aggregated statistics in Table 8 reveal, the patent propensity (patent/R&D) increases over time. Increases of patenting are beneficial to society in that more disclosure of inventions prevents potential duplication of research among players and increases the size of technology market. However, excessive patents generate complexity in the technology landscape and a “patent thicket” that stifles subsequent innovation. Understanding such social impacts of patenting is important for interpreting patent statistics as an innovation indicator.

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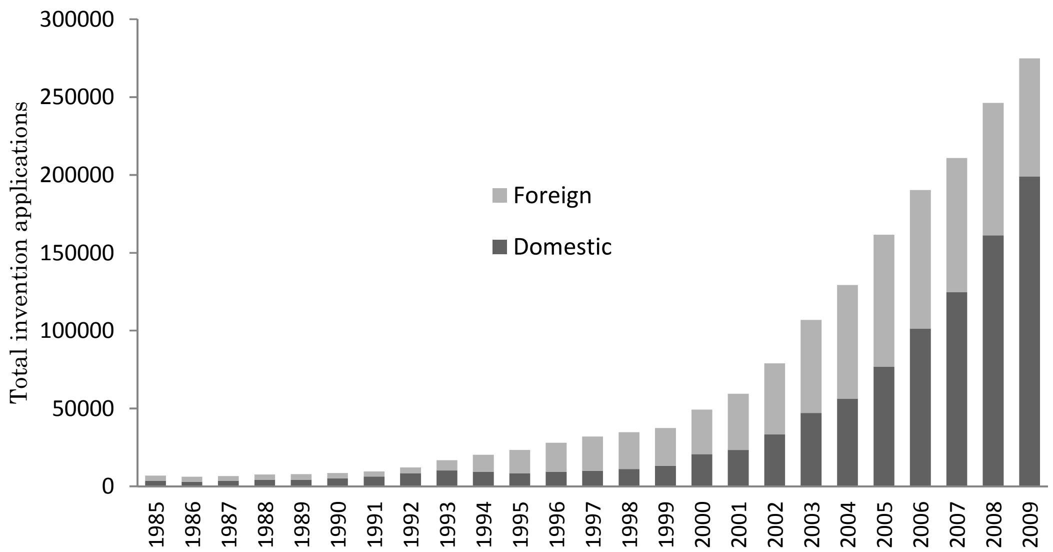

Fig.1 Growth of invention patent applications in SIPO (1985~2009)

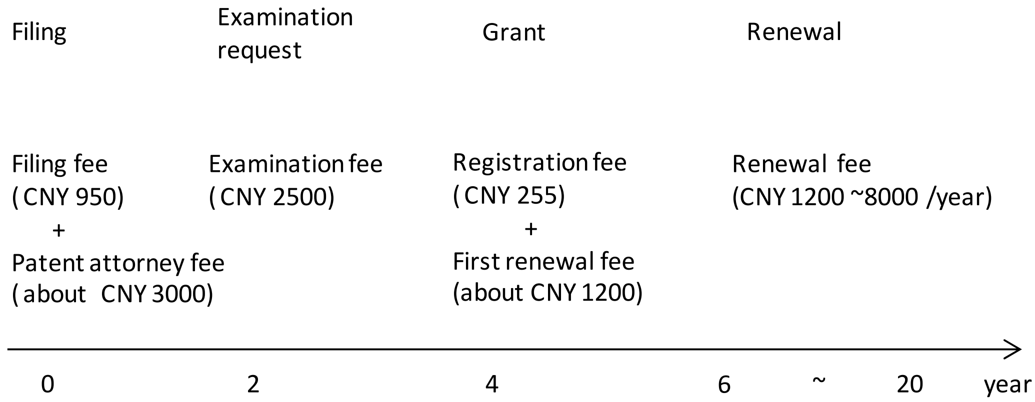

Fig.2 Filing and granting procedure for invention patents and relative costs in SIPO

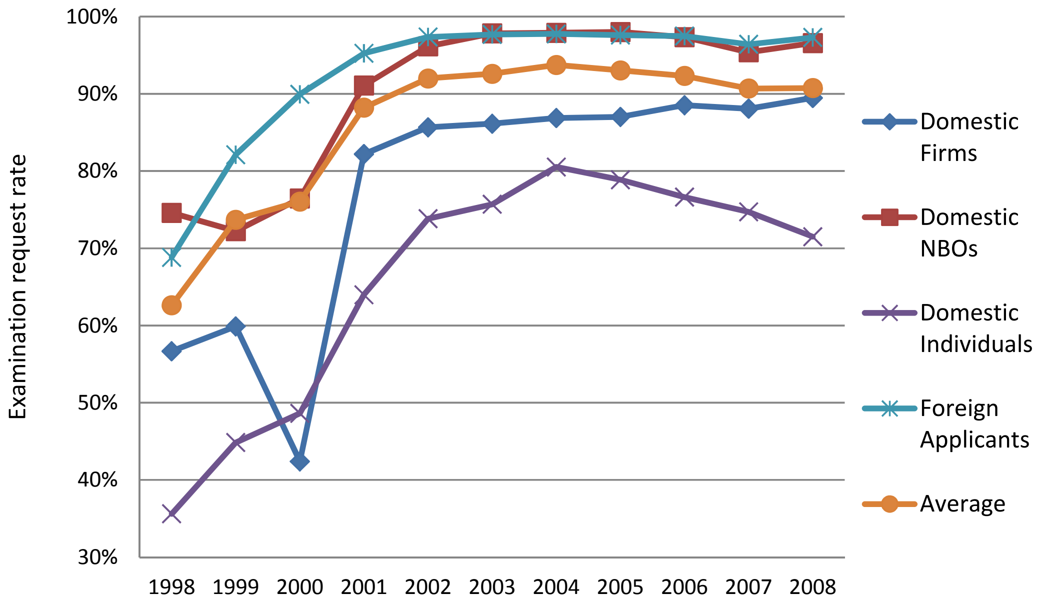

Fig. 3 Examination request rate of invention applications in SIPO (1998~2008)

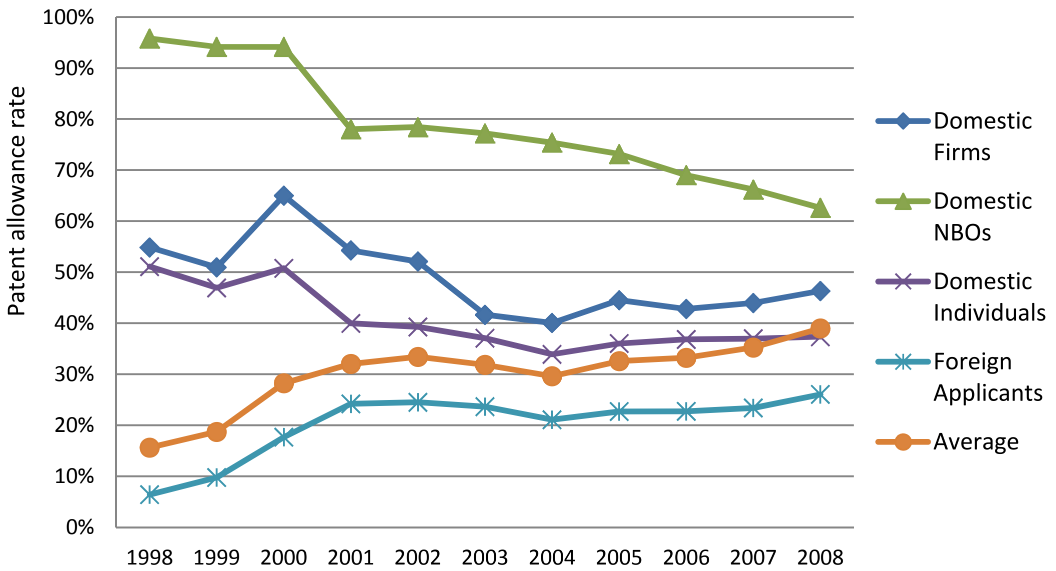

Fig. 4 Allowance rate of examined invention applications in SIPO (1998~2008)

Table 1 Summary of patent subsidy programs

Province	Start year	Filing fee subsidies	Examination fee subsidies	Grant contingent rewards
Beijing	2000	Fully	Partly	No
Tianjin	2000	Fully	No	No
Hebei	2005	Partly	No	Low
Shanxi	2003	Fully	Fully	No
Inner Mongolia	2002	Fully	Fully	No
Liaoning	2006	Fully	No	High
Jilin	2004	Partly	Partly	Low
Heilongjiang	2001	Fully	No	Low
Shanghai	1999	Fully	Fully	High
Jiangsu	2000	Fully	Fully	No
Zhejiang	2001 - 2005 2006 ~	No No	Fully No	No High
Anhui	2003	No No	No	High
Fujian	2002 - 2005 2006 ~	Fully Fully	Fully Fully	No High
Jiangxi	2002	Partly	Partly	No
Shandong	2003	Partly	Partly	High
Henan	2002	Partly	Partly	Low
Hubei	2007	No	No	Low
Hunan	2004 - 2006 2007 ~	Partly No	Partly No	No High
Guangdong	2000	Partly	Partly	No
Guangxi	2001	Fully	Partly	High
Chongqing	2000	Fully	No	Low
Sichuan	2001	Partly	Partly	No
Guizhou	2002	Fully	Partly	No
Yunnan	2003 2004 ~	Partly Partly	Partly No	Low Low
Tibet	2004	Fully	Fully	High
Shaanxi	2003	Fully	No	High
Qinghai	2006	Fully	Partly	No
Xinjiang	2002	Partly	No	High
Hainan	2001	Partly	No	No

Data source: the authors' collection from official documents published on local government websites and news reports or telephone interviews of local officials.

Table 2 Probit estimations of determinants of patent grants (Dataset A)

	All		Businesses		NBOs		Individuals	
Granted								
FilingSub	-0.264***	(0.00761)	-0.467***	(0.0128)	-0.0746***	(0.0158)	-0.0785***	(0.0129)
ExamSub	0.183***	(0.00808)	0.298***	(0.0139)	0.00965	(0.0175)	0.0597***	(0.0129)
GrantSub	0.289***	(0.00743)	0.442***	(0.0122)	0.108***	(0.0157)	0.132***	(0.0126)
ClaimScope	-0.229***	(0.00247)	-0.257***	(0.00396)	-0.216***	(0.00519)	-0.213***	(0.00412)
Firm	0.314***	(0.00452)						
NBO	0.609***	(0.00778)						
Non-device	0.169***	(0.00385)	0.216***	(0.00590)	0.0553***	(0.00863)	0.154***	(0.00650)
Experience	0.0130***	(0.000435)	0.0274***	(0.00102)	0.0163***	(0.000548)	-0.0220***	(0.00132)
Constant	-1.869***	(0.0690)	-1.757***	(0.198)	-1.268***	(0.0866)	-1.865***	(0.379)
Year dummies	Yes		Yes		Yes		Yes	
Region dummies	Yes		Yes		Yes		Yes	
Technology dummies	Yes		Yes		Yes		Yes	
Observations	581838		260596		113522		207720	
LogLik	-359664.1		-165533.8		-72694.9		-117693.8	
chi-squared	62440.6		19328.1		6427.1		10612.6	

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3 Probit estimations of determinants of patent grants (Dataset B)

	All		SOEs		POEs		FFEs	
Granted								
FilingSub	-0.303***	(0.0227)	-0.110*	(0.0640)	-0.301***	(0.0254)	-0.422***	(0.154)
ExamSub	0.0848***	(0.0246)	-0.259***	(0.0780)	0.195***	(0.0277)	-0.319***	(0.102)
GrantSub	0.224***	(0.0213)	-0.0189	(0.0662)	0.277***	(0.0238)	0.0554	(0.0950)
Claim	-0.271***	(0.00797)	-0.219***	(0.0238)	-0.276***	(0.00923)	-0.327***	(0.0224)
SOE	0.0775***	(0.0190)						
FFE	0.0550***	(0.0157)						
Non-device	0.0750***	(0.0115)	-0.0420	(0.0356)	0.0903***	(0.0136)	0.0517*	(0.0297)
Experience	0.00807***	(0.00208)	0.00864**	(0.00367)	0.0145***	(0.00299)	-0.0375***	(0.00819)
logEmp	0.0132***	(0.00349)	0.00186	(0.0101)	0.0102**	(0.00417)	0.0288***	(0.00974)
Constant	-1.617***	(0.525)	-5.975	(147.9)	-1.548*	(0.912)	-1.273	(0.829)
Year dummies	Yes		Yes		Yes		Yes	
Region dummies	Yes		Yes		Yes		Yes	
Technology dummies	Yes		Yes		Yes		Yes	
Observations	59429		6097		43176		10147	
LogLik	-39379.0		-4019.9		-28525.7		-6539.4	
chi-squared	3336.3		389.1		2522.8		878.5	

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4 OLS estimations of the determinants of patent claim breadth (Dataset A)

	All		Businesses		NBOs		Individuals	
GrantSub	-0.0494***	(0.00367)	-0.0483***	(0.00598)	-0.0333***	(0.00806)	-0.0427***	(0.00592)
Firm	0.0165***	(0.00239)						
NBO	-0.146***	(0.00423)						
Non-device	-0.0992***	(0.00206)	-0.0967***	(0.00293)	-0.134***	(0.00499)	-0.100***	(0.00355)
Experience	-0.00361***	(0.000237)	0.00852***	(0.000511)	-0.00501***	(0.000317)	-0.0138***	(0.000684)
Constant	-3.299***	(0.0374)	-3.401***	(0.0983)	-3.394***	(0.0493)	-2.768***	(0.197)
Year dummies	Yes		Yes		Yes		Yes	
Region dummies	Yes		Yes		Yes		Yes	
Technology dummies	Yes		Yes		Yes		Yes	
Observations	581838		260596		113522		207720	
Adj R-squared	0.105		0.0894		0.148		0.0803	

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5 OLS estimations of the determinants of patent claim breadth (Dataset B)

	All		SOEs		POEs		FFEs	
GrantSub	-0.0203*	(0.0104)	-0.0390	(0.0300)	-0.0123	(0.0120)	-0.173***	(0.0354)
SOE	-0.0712***	(0.00989)						
FFE	0.0891***	(0.00816)						
Non-device	-0.0921***	(0.00598)	-0.118***	(0.0194)	-0.104***	(0.00713)	-0.0396***	(0.0136)
Experience	0.000291	(0.00108)	0.00661***	(0.00195)	-0.00217	(0.00157)	0.00890**	(0.00371)
logEmp	0.0162***	(0.00182)	0.000413	(0.00553)	0.0160***	(0.00220)	0.0292***	(0.00444)
Constant	-3.794***	(0.276)	-3.792***	(0.705)	-3.242***	(0.482)	-4.004***	(0.369)
Year dummies	Yes		Yes		Yes		Yes	
Region dummies	Yes		Yes		Yes		Yes	
Technology dummies	Yes		Yes		Yes		Yes	
Observations	59429		6097		43176		10156	
Adj R-squared	0.0747		0.104		0.0783		0.0693	

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6 Heckman probit estimations of determinants of patent grants (Dataset A)

	All		Businesses		NBOs		Individuals	
Granted								
GrantSub	0.155***	0.0795***	0.240***	0.292***	0.0745***	-0.0750*	0.132***	-0.0645*
ClaimScope	-0.219***	-0.213***	-0.211***	-0.216***	-0.201***	-0.185***	-0.221***	-0.203***
GrantSub × ClaimScope		-0.0225***		0.0154*		-0.0429***		-0.0604***
Firm	0.208***	0.208***						
NBO	0.438***	0.439***						
Non-device	0.119***	0.119***	0.141***	0.141***	0.0243***	0.0246***	0.112***	0.111***
Experience	0.00736***	0.00735***	0.0123***	0.0122***	0.00893***	0.00903***	-0.0264***	-0.0264***
Constant	-0.970***	-0.950***	-0.733***	-0.746***	-0.691***	-0.650***	-0.750	-0.660
Examined								
FilingSub	-0.437***	-0.437***	-0.853***	-0.853***	-0.347***	-0.347***	-0.156***	-0.155***
ExamSub	0.331***	0.331***	0.637***	0.637***	0.149***	0.150***	0.154***	0.154***
Firm	0.398***	0.398***						
NBO	0.784***	0.784***						
Experience	0.0408***	0.0408***	0.0348***	0.0347***	0.0637***	0.0638***	0.00710***	0.00713***
Constant	0.0968	0.0968	0.737***	0.737***	0.805**	0.804**	-0.594*	-0.593*
Constant	-0.117***	-0.115***	-0.881***	-0.889***	-0.327***	-0.305***	-0.283	-0.323
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Technology dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	592547	592547	264696	264696	114091	114091	213760	213760
LogLik	-551549.1	-551542.2	-244296.0	-244294.5	-83287.9	-83280.3	-216958.2	-216943.4
chi-squared	26071.7	26098.3	10936.6	10954.9	3697.5	3713.1	8555.7	8674.4

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 7 Heckman probit estimations of determinants of patent grants (Dataset B)

	All		SOEs		POEs		FFEs	
Granted								
GrantSub	0.103***	0.00288	-0.0672	-0.239	0.150***	0.0812	0.0174	-0.153
ClaimScope	-0.256***	-0.246***	-0.209***	-0.192***	-0.251***	-0.245***	-0.325***	-0.305***
GrantSub × ClaimScope		-0.0302*		-0.0502		-0.0207		-0.0539
SOE	0.0460**	0.0460**						
FFE	0.0209	0.0203						
Non-device	0.0518***	0.0520***	-0.0745**	-0.0744**	0.0662***	0.0663***	0.0339	0.0349
Experience	0.00447**	0.00443**	0.0110***	0.0109***	0.00744**	0.00741**	-0.0448***	-0.0448***
logEmp	0.00289	0.00287	-0.0142	-0.0147	-0.00154	-0.00150	0.0192*	0.0188*
Constant	-0.621	-0.589	-5.279	-5.239	-0.484	-0.459	-0.703	-0.645
Examined								
FilingSub	-0.662***	-0.662***	-0.180*	-0.180*	-0.728***	-0.728***	-0.398*	-0.396*
ExamSub	0.546***	0.546***	-0.0124	-0.0124	0.651***	0.651***	-0.217	-0.217
SOE	0.215***	0.215***						
FFE	0.239***	0.239***						
Experience	0.0323***	0.0323***	0.0203**	0.0203**	0.0276***	0.0276***	0.0688***	0.0689***
logEmp	0.0467***	0.0467***	0.106***	0.106***	0.0421***	0.0421***	0.0608***	0.0608***
Constant	-0.703	-0.703	3.320	3.327	3.440	3.440	-0.533	-0.531
Constant	-0.394***	-0.395***	-0.246	-0.249	-0.644***	-0.644***	-0.632*	-0.635*
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Technology dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	60244	60244	6139	6139	43901	43901	10204	10204
LogLik	-51912.3	-51910.9	-4863.9	-4863.5	-38618.7	-38618.3	-7819.8	-7818.9
chi-squared	2331.2	2333.0	325.8	326.6	1679.0	1680.0	.	626.2

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 8 Patent propensity of domestic businesses and NBOs (2000~2008)

	Businesses					NBOs				
Year	Filed patents	Granted patents	R&D*	Filed patents /R&D	Granted patents/ R&D	Filed patents	Granted patents	R&D	Filed patents /R&D	Granted patents/ R&D
2000	6,906	2,488	537	12.9	4.6	1,897	1,365	359	5.3	3.8
2001	6,204	3,714	616	10.1	6.0	2,661	1,890	404	6.6	4.7
2002	11,102	7,102	765	14.5	9.3	4,628	3,490	487	9.5	7.2
2003	16,005	9,744	907	17.6	10.7	7,481	5,649	548	13.7	10.3
2004	21,342	12,178	1154	18.5	10.6	9,106	6,721	573	15.9	11.7
2005	31,999	18,029	1411	22.7	12.8	12,030	8,624	654	18.4	13.2
2006	45,633	24,845	1730	26.4	14.4	14,444	9,702	704	20.5	13.8
2007	59,628	31,307	2005	29.7	15.6	17,095	10,793	769	22.2	14.0
2008	80,284	37,781	2343	34.3	16.1	21,491	12,993	855	25.1	15.2
2004/ 2000	3.09	4.89	2.15	1.44	2.28	4.80	4.92	1.60	3.01	3.08
2008/ 2004	3.76	3.10	2.03	1.85	1.53	2.36	1.93	1.49	1.58	1.29

* R&D expenditures adjusted by GDP deflator (unit: 100 million yuan), sourced from China Statistical Yearbook on Science and Technology (2010).