Patent subsidy and patent filing in China

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This study examines the impacts of patent subsidy policies on patent filings in China. China had rapid growth in patenting in recent years and became the number one in patent filings in 2011. We study five neighboring cities in Jiangsu province, where in June 2006 one city, Zhangjiagang, not only significantly increased the amount of subsidy per patent application but also included a large reward for granted applications, while subsidies in the other cities remained unchanged. Using a difference-in-differences strategy we find that the number of invention patent filings from Zhangjiagang significantly increased, but the grant rate of an average patent application from Zhangjiagang did not drop after the policy change, compared to those from the other cities. Moreover, the total number of claims for each applicant in Zhangjiagang remained the same whereas the average number of claims per application from Zhangjiagang declined after June 2006. Thus, we find that the policy is ineffective. The increase in patent applications appears to be achieved by reducing the number of claims included in each application without increasing the total number of claims. Our findings indicate that applicants in Zhangjiagang were not significantly constrained by the cost of patenting before the policy change. They also suggest that applicants have significant discretion in the number of patents they can receive to protect a given number of claims. In the case studied here, the former was responsive to local financial incentives, while the latter was not.

JEL classifications:

"The generosity of China's incentives for patent-filing may make it worthwhile... to patent even worthless ideas... Patents are easy to file,... but gems are hard to find in a mountain of junk."

\- *"Patents, yes; ideas, maybe?"*, The Economist, Oct 14th, 2010

1. Introduction

In 2011 China became the world leader in the number of published invention patent applications, outpacing the United States, Europe and Japan. Patent applications in China increased from 63450 in 2001 to 391177 in 2010, an annual rate of 22.6%;[1] and domestic applications have grown even faster, from 30038 to 293066, by 28.8% per year during the period.[2] The driving forces behind this China patent boom have been debated. Some observers consider the boom to be an indicator of significant and genuine strides in China's innovative capacity, resulting from China's focused efforts, iconized by its "Medium to Long Term Plan for the Development of Science and Technology (2006)" (hereafter MLP), to promote its indigenous innovation and technological development and transform its economy from "made-in-China" to "invented/designed in China". Other observers, however, believe that the patent boom is largely due to various patent subsidy policies implemented by local governments to meet and/or exceed the patenting targets specified by the government.[3] They argue that patent subsidies incentivize applicants to file opportunistic applications for inventions of low patentability or low value that would have not been filed without those subsides. Thus they claim that most filings in this China patent boom are so-called "junk inventions".

This paper, to the best of our knowledge, conducts the first applicant-level empirical study

[1] Growth was much slower elsewhere: 4.6% in America, 5.6% in South Korea, 3.6% in Europe and -2.7% in Japan during the same period.

[2] *Patent applications by patent office (1983-2010)*, source: WIPO Statistics Database, available at `http://www.wipo.int/ipstats/en/statistics/patents/`

[3] The MLP and the ensuing National Intellectual Property Strategy (2008) specify overall national patenting targets, which are then allocated to local governments.

on the effects of patent subsidies on both the quantity and quality of patent filings in China. We compare five neighboring cities (Zhangjiagang, Taicang, Suzhou, Kunshan and Changshu), all within the Suzhou Municipality. In June 2006, the citiy of Zhangjiagang increased its patent subsidy for an invention patent application from YMB 1500 to YMB 3000 and added a reward of YMB 10000 if the application is granted. Around that time, patent subsidies in the other four cities remained unchanged.[4]

At first glance, one might reasonably conjecture the sizable increase in subsidy for patent filings and the hefty reward for patent grants would provide good incentives for applicants in Zhangjiagang to file applications for inventions that would have not otherwise received attention from the patent system. In particular, applicants could be incentivized to generate inventions that are patentable but of little or low expected value, because of the patent application subsidy and grant reward. Applicants can always abandon these patents if they turn out not to be commercially useful.[5] If the conjecture is true, the increase in patenting elicited by the local incentives represents a substantial response in inventing but with sharply declining quality.

We implement a difference-in-differences strategy and study patent filings before and after June 2006 by a panel of more than 3000 applicants in Zhangjiagang and the control cities, in a time window of July 2004 through December 2007. We find a significant increase in the number of invention patent filings from Zhangjiagang after June 2006. The patentability of patent applications from Zhangjiagang did not decrease after the policy change, as indicated by their grant rates compared to those from the other cities. However, the total number of claims for each applicant in Zhangjiagang remained the same, and the average number of claims per application from Zhangjiagang actually declined after June 2006.

These results do not support the argument that the increase in patent subsidies incentivize

[4]Note that the level and structure of patent subsidies have been different across the five cities.
[5]Patents are renewed annually in China.

applicants in Zhangjiagang to produce and file applications for inventions of lower quality (less patentable or less valuable) that they would not have been filed without the policy change. If this were the case, relative to those from the control cities, the total number of claims per applicant in Zhangjiagang should have increased because of more inventions being filed for patents, and/or the grant rate of patent applications from Zhangjiagang should have worsened due to less patentable inventions being filed. Given the total patenting expense of YMB 8000 from filing to grant, if an applicant files for an invention that is of low patentability and unlikely to get granted, it will, even with a patent filing subsidy of YMB 3000, incur a net loss in the end. Applicants in Zhangjiagang also did not seem to have additional inventions waiting "in the attic" which they turned into application in response to the hefty reward (otherwise the number of claims per applicant should have increased). Instead, they only seem to split their applications into multiple filings to collect more of the hefty reward for patent grants.

The finding that no additional inventions is evident in Zhangjiagang after the subsidy change suggests that, before the policy change in 2006, applicants in Zhangjiagang had little financial constraint. It is not a surprising result given that this is an economically developed region in China and that the cost of patenting in China is relatively small. Few of their inventions remain unpatented due to the cost of patenting. On the other hand, their inventive output appear inelastic with respect to the small incentive change implicit in the application subsidies and grant reward. They did not produce many additional inventions in response to the policy change in 2006. What they could do was to break up inventive claims into multiple patent filings that were as patentable as previous filings and to collect greater reward, which they did.

Our empirical findings shed light on the effects of patent subsidy policies in China. A majority of patent filings in China are from economically developed regions such as the coastal province in which Zhangjiagang is located. Assuming that our finding that applicants have little financial constraint in patenting holds true for other developed regions, it does not seem necessary to have those local patent subsidy policies, which, depending on their design, might merely boost the number of patent filings without actually increasing the stock of patented inventions, or have little effect.[6]

Our results suggest that applicants in Zhangjiagang likely know more about the patentability than the commercial value of their inventions. With little financial constraint, they likely file applications for all patentable inventions. These findings provides a novel perspective to a broad literature, both theoretical and empirical, on the optimal design of the patent system (see, e.g., Gallini, 2002; Farrell and Shapiro, 2010), and more particularly, on the use of patent fees as a policy tool that often assumes an expected profit maximizing patenting strategy for applicants (Scotchmer, 1999; Cornelli and Schankerman, 1999; Gans et al., 2004; Hunt, 2006; Marco and Prieger, 2009; Caillaud and Duchêne, 2011; De Rassenfosse, 2012. Also see De Rassenfosse and Van Pottelsberghe de la Potterie, 2012 for a review).[7]

Finally, our findings might have interesting policy implications for on-going implementation or discussion of patent fee policies, in the U.S., Europe[8] and other patent offices in the world. The United States Patent Office (USPTO), for example, proposes a new fee structure to "subsidize filing, search, and exam fees to enable lower cost of entry into patent system", and includes a 50% reduction for small entities and a 75% reduction for micro entities.[9]

[6]Our findings only show that the increase in subsidies did not have an effect on invention measured by patented claims. Given that the increase doubled the previous 1500 RMB subsidy and added a grant reward, it is unlikely that the previous subsidy was more effective.

[7]Our paper focuses on the effects of patent subsidies on applicants' filing behavior, as we investigagte the immediate increase in patent filings from Zhangjiagang, right after the policy change in June 2006. Patent subsidies may impact firms' R&D behavior as well, as a subsidy on patent filings is also a subsidy on R&D (Segerstrom, 1991; Almus and Czarnitzki, 2003; González et al., 2005; Özçelik and Taymaz, 2008). Because of the lag between R&D activity and patent filings, our results are unlikely related to change in firms' R&D behavior.

[8]For a recent discussion of patent fees by Nikolaus Thumm, EPO Chief Economist, see http://is.jrc.ec.europa.eu/pages/ISG/patents/documents/NikolausThummfeesandpricing.pdf

[9]The Executive Summary of Patent Fee Proposal, submitted to the Patent Public Advisory Committee on Feburary 7, 2012 by the USPTO in accordance with the Leahy–Smith America Invents Act, is available at http://www.uspto.gov/aia_implementation/fee_setting_-_ppac_hearing_executive_summary_7feb12.pdf

Underlying these policies is the view that applicants, small size firms in particular, are financially constrained in filing for patents, which may or may not hold in all countries that differ in firm innovative activity and patenting fees.

The remainder of the paper is organized as follows. In section 2 we provide a brief review of China's innovation strategies and the subsidy policies, with more information for the six cities studied in the paper. Section 3 explains our data and methodology. Section 4 shows the estimated effects of the policy change on the quantity and quality of patent applications. Section 5 concludes.

2. Background

2.1 China's Recent Indigenous Innovation Strategy

Since it opened to the world economy three decades ago, China's economic development has been one of "made in China", relying on its low-cost manufacturing of existing products. However, promoting innovation and technological development has long been an important theme for the Chinese government, exemplified by its 863 Program and 973 Program.[10] Since 2000, China has made more systematic and ambitious efforts to strengthen its innovation capacity, increasing its spending on R&D (a roughly 10% increase each year since 2000) and expanding enrollment in higher education.

The "Medium to Long Term Plan for the Development of Science and Technology (MLP)," initiated in 2006, was the culmination of the extended effort by the Chinese government to promote its "indigenous innovation", enabling China to become an "innovation-oriented society" and a global leader in science and technology. The MLP encompasses several of the

[10]The 863 program, established in March 1986 and also known as the State High-Tech Development Plan, is a program funded by the central government to stimulate the development in a range of key technological fields, including biotechnology, space, information technology, new materials, etc. The 973 program, initiated in 1997 and also known as National Basic Research Program, is a basic research program dedicated to areas such agriculture, health, energy, environment, etc.

Chinese government's long-term policy goals, including building domestic R&D capabilities to upgrade Chinese firms' innovative capacity and promoting domestic firms' contributions to the Chinese economy rather than relying on foreign know-how and technology. In June 2006 the State Council issued a list of rules for implementation of the supporting policies for the MLP. These policies are implemented by government ministries and agencies at all levels.[11]

2.2 China's IP Strategy and Patent Subsidy Policies

The MLP sets objectives for IP creation and commercialization by the year 2020 in areas such as patents and technical standards.[12] Further emphasis on the importance of IP for the goals of the MLP came with the announcement of the National Intellectual Property Strategy in 2008 (planned since 2005) and the recent National Patent Development Strategy (2011-2020) in 2010. Both Strategies set goals for China to become a country generating a comparatively large flow of domestic IP and urge support of market entities to create IP through the use of policies including finance, investment and government procurement. The strategies also support the inclusion of indicators of IPRs in the system for assessing the performance of local governments and state-owned enterprises.

Under these IP goals and mandates, local governments at all levels have implemented patent subsidy policies, to improve patenting awareness and boost innovation.[13] Shanghai implemented China's first patent subsidy policy in 1999, and by around 2003 almost all provinces had some subsidy policies in place. In addition many cities have their own subsidies for patent applications. Patent subsidies at province and city levels come in a variety of

[11]There are altogether 99 supporting policies. The National Development and Reform Commission (NDRC) is responsible for the largest number of these policies (29), followed by the Ministry of Finance (MOF) with 21 policies, the Ministry of Science and Technology (MOST) with 17, and the Ministry of Education (MOE) with 9 polices. (Serger and Breidne, 2007).

[12]For example, one goal is to become one of the top five countries in terms of invention patents granted to its citizens.

[13]The central government also has a patent subsidy for international filings, which is implemented by the Ministry of Finance.

forms: some provide a fixed amount of reimbursement for patent applications, regardless of the actual costs or whether the application gets granted or not; some subsidize patent filings based on applicants' actual out-of-pocket spending, usually with a cap; still others compensate applicants with a portion of the application fee and award a prize (usually much larger) if applications get granted.[14]

It is noteworthy that the SIPO has long implemented a patent fee postponement policy, in accordance with Article 98 of the patent law. This Article allows individual applicants and firms in financial distress to postpone 80-85% and 60-70%, respectively, of the fees incurred at the initial stage of a patent application, including the application fee, examination fee, and yearly maintainance fees for the first three years. Applicants are supposed to pay these postponed fees later after their patents make a commercial profit; but this requirement has not been enforced by the SIPO.[15] In practice, Article 98 is commonly used by individual applicants but rarely by by firms. When requesting a fee postponement firms need to show a proof of financial constraints (such as their operation is at a loss) that must be certified by the local government; while individuals are not required to show any proofs of financial constraints. Table 1 shows some of the basic fees for the three types of patent applications.

Table 1. Patent fees

Type	Application	Examination	Attorney fees	Maintenance/year
Invention	950	2500	4000+[a]	900-8000[b]
Utility Model	500	N/A	2500+	600-2000
Design	500	N/A	1500+	600-2000

[a] The exact legal fee depends on patents and lawyer offices.
[b] The maintenance fee increases incrementally roughly every 3 years.

[14]The reward is only for invention patents, since utility model and design patent applications naturally have an almost 100% grant rate.

[15]The postponed fees are essentially waived, since it is difficult for the SIPO to check and verify whether a patent is truly profitable ex-post, and applicants have little incentive to pay it back.

2.3 China's Patent System and Recent Patenting Surge

China started to envision its first modern patent law in July 1978, shortly after its open-door policy. After a heated debate and 25 revisions , the patent law, modeled after those of Japan and Germany, became effective on April 1st, 1985. The Patent Law has since been amended three times, in 1992, 2001 and 2008, respectively. The first two amendments were made during the process of China's negotiation of entry into the WTO and largely aimed at harmonization of the Chinese Patent Law with those in other countries and the WTO/TRIPS principles.[16] The Patent Law was amended again in 2008, as part of China's effort to promote indigenous innovation.

There are three categories of patents in China: invention patents, utility model patents and design patents. Invention patents are granted after a substantive examination of utility, novelty and non-obviousness; the other two need only a preliminary examination (which results in an almost 100% grant rate). Currently invention patents, utility models and design patents have life terms of 20 years, 10 years and 10 years, respectively. After a patent is issued, the patentee needs to pay annual renewal fees to maintain the patent right; otherwise, the patent is deemed to be abandoned. The renewal fees for invention patents are higher than those for utility models and design patents. Invention patents are of the main interest to researchers due to their similarity to the most prevalent types of patents elsewhere with respect to the standard of patentability and terms of protection.

Patent application growth in China in recent years has drawn international attention (Hu and Mathews, 2008; Eberhardt et al., 2011). Figure 1 shows the invention patent application at China's State Intellectual Property Office (SIPO) since 1985 when the patent law was first implemented. For a long period of time, the number of domestic applications at SIPO has been on par with that of foreign filings. However, domestic filings have been growing more

[16] The first amendment was made when China started its effort to become a member of the WTO and the second right before China entered the WTO.

rapidly particularly after 2003-2004, and have since greatly surpassed foreign applications. There is no sign of a slow-down even after 2008, when the global recession reduced the growth of foreign applications at SIPO.

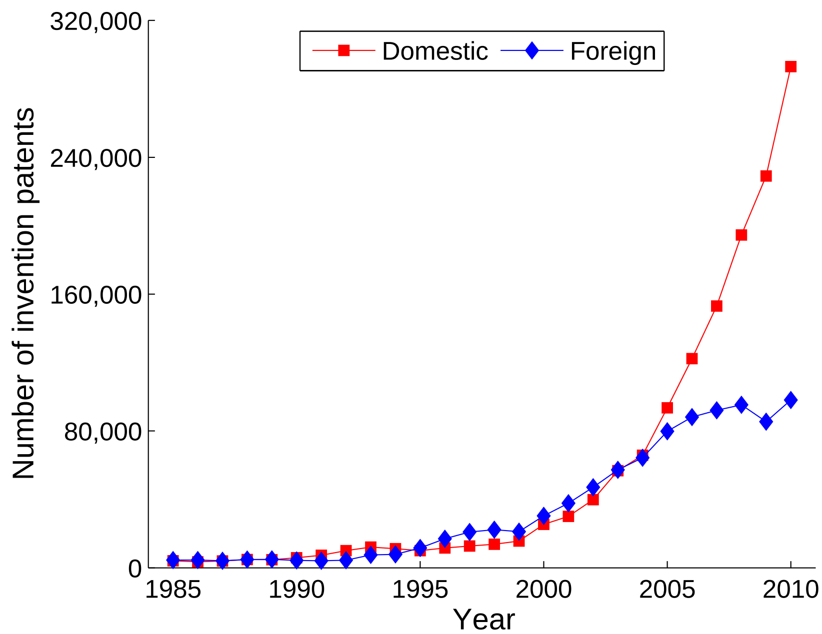

Fig. 1. Patent application growth at SIPO

The recent surge in China patenting is especially intriguing,[17] as patents have long been used as an indicator of innovative activity and technological growth (Griliches, 1990; Kortum, 1997). Some observers argue that one major force driving this China patent boom is the patent subsidy policy implemented by local governments to meet and/or exceed patenting targets specified by the central government.[18] They argue that patent subsidies increase inventors' propensity to file applications for relatively minor or trivial inventions that would have not been filed without those subsides. Therefore, most filings in this China patent boom

[17]Some studies investigate the growth of China patenting before 2004. Tests of spillover effect from foreign direct investment (FDI) were inconclusive (Liu, 2002; Cheung and Lin, 2004; Hu and Jefferson, 2009; Girma et al., 2009). Hu and Jefferson (2009) also suggest that other factors, including an intensification of research and development (R&D), entry into WTO, and more importantly the 2000–2001 amendments to the patent law that offered stronger protection to patent holders, all of which contributed to the rise in patenting.

[18]The MLP and the ensuing National Intellectual Property Strategy (2008) specify overall national patenting targets, which are then allocated to local governments.

are "junk inventions", and do not suggest that China has made significant progress in its pursuit of "indigenous innovation".[19]

A recent paper, Li (2012), using invention patent application data at the provincial level, shows that patent subsidy programs at the provincial level are an important factor in the recent patent growth in China, and that the grant rate of patent applications after the implementation of those subsidy policies has actually increased.[20] However, it is a provincial-level study and cannot take into account the fact that many cities have their own subsidy programs on top of the provincial subsidy program.

3. Research Design and Data

We conduct an applicant level empirical study on the effects of patent subsidies on patent filings, in terms of both quantity and quality of patent filings in China.

We compare six neighboring cities (Zhangjiagang, Wujiang, Taicang, Suzhou, Kunshan and Changshu), all within the Suzhou Municipality in east China's Jiangsu Province.[21] We take advantage of a policy change in patent subsidies in Zhangjiagang in June, 2006, and investigate the effects of this change on patent filings by applicants in Zhangjiagang, using

[19]Patent subsidies can be also viewed as one type of R&D subsidy. Both theoretical and empirical studies have shown that R&D subsidies stimulate private R&D activities and promote economic growth (Segerstrom, 1991; Almus and Czarnitzki, 2003; González et al., 2005; Özçelik and Taymaz, 2008), although some find a crowding-out effect between public and private R&D spending (for example, David et al. (2000)). The impacts of patent subsidies on firms' R&D behavior, though not the focus of the paper, is an interesting research question.

[20]Another main concern of the subsidy programs is that they may reduce quality, by encouraging applicants to file more low quality patents (Jiachun et al., 2008), with the result that a higher proportion of patent applications are rejected by the patent office, resulting in a waste of resources. An increase in applications may also increase the average workload of the patent examiners, making it more difficult for them to perform a fully comprehensive search of the prior art. This leads to more dubious applications being granted and lower criteria of the patent examination (Philipp, 2006). More application can also mean longer examination times, which serve as a hidden cost of delay. This has not happened in China, as SIPO has greatly enhanced its workforce in the past decade in terms of both the number and qualifications of patent examiners. The average examination time for an invention patent has been stable at roughly 24 months since 2005.

[21]As will be shown, Wujiang fails the parallel trend criterion for being a valid control city and is removed from the study

as a control group applicants in other cites whose patent subsidies remained unchanged.

This setting provides us a pseudo natural experiment to identify the effects of patent subsidies on patent filings. In the context of our study, patentees in Zhangjiagang are comparable to those in the other five cities in the same Suzhou Municipality. Also, various policies at the provincial and municipal levels that could be relevant for patent filings are controlled as they are the same for applicants in both Zhangjiagang (the treatment city) and the control cities.

The Suzhou Municipality is close to Shanghai and is one of the most economically developed regions in China. In a survey released in 2005 by The National Bureau of Statistics on economic competence of Chinese small cities, the six cities all ranked among the top 10. Moreover, the economy of Suzhou Municipality is dominated by private small or medium size enterprises.[22] Therefore, the results in the paper may be relevant to the more developed regions in China. Table 2 exhibits some summary statistics of the cities in 2008.

Table 2. Summary statistics for the cities[a]

	Changshu	Kunshan	Suzhou	Taicang	Wujiang	Zhangjiagang
Area (km^2)	1094.0	864.9	1649.7	620.0	1092.9	772.4
GDP (billion Yuan)	115.0	150.0	271.8	52.8	75.0	125.0
Primary industry	1.9	1.2	2.2	1.8	1.8	1.5
Secondary industry	66.0	97.9	153.7	31.5	46.9	78.3
Tertiary industry[b]	47.1	50.9	115.9	19.5	26.3	45.3
Population (thousand)	1451	1241	3332	665	1096	1189
Per-capita GDP (Yuan)[c]	79263	120881	81571	79449	68434	105156
Number of firms	15435	23798	60504	8064	16346	17132
Average Size of firms	26.7	13.8	13.2	17.2	14.6	21.7

[a] All data are collected at the end of 2008.
[b] R&D is included in this sector.
[c] The national average in 2008 is 23708 Yuan.

The six cities all implemented patent application subsidies in the year 2003, and have

[22]At the end of 2008, 83.9% of the firms in Suzhou Municipality were privately owned, which are usually much smaller compared to the State owned enterprises.

since raised the subsidies a few times. The subsidies came from the city budget and were administered by the Science and Technology Bureau in each city. To get the patent subsidy, an applicant needs to show a receipt for patent filing issued by SIPO that certifies that the patent application has been received and application fees have been paid.

Between July 2004 and December 2007, the subsidy policies remained unchanged in all cities but Zhangjiagang, which had an increase in subsidies for all three types of patent applications on June 12th, 2006. More specifically, Zhangjiagang increased its subsidies for patent filings from YMB 1500, 1000, 500 to 3000, 1500, 1000 for applications of invention patents, utility model and design patents, respectively. Moreover, it started to award a prize of YMB 10000 for grant of an invention patent application.[23] See Table 3 for an overview of subsidy policies in the six cities between July 2004 and December 2007.

Table 3. Policy overview – subsidy for the three types of patents

City	July 2004 - June 2006			July 2006 - December 2007[b]		
	type 1	type 2	type 3	type 1	type 2	type 3
Zhangjiagang	1500	1000	500	3000+10000[a]	1500	1000
Wujiang	2000	1000	800	unchanged		
Taicang	4000+5000	1000	1000	unchanged		
Suzhou	4000	1000	1000	unchanged		
Kunshan	4000	1000	500	unchanged		
Changshu	2000	1500	1000	unchanged		

[a] The subsidy after "+" is for granted patents.
[b] We cut off at December 2007 because of two facts: the subsidy policy in Changshu changed after April 2008; and there is considerable data truncation after 2008 in our dataset.

As shown in Table 1, the estimated total expenditure, from filing to issuance including legal fees, for an invention patent application is about YMB 8000, and the estimated costs for utility models and design patents are about YMB 3000 and 2000, respectively. Thus the changes in patent subsidies in Zhangjiagang are sizable relative to the total expense for filing

[23]This award does not apply to filings of utility model and design patents, which are almost sure to be approved due to a lack of substantive examination.

patent applications in China. Invention patents are of the highest quality and subject to a similar level of scrutiny as their counterparts in the developed world. They draw most interest from researchers and therefore our study focuses on invention patents only.

3.1 The endogeneity issue

The first question we need to ask, before we move to the treatment effect of the policy change, is whether the subsidy in Zhangjiagang was a response to industry demand. Essentially, we ask whether the policy is endogenous with respect to the patenting activities in Zhangjiagang. We found on the government official website of the treated city Zhangjiagang the following information that we believe was related to the subsidy policy change: On Dec 23, 2005, the city government made some changes in their leadership, and for the first time, a vice director (Mr Yuan, Xu) was assigned to be responsible for the "patent department". Following the change, on Jan 23, 2006, the patent department made an announcement to clarify its duties, which include, among others, drafting and implementing IP policy, building the city as an IP model city, and rolling out the patent subsidy. The subsidy increase was announced on June 12, 2006. Since it's quite common in China for new leaders to bring about new policies in their favor, we believe the information can answer a big part of the endogeneity question of the subsidy policy: it is the result of a leadership reshuffle, which is not likely to be a response to the industry's need.

3.2 The model

We use a difference-in-differences method to study the treatment effect of the subsidy increase in Zhangjiagang, using the other cities as control cities. The model to be estimated is:

$$y_{ict} = \beta \cdot x_{ct} + \alpha_c + \lambda_t + \varepsilon_{ict} \tag{1}$$

where y_{ict} is the number of patent applications by applicant i in city c during half-year t. The policy variable is x_{ct}, which is a dummy term, equaling to 1 for Zhangjiagang after June 2006. The city fixed effect is α_c.[24] The half-year time fixed effect is λ_t, and ε_{ict} is an idiosyncratic error term. The coefficient of interest, the average treatment effect of the policy change on applicantions in Zhangjiagang, is β.

In this paper, we address the robustness of the results in two steps. Firstly, we compute the difference-in-differences estimates of the treatment effect in Zhangjiagang with respect to each of the control cities and the pooled control cities, to make sure that the possible effect we observe is not due to some specific events in one or a few control cities. Secondly, we construct a "placebo treatment" to test the validity of the control cities. For each control city (for example, Changshu), we assume a policy change occurred in June 2006; then we compare Changshu to the remaining control cities by Equation 4 to estimate the "treatment effect" of the policy change on applications in Changshu. If we indeed find a significant treatment effect, it implies that applications in Changshu may not have trend parallel to those of the other control cities. Moreover, it will put doubt on our analysis in this case, since there is no guarantee that applications in the treated city Zhangjiagang would be similar (in the absence of the policy change) to those in the control cities either.

3.3 Data description

We obtained a rich dataset from SIPO covering all three types of patents filed from these cities from 2002 to 2010. We use the period from July 2004 to December 2007 for the purpose of our study. The application data include patent application information, patent type, legal status, and applicant and inventor information. During the study period, there are 3582

[24]Applicant level fixed effects can control non-parametrically for differences across cities in the distributions of different types of applicants. But in this canonical difference-in-differences setting with no within-group-time-varying explanatory variables, controlling for applicant-fixed effects gives exactly the same estimates as controlling for city fixed effects (though standard errors are slightly different). A simple algebra derivation can be found in Appendix A.

applicants (firms and individuals) who applied for 42035 patents of all types (7386 invention patents, 9148 utility models and 25501 utility models). We aggregate patent applications at the applicant level (firms or individuals) and divide the time period into 7 half-years.

Since most of the applicants filed very few invention patents during the study period; while there are some very "large" applicants (for example, Foxconn) that applied for a great number of patents, we remove these "large" patentees to make sure our results are not driven or affected by these few applicants. These large applicants may also respond very differently from the small and mid-sized applicants to the subsidy policies. Figure 2 plots the histogram of total invention applications in all the cities. To make the figure more readable, we do not show applicants that made totally less than (or equal to) 5 invention applications. It appears that 100 applications is a good "cut-off" level.[25] By this criterion, we remove 13 applicants (10 firms and 3 individuals). After this step, we are left with a panel of 3569 applicants with 35414 applications (4399 invention patents, 6957 utility models and 24058 design patents) over 7 time periods.

In Table 4 we provide summary statistics for the number of invention patent applications in the six cities.[26] It can be seen that, in terms of pre-policy-change applications, the treated city (Zhangjiagang) is similar to Changshu and Taicang. A comparison of their post-policy-change applications shows that Zhangjiagang has the largest number of applications. In fact, Zhangjiagang has the largest increase in average applications among all the cities, and the change is significant compared to all the control cities except Wujiang. However, as shown in Section 3.4, the pre-treatment trend in Wujiang is significantly different from that of the treated city Zhangjiagang. Therefore Wujiang is not a valid control city in our study and we will remove it from our controls.

[25] The results are robust to whether we include applicants near this "cut-off" value.

[26] We do not separate firm applicants from individual applicants because the distinction is not clear-cut. Many of the individual applicants are themselves employees or employers of some firms but they file individual patent applications. Moreover, we do not expect the two groups of patentees to respond differently to the policy change.

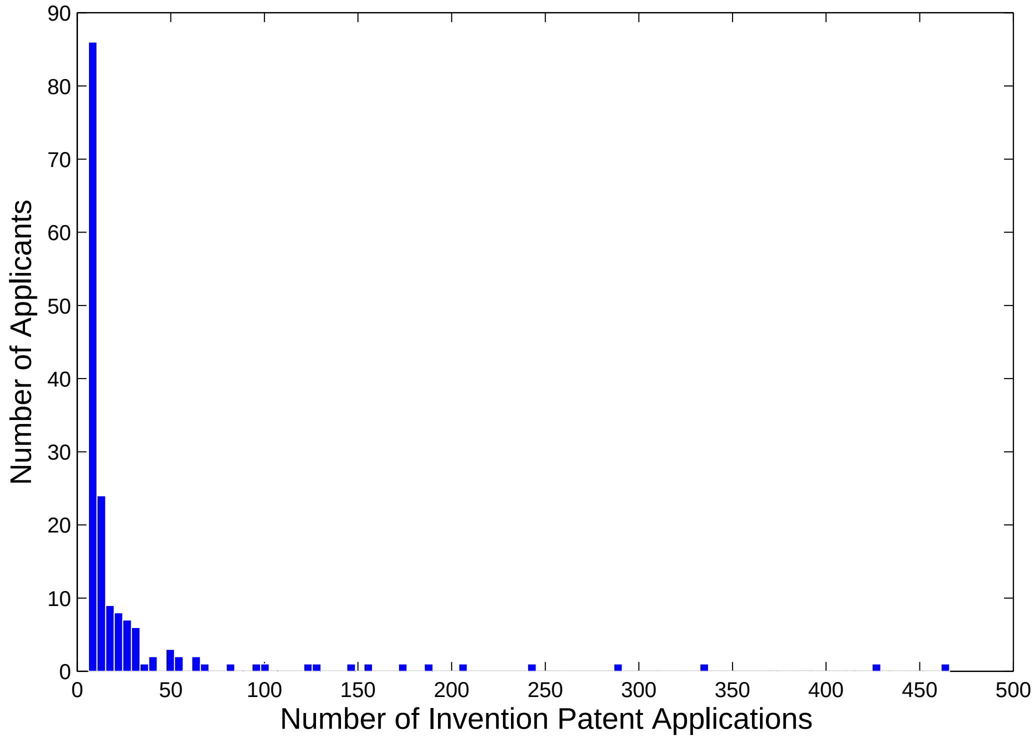

Figure 2. The histogram for applicants of total invention applications

Table 4. Comparison of average invention applications before and after the policy change in Zhangjiagang

City	Before June 2006	After June 2006	# of applicants
Changshu	0.24 (0.04)	0.72 (0.08)	484
Kunshan	0.37 (0.07)	0.84 (0.17)	547
Suzhou	0.43 (0.06)	0.78 (0.10)	1480
Taicang	0.19 (0.04)	0.76 (0.11)	279
Wujiang	0.43 (0.07)	1.37 (0.36)	314
Zhangjiagang	0.19 (0.04)	1.19 (0.13)	465

Standard errors are reported in parentheses.

3.4 Test of the parallel trend assumption

In order to estimate the impact of a policy, we need the so-called "parallel trend assumption" to hold: in the absence of a policy change, the period-specific unobservables exhibit parallel trend between the treated and control units. In this section, we use the data before the policy change, and test whether a linear time trend interacted with a dummy for being in Zhangjiagang (the treated city) is significant:

$$y_{ict} = \gamma \cdot t \cdot I_{Zhangjiagang} + \alpha_c + \eta \cdot t + \varepsilon_{ict} \tag{2}$$

where α_c is the city dummy and $\eta \cdot t$ controls for the common linear trend.

The results are shown in Table 5. We do not find evidence against the parallel trend assumption for any of the cities except Wujiang, which seems to have a significantly different trend from the treated city in the pre-policy change period. Therefore, the policy effect on the filings of invention patents based on the comparison of Zhangjiagang to Wujiang using the difference-in-differences method may not be very informative. In light of this finding, we do not include the city of Wujiang in the controls.

Table 5. Test of parallel trends between Zhangjiagang and the control cities
$y_{ict} = \gamma \cdot t \cdot I_{Zhangjiagang} + \alpha_c + \eta \cdot t + \varepsilon_{ict}$

	Changshu	Kunshan	Suzhou	Taicang	Wujiang	Pooled (w/o Wujiang)
γ	-0.0018	0.0004	0.0057	-0.0125	-0.0408**	0.0015
	(0.0095)	(0.0112)	(0.0162)	(0.0122)	(0.0175)	(0.0108)

Robust standard errors clustered at applicant level in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

After removing Wujiang from our control cities, the panel consists of 3255 applicants with 27317 applications (3832 invention patents, 6173 utility models and 17132 design patents) over 7 time periods. Next we present some qualitative evidence in graphs. Figure 3 shows the average number of invention patent applications from applicants in Zhangjiagang compared to applications from the pooled control cities. Keep in mind that half-years 1–4 constitute the pre-treatment period and half-years 5–7 are in the post-treatment period.[27]

[27]The rational for comparing Zhangjiagang to the pooled control cities relies on the assumption that the control cities have similar trend to each other. We provide comparisons of invention patent applications

The pre-treatment trends of applications growth in Zhangjiagang and in control cities seem to be parallel. It appears that a difference-in-differences comparison for invention patent applications may result in a positive effect for Zhangjiagang.

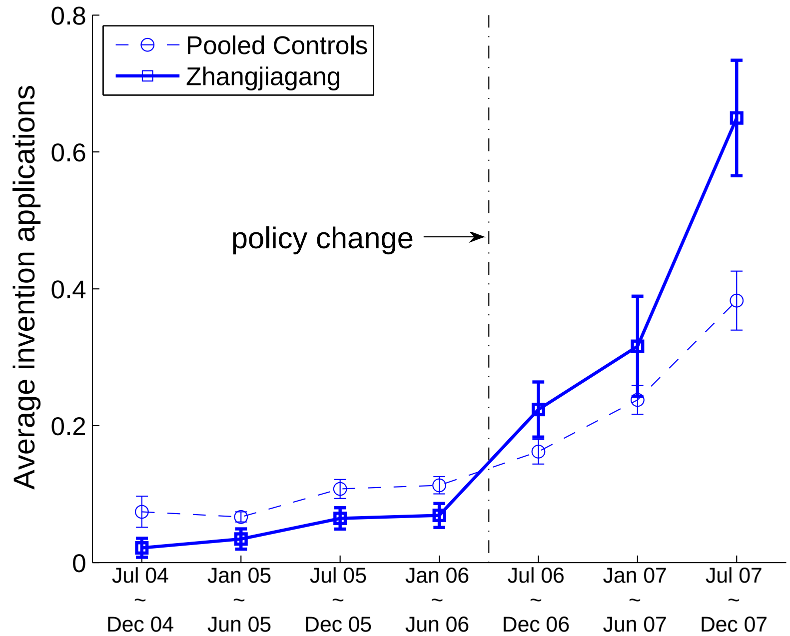

Figure 3. Comparison between Zhangjiagang and the pooled control cities

4. Results

4.1 The Effect on the Quantity of Invention Patent Applications

4.1.1 Results from Difference-in-differences Study

In this section we report the econometric estimates of the policy treatment effect on the quantity of invention patent applications. As explained in Section 3.2, we conduct a pair-wise difference-in-differences analysis to estimate the treatment effect, the results of which

in Zhangjiagang with each control city in Appendix B. Indeed, except for the city of Wujiang, which is removed from the analysis based on Table 5, all control cities seem to have a parallel trend to the treated city before the policy change.

are reported in the first row of cells in Table 6. The remaining rows of cells provide the estimated "placebo treatment effect". The controls are considered "good" or more valid if all "placebo treatment effects" turn out to be insignificant. We cluster the standard errors at the applicant level to control for serial correlation of the applications for each patentee.

Table 6. The effect on the quantity of invention patent applications
$y_{ict} = \beta \cdot x_{ct} + \alpha_c + \lambda_t + \varepsilon_{ict}$

Treated/Control	Taicang	Suzhou	Kunshan	Changshu	Pooled Controls
Zhangjiagang	**0.145****	**0.196*****	**0.160****	**0.167*****	**0.179*****
	(0.0567)	(0.0523)	(0.0686)	(0.0500)	(0.0471)
# of applicants	744	1945	1012	949	3255
# of observations	5208	13615	7084	6643	22785
Taicang		0.0514	0.0151	0.0224	0.0379
		(0.0480)	(0.0655)	(0.0455)	(0.0433)
# of applicants		1759	826	763	2790
# of observations		12313	5782	5341	19530
Suzhou			-0.0363	-0.0290	-0.0368
			(0.0616)	(0.0399)	(0.0396)
# of applicants			2027	1964	2790
# of observations			14189	13748	19530
Kunshan				0.00736	0.0237
				(0.0597)	(0.0578)
# of applicants				1031	2790
# of observations				7217	19530
Changshu					0.0141
					(0.0352)
# of applicants					2790
# of observations					19530

Robust standard errors clustered at firm level in parentheses
* $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

Following our discussion in Section 3.2, we observe from Table 6 that the subsidy increase has a rather consistent and significant effect on patentees in Zhangjiagang. On average, the policy change increased the invention patent filed by patentees in Zhangjiagang by roughly 0.179 applications/half-year, compared to other cities. The average number of invention patent applications per patentee in Zhangjiagang increased by 0.35 applications/half-year, from the pre-treatment average of 0.047 (0.19 divided by 4 half-years) applications/half-year to the post-treatment average of 0.397 (1.19 divided by 3 half-years) applications/half-year. Therefore, the policy change can explain roughly 50% of the increase in Zhangjiagang.[28] Moreover, the "placebo treatment effect" results are very encouraging—none of the placebo policy changes produces a significant estimate. This finding also gives us more confidence in the parallel trend assumption for these cities.

4.1.2 Robustness checks

We conduct the estimation using alternative specifications to test the robustness of the results. Firstly we include applicant level fixed effect in the analysis. As explained in Appendix A, the coefficients will remain the same but the standard errors can be different. The results are reported in the first column of Table 7. It seems when we cluster the standard errors at the applicant level, controlling for applicant level fixed effects causes virtually no change even in the standard errors of the estimates.

One concern is that what we observe in Section 4.1.1 is simply due to the "Ashenfelter's dip" (Ashenfelter, 1978), i.e., applicants in Zhangjiagang anticipated the policy changed and strategically delayed their applications to post-treatment period in order to claim the subsidy. In our study this may be of less concern since applications made during the first half of 2006 (half year before the announcement of the policy change) were also eligible for the subsidy.[29] Since we do not have information of the legal history of the subsidy plan, we still want to be sure that the treatment effects are robust to omitting the period between shortly before and after the policy change. In column 2 of Table 7, we report the estimates omitting data from 2006, half year before and after the policy announcement. The estimated effect is very similar, though the significance level is lower, which may be due to less data.[30]

Next we make a few refinements on our applicant selection. Since a lot of the applicants

[28] See Section 4.1.3 for more analysis on inference.

[29] In an announcement made in August 2006, the first batch of subsidies after the policy change was

Table 7. Robustness Checks
$y_{ict} = \beta \cdot x_{ct} + \alpha_c + \lambda_t + \varepsilon_{ict}$

	(1) Firm-fixed effect	(2) Ashenfelter's Dip	(3) Invention Firms Only	(4) Unbalanced Panel
β	0.179***	0.215***	0.400***	0.203***
	(0.0471)	(0.0636)	(0.1066)	(0.0766)
Clusters	3255	3255	1237	1684
N	22785	16275	8659	9457

Robust standard errors clustered at applicant level in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

(1) Use applicant fixed-effect instead of city fixed-effect.
(2) Omit data half year before and after the policy announcement.
(3) Exclude applicants that didn't make any invention patent applications.
(2) Use only applicants that "exist".

have never made an invention patent application (i.e., they file only for utility model patents and design patents), we exclude these applicants to test whether the effect is robust. Technically this specification removes from the dataset many applicants that made 0 invention patent applications both before and after the policy change. The results, reported in column 3, turn out to be significant and larger.

In the last refinement, we select our applicants by a stricter criterion: since we can only infer the activity of an applicant based on patent filing date, we classify an applicant to be in "existence" if it has ever filed a patent (any type). In this way we construct an unbalanced panel that only consists of applicants that are more surely conducting innovative activities. We report the results in the last column of Table 7.

given to applications filed in the first half of 2006.

[30]Since the reward for the first half of 2006 is retrospective, we also consider the case that applicants knew this fact before 2006 and delayed their applications from late 2005 to early 2006. We therefore drop one year before the policy change (and half year after) and the results are almost the same with estimated effect of 0.215 and p-value of 0.001.

4.1.3 Inference

In this section, we discuss the inference problem due to our data constraints. In all the previous analyses, we cluster the data at the applicant level, which addresses the serial correlation problem but assumes independence among firms/inventors within a city. However, applicants in the same city may have a grouped structure and thus are correlated with each other by common group errors. Failing to account for the presence of a common group error (at the city level in our case) can lead to downward biased standard errors (Moulton, 1986). Clustering at city level using a robust covariance estimator can solve the problem only if the number of groups is large (Donald and Lang, 2007). In our study we only have 5 cities, so it is not possible to consistently estimate a robust variance-covariance matrix. This is also the main critique for some influential papers like Card (1990) and Card and Krueger (1994).

In this section, we use two techniques to deal with the inference problem. The first method is the two-step estimator proposed by Donald and Lang (2007). We first average the data at city-by-treatment cells, effectively collapsing the data into 10 cells (5 cities $\times$ 2 periods). Then we calculate the change in average applications (per applicant per half-year) for each city between the two periods, i.e., the first differences in a difference-in-differences setting. We regress these differences on a dummy for being the treated city. If we assume the group errors are homoskedastic,[31] the t-statistic from this regression is distributed asymptotically as t_{c-2} when the number of observations in each group goes to infinity, where c is the number of cities in our case. This is a reasonable approximation in our study since we have hundreds of observations in each city-by-treatment cell. The estimated coefficient from this method is 0.167 with a standard error of 0.0241, which gives a t-statistic of 6.91. With 3 degrees of freedom, p-value is 0.0062, which is significant at the 1% level. The estimate is also very close to the value we get in Section 4.1.1, though the significance level is somewhat lower (as

[31]This assumption may not hold in the difference-in-differences case since the group errors have a time dimension.

expected).

The two-step estimator still relies on some distributional assumptions that might not hold for our data. To address this issue, we propose a permutation style estimator, which is closely related to Fisher's exact test (Anderson, 2008; Bertrand et al., 2004). We test the null hypothesis that the policy change had no effect in Zhangjiagang. Suppose the policy change is assigned to a randomly chosen city at a random time. We can estimate the effect of the pseudo policy change on the treated cities as in Section 4.1.1. Since the policy is assigned at city level, the autocorrelation structure within the cities are preserved. The calculated placebo policy effects from all the policy assignments form the empirical distribution of the policy effect under the null hypothesis. Essentially, we ask "how likely is it that I observe a change of at least this level if the policy were randomly allocated?" The p-value is thus approximately the proportion of the policy effects that exceed the observed effect. The strength of this test is that it does not require any distributional assumption.[32] Since we have 5 cities over 7 time periods in our study, we can enumerate all cases of the random assignment of the policy. There are $5 \times 6 = 30$ different cases in total.[33] The observed t-statistics of 3.331 is the largest of them in absolute terms (see Figure 4). Therefore we have a p-value of $1/30 = 0.0333$, which implies that the observed t-statistic is significant at 5% level.

4.2 The effect on the quality of invention patent applications

One natural question following the results of Section 4.1 is whether the quality of the patent applications dropped after the subsidy increase. In other words, whether applicants took advantage of the subsidy on filing fees and filed some dubious applications that have low patentability. In this section we investigate the change in patentability of the patent applications after the policy change. We consider the grant status of patent applications and conduct

[32]Its weakness, however, is that it cannot provide an estimate of the policy effect.
[33]There are 5 cities with 6 time point for each city that we can assign the placebo policy.

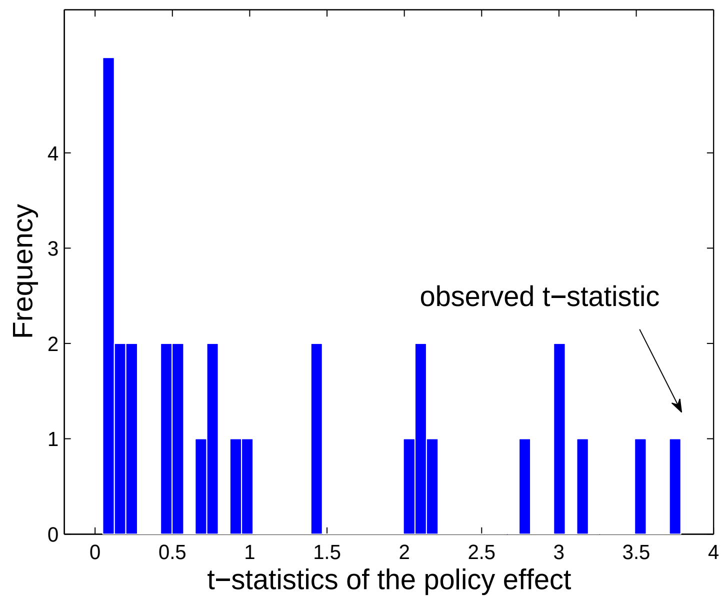

Figure 4. The histogram of the t-statistics from the permutation test

a difference-in-differences analysis to take into account any possible change in examination criteria. The model we use is similar to Equation 4. The model to be estimated is:

$$g_{pct} = \beta \cdot x_{ct} + T_i + \gamma_c + \lambda_t + u_{pct} \tag{3}$$

where g_{pct} is a dummy variable indicating the grant of patent p. The policy variable is x_{ct}, which equals 1 for Zhangjiagang after June 2006. Similarly we use the half-year time fixed effect λ_t and city fixed effect γ_c. We add 31 technology fixed effects T_i to the model, to control for any differences in grant rate in technology fields even in the absence of a policy change. u_{pct} is an idiosyncratic error term. The coefficient of interest is still β.

Of the 3832 invention patent applications in our study, we have the final legal status on 3512 applications. Among these application, 1495 were granted, while the remaining were either rejected or withdrawn. In Table 8 we once more show a table with pair-wise comparison and placebo treatment effect estimation. Based on the estimates, there is no evidence of a

Table 8. The effect on the grant rate of invention patent applications
$g_{pct} = \beta \cdot x_{ct} + T_i + \gamma_c + \lambda_t + u_{pct}$

Treated/Control	Taicang	Suzhou	Kunshan	Changshu	Pooled Controls
Zhangjiagang	0.228***	0.00447	-0.00867	0.0375	0.0199
	(0.0751)	(0.0795)	(0.0974)	(0.0862)	(0.0758)
# of applicants	28	31	30	28	31
# of observations	829	2232	1168	1044	3512
Taicang		-0.219*	-0.197	-0.182*	-0.203*
		(0.108)	(0.127)	(0.0966)	(0.106)
# of applicants		31	30	28	31
# of observations		1887	823	699	2925
Suzhou			-0.0270	0.0672	0.0509
			(0.0734)	(0.0555)	(0.0507)
# of applicants			31	31	31
# of observations			2226	2102	2925
Kunshan				0.0676	0.0391
				(0.0885)	(0.0761)
# of applicants				30	31
# of observations				1038	2925
Changshu					-0.0522
					(0.0535)
# of applicants					31
# of observations					2925

Robust standard errors clustered at firm level in parentheses
* $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

change in quality in Zhangjiagang after the subsidy increase. In fact, the difference-in-differences estimates show Zhangjiagang experienced an increase in grant rate after the policy change compared to all cities except Kunshan (though not significant). Therefore there is especially no evidence of a drop in quality compared to the patent applications in control cities.

Since roughly 8% of the patents (320 out of 3832 applications) do not have information about final grant status, we may be concerned with possible bias when using grant status to approximate patent quality. A break-down of these no-responsive patents by cities shows that only 96 (roughly 30%) of them come from the treated city Zhangjiagang. Therefore the bias does not appear to be a concern.

The results are not surprising if firms and inventors have some reasonably good understanding of the patentability of their inventions. The low subsidy on filing fees is far from enough to cover the application cost, such that applicants will still incur a considerable loss if their applications are rejected. Therefore the subsidy scheme did not encourage them to file more patents that were less patentable.

4.3 The effect on the number of claims

The applications in Zhangjiagang increased significantly after the policy change, while the quality of these applications did not decrease. This might seem to imply that applicants in economically developed regions in China still respond at the margin to financial incentives on patenting, i.e., they have R&D output that were not filed for patent applications because the cost of patenting is too high.[34] However, before drawing that conclusion, we need to find evidence that these "extra" applications indeed came from the stock of innovation that would not be filed without the subsidy increase. We do not observe firm's R&D behavior or patenting strategies, so we can only infer them from the application data. One important patent characteristic is the number of claims, which is usually a good indicator of patent breadth. If the "extra" applications came from the existing innovation that would otherwise not be filed for patents, we would expect to see an increase in the total number of claims over the patent applications filed by firms and individuals in the treated city.[35] We use the panel of applicants that filed for invention patents to test the hypothesis. We use exactly the

[34]A further implication is that firms conducted more innovative work due to the subsidy increase and therefore filed for more applications. We would expect their value or their probability of success to reflect diminishing marginal returns. However, given the short time span of the study, we believe the effect of the subsidy on innovation may not be found yet.

[35]The increase needs not to be proportional to the increase in the number of applications, considering the extra applications may not be as valuable.

same model as Equation 4,

$$tot_{ict} = \beta \cdot x_{ct} + \alpha_c + \lambda_t + \varepsilon_{ict} \tag{4}$$

except that the dependent variable tot_{ict} becomes the total number of claims from patent applications filed by applicant i of city c in half-year t. The policy variable is x_{ct}, $x_{ct} = 1$ for Zhangjiagang after July 2006. We control for the city and time fixed effects as in Equation 4. The results are reported in Table 9.

Table 9. The effect on the total number of claims
$tot_{ict} = \beta \cdot x_{ct} + \alpha_c + \lambda_t + \varepsilon_{ict}$

Treated/Control	Taicang	Suzhou	Kunshan	Changshu	Pooled Controls
Zhangjiagang	0.607	-0.125	-1.443	-0.368	-0.290
	(0.505)	(0.635)	(1.357)	(0.610)	(0.515)
# of applicants	301	754	342	410	1237
# of observations	2107	5278	2394	2870	8659
Taicang		-0.731	-2.050	-0.974*	-1.003*
		(0.611)	(1.346)	(0.585)	(0.513)
# of applicants		675	263	331	1047
# of observations		4725	1841	2317	7329
Suzhou			-1.318	-0.243	-0.358
			(1.398)	(0.700)	(0.695)
# of applicants			716	784	1047
# of observations			5012	5488	7329
Kunshan				1.075	1.349
				(1.388)	(1.345)
# of applicants				372	1047
# of observations				2604	7329
Changshu					0.0989
					(0.640)
# of applicants					1047
# of observations					7329

Robust standard errors clustered at firm level in parentheses
* $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

Surprisingly, we do not find an increase in the total number of claims for applicants in Zhangjiagang, compared to the control cities. Moreover, three of the four comparisons to the control cities turn out to be negative. Though the effects are in general not significant, it is clear there is no evidence that the total number of claims increased after the policy change. Since the number of applications increased significantly, one plausible explanation is that applicants broke up their patents to get more applications out of the same amount of R&D output. In this way, the technical quality of their applications did not decrease and thus they can claim more rewards from the subsidy program. But in this case, no more innovation output was patented due to the subsidy increase.

We divide the total number of claims by the total number of applications to get the average number of claims per patent application for each applicant (avg_{ict}). A difference-in-differences comparison confirms that applicants in the treated city Zhangjiagang experienced a decrease in the average number of claims (Table 10).

The finding has important policy implications. The subsidy scheme (which combines a low subsidy on filing fee and a high reward for granted patent applications) does not lead to a decline in patentability, but it also does not lead to an increase in the total number of claims. It seems that applicants, lured by the high reward offered to granted patents, split their patents to get more applications granted and thus more rewards. The rewards together with the subsidy on filing fees in fact give the patentees a monetary gain over their applications. Under the Chinese patent system, the patents are renewed every year. Patentees can always choose to abandon their patents if they turn out to be not valuable. Therefore, with such a subsidy scheme, it is a dominant strategy for applicants to break up their applications. This is not a desirable policy outcome.

Therefore, at least in these economically advanced cities in China, we do not find evidence that firms and individuals have financial constraint on patenting. In other words, they do not seem to have R&D output that would be filed for patent applications if the associated patent fees are reduced. Because if they do, we would expect the total number of claims to increase together with the total number of applications.

Table 10. The effect on the average number of claims
$avg_{ict} = \beta \cdot x_{ct} + \alpha_c + \lambda_t + \varepsilon_{ict}$

Treated/Control	Taicang	Suzhou	Kunshan	Changshu	Pooled Controls
Zhangjiagang	**-0.933**	**-1.423***	**-1.431**	**-2.279*****	**-1.510****
	(0.885)	(0.756)	(0.905)	(0.793)	(0.709)
# of applicants	301	754	342	410	1237
# of observations	395	1040	503	554	1712
Taicang		-0.516	-0.285	-1.240*	-0.603
		(0.661)	(0.837)	(0.653)	(0.603)
# of applicants		675	263	331	1047
# of observations		915	378	429	1452
Suzhou			-0.0565	-0.785	-0.293
			(0.671)	(0.507)	(0.464)
# of applicants			716	784	1047
# of observations			1023	1074	1452
Kunshan				-0.881	-0.0843
				(0.677)	(0.620)
# of applicants				372	1047
# of observations				537	1452
Changshu					0.870*
					(0.448)
# of applicants					1047
# of observations					1452

Robust standard errors clustered at firm level in parentheses
* $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

5. Conclusion

We evaluate the effectiveness of the patent subsidy policies in China by a case study in Suzhou Municipality, where the subsidy policies resemble many other regions of China. Using a panel of more than 3000 patentees between July 2004 and December 2007, we identify a significant increase in the number of invention patent applications from firms in Zhangjiagang after the city increased the patent subsidy by a considerable amount. Meanwhile, the grant rate of patent applications from Zhangjiagang did not drop. The results suggest that the effect is largely due to the award on granted patents, rather than that of the subsidy on application fees. We infer that a subsidy scheme with low subsidy on filing fees and high reward if the patent is granted may discourage applicants from filing low quality patents.

On the other hand, we find that the total number of claims for each patentee did not increase. Therefore, it's likely that the increase in the number of applications is due to patentees broke up their patents to get more applications (and thus more subsidies). We confirm by showing the average number of claims per patent indeed dropped after the subsidy increase. The fact that applicants can actually make a profit out of the subsidy program if their applications get granted provides incentive for them to split the applications.

Therefore, we find the net effect of the application subsidy and reward upon grant is to motivate patentees to file the same claims in more applications with fewer claims per application. The social welfare effect of the subsidy program is likely to be negative. The extra applications, at the least, increased the workload of both the patentees and the patent office without contributing to more effective patenting.

It seems that firms and inventors in our study region did not face financial constraints in patenting before the subsidy increase. Since the economically developed regions in China file the majority of the patent applications and many use patent subsidy strategies similar to that of Zhangjiagang, our findings put into doubt the necessity of these local patent subsidy policies. The subsidies might merely boost the number of patent filings without actually increasing the stock of patented inventions.

Moreover, our findings show that a patent subsidy that contracts on quantity (number of applications) or even patentability may not guarantee an increase in the total amount of effective patenting. Based on the findings, a better patent subsidy scheme should compensate the applicants only a very small proportion of the patent filing fees, so as to prevent the opportunistic filings; and should let the applicants bear still a small cost or at most make even over a granted patent, such that they don't have the incentive to break up their patents to get more rewards. Providing subsidies to cover part of the maintaining fees in the early years of a patent life, or providing rewards only to patents that go to the product development stage, may achieve the results.

Our finding is different from some surveys in US and EU that show cost of patenting is perceived to be one of the greatest barriers for acquisition of IP rights. In a survey of over 1000 firms in the US manufacturing sector, Cohen et al. (2000) finds that 16% of the respondents cite application cost as the most important reason not to patent. In a recent paper, Rassenfosse and Potterie (2012) find that the drop in patent fees at the EPO contributed to the observed increase in patent filings in the mid-1990s. We believe the main reason is that the cost of patenting under China's current patent system is still quite low, compared to those in the developed world.[36]

Our results raise several issues for further research. The dataset used in the study is small and only included six cities. To what extent can the results be extended to other cities in China, or to other countries? We also ignore other potential pitfalls from the increased patent applications. For example, our limited dataset cannot answer the question of whether increased applications decreases the criteria for examination, thus leading to more "junk" patents. These are questions for future research.

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[36] As shown above, the cost for filing an invention patent is around 8000 Yuan, or roughly 1300 Dollar. On the other hand, even in some early estimates, the costs of filing a patent in US and EU were much higher. The average cost of filing a patent in US was estimated to be 10000 to 30000 Dollar (Lemley, 2000). The total external pre-grant cost for a representative EPO patent application was estimated at 10000–15000 Euro in 2004 (available at `http://www.effi.org/system/files?file=cost_anaylsis_2005_study_en.pdf`).

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A. The equivalence of applicant-fixed effects to city-fixed effects

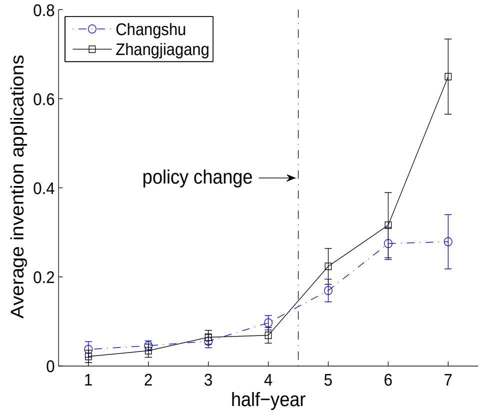
For simplicity, we assume only two cities, $c = 0$ and $c = 1$, and two time periods, $t = 0$ and $t = 1$. Then in Equation 4, we decompose the error term into two parts: $\varepsilon_{ict} = u_{ct} + \epsilon_{ict}$, such that $\frac{1}{N_{ct}} \sum_i \epsilon_{ict} = 0$. Denote $\bar{y}_{ct} = \frac{1}{N_{ct}} \sum_i y_{ict}$ for any city-time cell. The difference-in-differences estimator is

$$\begin{aligned}
&(\bar{y}_{11} - \bar{y}_{10}) - (\bar{y}_{01} - \bar{y}_{00}) \\
=&[(\beta + \alpha_1 + \lambda_1 + u_{11}) - (\alpha_1 + \lambda_0 + u_{10})] - [(\alpha_0 + \lambda_1 + u_{01}) - (\alpha_0 + \lambda_0 + u_{00})] \\
=&[\beta + (\lambda_1 - \lambda_0) + (u_{11} - u_{10})] - [(\lambda_1 - \lambda_0) + (u_{01} - u_{00})] \\
=&\beta + [(u_{11} - u_{10}) - (u_{01} - u_{00})]
\end{aligned} \tag{5}$$

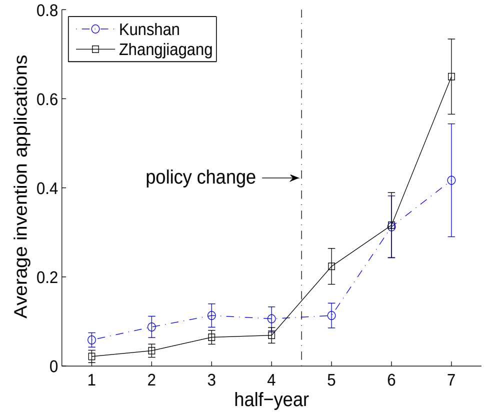
With the common-trend assumption, $E(u_{11} - u_{10}) = E(u_{01} - u_{00})$ and we get the estimate of the policy effect β in expectation. If we use applicant-fixed effect γ_i, the city-fixed effects (α_i's) in the first differences change to $\frac{1}{N_{c1}} \sum_i \gamma_i - \frac{1}{N_{c0}} \sum_i \gamma_i$, which still is canceled out because the panel is balanced. Therefore the estimate with applicant-fixed effect is the same as in Equation 5.

B. City by city comparison of the parallel trend assumption

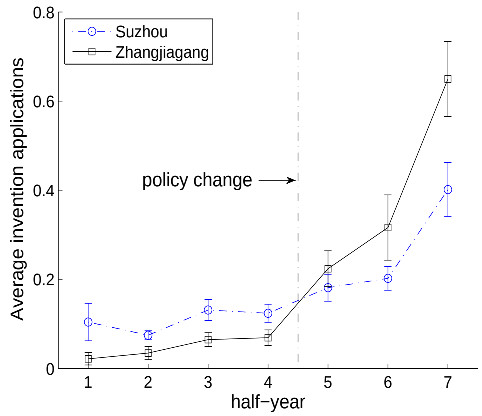
We compare the average applications of invention patents in Zhangjiagang with each control city in Figure 5. It seems that except for Wujiang, the parallel trend assumption holds quite well for all cities. Moreover, it seems applicants in Zhangjiagang experienced an increase in average patent applications from a difference-in-difference comparison with each of the control cities except Wujiang.



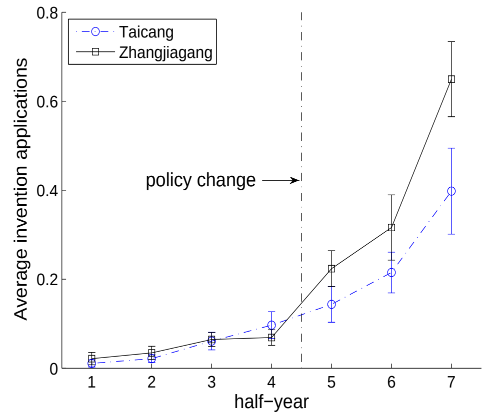
(a) Zhangjiagang vs Changshu



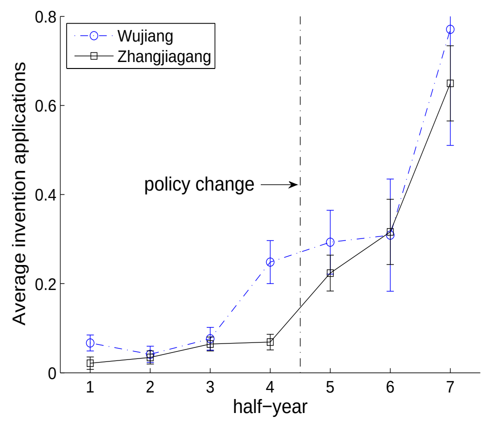
(b) Zhangjiagang vs Kunshan



(c) Zhangjiagang vs Suzhou



(d) Zhangjiagang vs Taicang



(e) Zhangjiagang vs Wujiang

Figure 5. City by city comparison for invention patent applications