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Behind the recent surge of Chinese patenting: An institutional view

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ABSTRACT

This paper examines a number of forces that have possibly contributed to the explosive growth of Chinese patenting over the past decade. After a review of previous hypotheses and conventional wisdom, this study proposes an additional explanation and argues that patent subsidy programs implemented by each provincial region have played an important role in the growth of Chinese patenting. This institutional change, taking place at the province-level, has induced an increase in patent propensity among not only firms, universities, and research institutes, but also individuals. Empirical evidence based on publicly available data provides solid support for this argument. It was also found that a larger fraction of applications are granted patent rights since the implementation of such programs, suggesting that reduction in patent application quality may not be a serious concern, unless the criteria used for patent examination have been lowered.

1. Introduction

The past two decades have witnessed an explosive growth in domestic patents in China.[1] According to the harmonized patent statistics published by the World Intellectual Property Organization (WIPO), the number of residential patent applications per million population in China grew by almost 13-fold from 1995 to 2007. By the end of 2007 China had surpassed Korea in number of resident domestic patent filings and now ranks third in the world, only trailing Japan and the United States (panel (a) of Fig. 1). With respect to the number of patent filings to both domestic and foreign patent offices, the growth of patent families by Chinese inventors has been surprisingly remarkable as well,[2] as depicted in panel (b) of Fig. 1.

The jump in Chinese patenting is an interesting and to some extent unexpected phenomenon. On the one hand, since patents are often considered an indicator of technological change and innovation (Griliches, 1990), one may wonder whether such a rapid rise in Chinese patenting signals a transition for China from a technological follower to a technological leader and reflects a favorable outlook for China's catching-up with western countries. On the other hand, China is still regarded as a country with weak intellectual property rights (IPR) protection (Zhao, 2006). With regard to the patent rights index reported by Park (2008), China ranks far behind most western countries. In an era of aggressive international harmonization of IPR protection, it is not clear if the rapid upswing in patenting represents an important change in the Chinese inventors' innovation behavior and strategy, or how it impacts the technological capability and competitive edge of Chinese firms. The explosive growth of Chinese patents has therefore attracted much attention from both economists and innovation scholars (Hu and Jefferson, 2009; Li, 2009).

Based on a comprehensive dataset drawn from a series of annual surveys of Large & Medium-sized Industrial Enterprises (LMEs) in China, Hu and Jefferson (2009) tried to unravel the causes of the patent surge from 1995. They found that the intensification of research and development (R&D), the continuing surge of foreign direct investment, the stronger legal system and ownership reform have all contributed to the jump in patent applications in China. Although insightful, the conclusion that these authors have reached cannot convincingly explain the dramatic increase in Chinese patenting as a whole. For one reason, the data analyzed by the authors covers only the period from 1995 to 2001. Based on a dataset that only spans this relatively short period, their conclusion can at best explain the increase of patents up to 2001. As will be seen shortly; however, Chinese patenting began to surge in

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[1] In China, there are three types of patents: invention, utility model, and design. Because of the technological importance of inventions, in this paper, I will focus on invention patents only. Therefore, unless specified otherwise, all patents in this study refer to inventions.

[2] According to the definition given in the WIPO statistics database (June, 2009), "a patent family is defined as a set of patent applications inter-related by either priority claims or Patent Cooperative Treaty (PCT) national phase entries, normally containing the same subject matter. Statistics based on patent family data eliminates double counts of patent applications that are filed with multiple offices for the same invention. Counts are based on the priority (first filing) date. Country of origin is the residence of the first-named applicant (or assignee)". The WIPO statistics database was accessed on January 2, 2010 at: http://www.wipo.int/ipstats/en/statistics/patents/.

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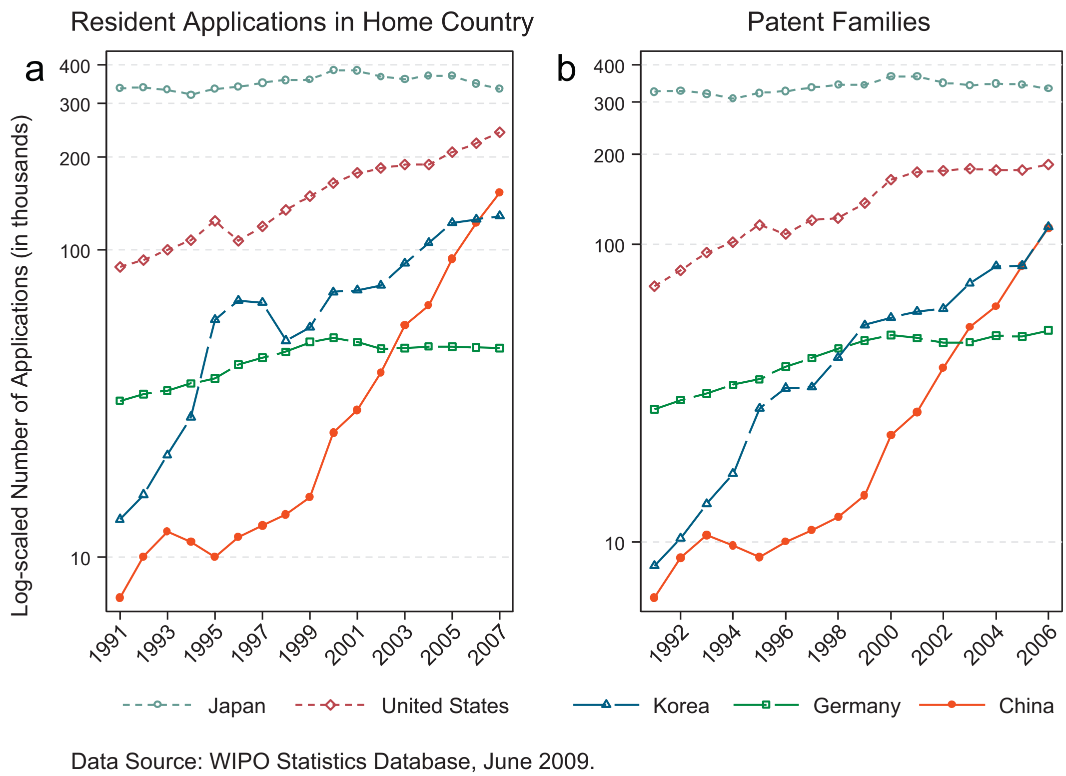

Fig. 1. Number of resident applications in home country by first inventor's country of origin.

2000, and a rapid increase in patents actually occurred afterwards. More importantly, the analysis was limited to only LMEs, which account for a very small proportion of Chinese patents, leaving out the patent jump for small firms, universities, research institutes and individuals.[3] As a result, a large part of the puzzle has yet to be unraveled.

As a matter of fact, the surge in patents is not unique to China. In the 1980s, the United States experienced an upsurge in domestic patenting. By a process of elimination, Kortum and Lerner (1999) attributed the surge to the overhaul of innovation management among firms.[4] Unlike the United States, however, China is a transitional economy. A number of economic forces have accompanied China's explosive growth of patents. Since its opening-up at the end of the 1970s, China has continuously undergone both economic and institutional transition to a market economy. A confluence of concurring factors makes it a very complex issue to untangle the underlying causes of the surge in Chinese patents. A number of influential events have occurred that coincide with the patent jump. On December 11, 2001, China was accepted as a member of the World Trade Organization (WTO). Shortly before that, in July of 2001, the second amendment to the Chinese patent law took effect, bringing China in line with international norms. China's accession to WTO has fundamentally changed the business environment in which local firms operate, which will undoubtedly lead to an adjustment or overhaul in the competition and innovation activities of firms. The amendment to the patent laws has not only broadened the scope of patent protection, but has also strengthened the enforcement mechanism. The pro-patent change in the legal environment for patent holders has had a far-reaching impact on inventors' propensity to patent. Besides these pro-patent institutional changes, intensification of R&D investment, ownership reform, the emergence of new technologies, continuous inflow of foreign investments, and increasing agglomeration are all candidates for explaining the patent jump (Hu and Jefferson, 2009). The list of possible causes can be expanded further. Without a careful examination and analysis; however, it is unwise to attribute the upsurge either to any one or to all these factors.

What then is really behind the recent patenting explosion in China? Motivated by this question, this paper attempts to provide an institutional explanation for the explosive growth of invention patent applications from 1995 to 2007. Toward this end, I first review and examine previous explanations and hypotheses, and then take an institutional perspective to explain the recent patent upsurge. More specifically, I argue that patent subsidy programs aimed at encouraging patenting through deductions and reimbursements of application fees represent one of the important driving forces. Together with R&D intensification and a pro-patent legal change, they have fostered the jump in Chinese patents significantly. Since 1998, these pro-patent programs have been launched and implemented by an increasing number of administrative provincial governments. Surprisingly, none of the previous research has empirically examined the effect of this type of sponsorship program. In this paper, I discuss the extensive effect of subsidy programs on bolstering patent propensity among various groups of applicants, including firms, universities, research institutes, and individuals. Based on province-level data across different applicants, empirical evidence from regression analyses provides solid support for the above-mentioned argument. One may worry whether these subsidy programs could induce an increase in low-quality patent applications. An empirical examination shows that the grant ratio of applications has increased since the implementation of patent subsidy programs. It implies that the concern about

[3] Another drawback associated with their analysis is that the authors did not distinguish between inventions and utility models, mainly due to data limitations.

[4] Hall and Ziedonis (2001) argued that the strengthening of U.S. patent rights in the 1980s is an important factor that has boosted the patent growth, at least in semiconductor industry. See also Jaffe (2000), Hall (2005, 2007) for a thorough discussion of the patent surge in the United States.

patent application quality may not be warranted, unless the standards for patent examination have been significantly lowered in response to the increase in patent applications.

This paper is organized as follows: In the next section, I review previous explanations and present evidence that supports or challenges these hypotheses. Adopting an institutional approach, I introduce an institutional explanation and discuss why the implementation of patent subsidy programs is an alternative explanation for the patent jump in Section 3. In Section 4, empirical methodology and data are discussed. A series of regressions based on official data are reported as empirical evidence to support my arguments. In Section 5, both policy and research implications drawn from empirical results are discussed. Finally, Section 6 concludes.

2. A review of alternative explanations for China's patent surge[5]

Rapid patent growth is not isolated to one particular country. Japan, the United States and Korea have all witnessed an explosive growth of patenting during the last century. Prior studies on patent upsurges have pointed to various causes (Kortum and Lerner, 1999; Song, 2006; Hu and Jefferson, 2009). In order to examine whether and to what extent they have contributed to the recent patent surge in China, I present below a thorough examination of hypotheses from previous studies in a search for evidence to either support or challenge them.

2.1. R&D intensification

R&D is one of the most important inputs to the process of generating new patentable inventions. Intensification of R&D channels more resources into innovative activities and thus causes an increase in patentable inventions. In China, R&D intensity, measured by the ratio of R&D expenditure to GDP, climbed from 0.57% in 1998 to 1.49% in 2007. During the 10-year period from 1998 to 2007, R&D investment in China increased by 5-fold (in inflation-adjusted Chinese RMBs). Therefore, one initial conjecture is that the upsurge results from an intensification of R&D investment in China.

When subject to a careful analysis, however, the R&D intensification hypothesis itself cannot provide a satisfactory explanation for the patent jump. According to WIPO statistics, the number of patent applications, averaged over R&D expenditure, more than doubled in China from 1997 to 2007,[6] suggesting that the number of patents increased much faster than R&D investment. In light of voluminous empirical evidence from previous work that the elasticity of the number of patents with respect to R&D investment is less than 1 (Cincera, 1997; Hausman et al., 1984; Hu and Jefferson, 2004, 2009; Li, 2006, 2008), the contribution of R&D expenditure to patent growth should be moderate.

Besides the increase in R&D expenditures, an increase in high quality R&D staff may also have contributed to patent growth. An examination of ratios of high-quality staff (including both scientists and engineers) among full-time equivalent R&D personnel, however, challenges this view. From 2000 to 2007, the ratio of scientists and engineers remained almost constant in those eastern provinces in China, while these provinces witnessed a faster growth in patenting. It suggests that the increase in overall quality of R&D staff is not a driving force underlying the countrywide patent upsurge. Therefore, the puzzle of why Chinese patenting has grown so much cannot be satisfactorily solved by merely looking at the input effect of R&D intensification. It seems essential to examine the factors that have caused the dramatic increase in patent filing propensity for Chinese inventors.

2.2. A pro-patent legal change

Patenting is one legal mechanism for protecting innovations. The legal environment stipulates the benefits and costs of patent protection for patent holders, which undoubtedly impacts an inventor's willingness to patent. A favorable legislation change that offers broader and stronger protection for patent holders is usually considered as a crucial force for enhancing inventors' propensity to patent, and has attracted much scholarly attention in previous studies. For example, Kortum and Lerner (1999) examined such a change in the U.S. legal environment that took place in the early 1980s and termed it as the friendly court hypothesis. Although they rejected this hypothesis, later work such as that by Hall (2005) has raised questions about this rejection and provided some support for the hypothesis. Song (2006) demonstrated that the friendly court hypothesis is a valid explanation for the rapid patent growth in Korea starting in the early 1990s, supporting the importance of a pro-patent legal environment.

Chinese patenting began to surge in the year 2000, one year before China's accession to WTO (Hu and Jefferson, 2009). From 1995 to 2000, the annual growth rate of invention patent applications was about 11.7% a year. After 2000, invention patent applications rapidly grew at a rate of 29.3% a year until the year 2007. Further analysis shows that the year 2000 was also a watershed for foreign invention applications which had a similar upswing after the year 2000. The growth rate of foreign applications jumped from 16% per annum prior to that year to about 20% annually afterwards. What happened in the year 2000 then?

In fact, it was in 2000 that the Second Patent Law Amendment was enacted in China. Enforced since July of 2001, the new amendments are in accordance with the TRIPS requirements and offer stronger protection for patent holders. To give an example, under the new law, patent holders are able to require an injunction against alleged infringements before a court decision is made, and state assignees now enjoy equal treatment for obtaining patent rights as their non-state counterparts (Hu and Jefferson, 2009).[7] In terms of the patent right index listed in Park (2008), China ranked 69th among 123 countries in 1995. By 2005, China had moved up to 34th, representing a remarkable progress in patent protection. A pro-patent change in Chinese patent law thus suggests that an examination of the so-called friendly court hypothesis is in order.

As argued by Kortum and Lerner (1999), if the friendly court hypothesis holds valid in China, both Chinese and foreign inventors should find patenting in China increasingly attractive, when compared to patenting elsewhere. Furthermore, the pattern of patent growth should be relatively uniform across technologies, patentees and regions.

In order to see whether China presently has a favorable legal environment for inventors, it is useful to examine the number of patent applications to both the Chinese State Intellectual Property Office (SIPO) and home country offices for inventors from four countries: Japan, the U.S., Korea and Germany. Inventors from these four countries are more active in filing applications to the Chinese SIPO than inventors from other countries, and contributed more than three quarters of the total foreign invention applica-

[5] A longer version of Section 2 with supporting figures and tables is available from the author upon request.

[6] In the official WIPO statistics database (June, 2009), R&D expenditure was deflated on 2005 purchasing power parities and lagged by one year to derive the resident patent filings to R&D ratio.

[7] For a detailed description of the change of intellectual property environment in China, please refer to Yang and Clarke (2005). Yang (2008) provides a comparison of the invention patent system between China and the US.

tions in China in 2007. The statistics show that patenting filed in China by inventors from these countries has been rising much faster than patenting in their home countries, especially since 2000, suggesting that China has indeed become a favored destination for foreign inventors seeking patent protection. This finding is consistent with the prediction from the friendly court hypothesis.

In terms of Chinese patenting in other countries, however, it is found that Chinese patent filings to both European Patent Office (EPO) and the United States Patent & Trademark Office (USPTO) have experienced a similar rapid rise. From 1995 to 2006, Chinese patenting in USPTO and EPO has increased more than 25-fold and 47-fold, respectively, which is far more than can be attributed to R&D intensification. Because the friendly court hypothesis has nothing to say about the attractiveness of the U.S. as a patenting destination, it is thus clear that, the pro-patent legal change, together with the increasing intensification of R&D investment cannot explain completely why Chinese inventors' propensity to patent in the US (and EPO) has also increased so rapidly.[8]

Moreover, the pattern of patenting growth suggested by the friendly court hypothesis is not in accordance with the regional distribution of Chinese patenting at the province level. In other words, the pro-patent legal change cannot explain the increasing variation in patenting across Chinese provinces. As discussed above, if the change in patent law has provided an effective incentive for Chinese inventors, its impact on inventors' patent propensity should be uniform nationwide. In reality, however, this is not the case. For example, although the proportion of R&D conducted in the eastern region has been increasing slowly since 1997,[9] there is a jump in the share of patent applications from the eastern region in 1999. Since then, the relative share of patenting has been rising at a faster rate than that of R&D investment, implying that regional variation in patenting is increasing across regions in China.[10] Apparently this cannot be explained by the change in the legal environment, which affects the whole country. The regional pattern of patenting growth thus suggests that region-level factors should be taken into account as well.

Overall, R&D intensification and the pro-patent legal change together cannot give a complete explanation for why Chinese patenting has been increasing so fast after 2000. The favorable change in Chinese patent law, although important, represents only one of the dominant forces underlying the recent Chinese patent upswing.

2.3. Fertile technology opportunities

According to the fertile technology hypothesis in Kortum and Lerner (1999), the patenting upsurge could also be driven by breakthroughs in certain special technologies. If this were the case for the Chinese patenting surge, one would expect an uneven growth of patenting across technology fields. A few technologies would account for a large part of the growth in patenting, and the majority of technologies would experience little increase. To test this hypothesis, I exploited information on the technological dimension of patent data and examined the growth pattern of patenting in different technologies as defined by international patent classification (IPC).

IPC is an internationally harmonious classification system that describes the specific area of technology to which a patent is related. In China, each patent application to SIPO is assigned to one or more IPC classes that are regarded as most relevant. By decomposing the rise in patenting by IPC, one is able to see whether the rise in Chinese patenting is highly concentrated in a few dynamic technologies or broadly distributed across many technologies. In order to compare the patenting distribution over an equal time span before and after 2000, I focused on a shorter period, the application years 1995–2004, and divided this 10-year period into two 5-year periods: 1995–1999 and 2000–2004. For each 3-digit IPC class, I calculated the fraction of patent applications that appeared in the second-five period.[11]

As noted above, the growth of Chinese patenting was slow during the first period, while over the second five years, patenting took off and began to rise rapidly. This is confirmed by the observation that the fraction of patent applications in the second period is over 60% across all IPCs, implying that all classes experienced an increase in patenting after 2000. This pattern provides some support for the friendly court hypothesis which suggests that patent propensity should be as sensitive to a pro-patent legal change in one technology as in any other. However, what is striking is the large number of technology classes that appear to be rapidly improving areas for technological discovery. The fraction of patenting in the second period is over 80% in as many as 25 classes among 110 three-digit selected IPCs. In light of the fact that the absolute number of applications in some of these pro-patenting classes may be small, I further examined six classes containing more than 5000 applications over the 10-year period.[12]

The share of patenting in these six pro-patenting classes has been slowly increasing since 1995. It climbed to 21.5% in 1999 from less than 14% in 1995, and suddenly jumped to 32.6% in 2000. Since then, it has been fluctuating between 30% and 35%. If technological opportunities had increased in some classes, the increase in the relative share of patenting in these areas should have lasted for a longer period. This is clearly not what one can conclude from the data. Moreover, in a comparison of the growth pattern of patenting between these six pro-patenting classes and all other IPC classes, it was found that patenting in two groups of technology classes increased at almost the same rate after 2000. Specifically, between 2000 and 2007, the annualized growth rates of patenting for the six pro-patenting classes and all other IPCs are 30.9% and 28.9%, respectively. Given that patenting in non-pro-patenting classes also increased at a remarkable rate after 2000, it seems to suggest that the fertile technology hypothesis is unlikely to be the real driving force behind the Chinese patent surge.

[8] As one reviewer mentioned, the overall growth of Chinese patenting in USPTO and EPO can partly be explained by a shift in Chinese inventors' expectations about the growth of the market size in the U.S. and European countries.

[9] According to the Chinese National Bureau of Statistics, thirty mainland provinces are classified into three tiers based on their economic development level. The eastern region includes twelve provinces: Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi, and Hainan. The central region includes nine provinces: Shanxi, Neimenggu, Jilin, Heilongjiang, Henan, Hunan, Hubei, Jiangxi, and Anhui. The remaining nine provinces are classified into the third tier, the western region.

[10] Li (2009) notices a similar phenomenon that the share of top 10 provinces in Chinese patenting has increased remarkably from 1998 to 2005, while the share of R&D investment in these provinces remained almost unchanged. He attributes the enlarging disparity to a structural shift of R&D resources toward enterprises in some provinces. Although supported by empirical evidence, it cannot explain why university patenting also suddenly increased during the same period, as we will shortly see below.

[11] Because randomness in the invention process will also generate a variation in the fraction of patenting coming in the second period, which will confound with the variation caused by structural differences in technological opportunities across IPC classes, and in order to highlight the structural variation, I considered only the IPC classes with more than 100 applications over the whole period, which actually contains 99.8% of domestic patents.

[12] The six pro-patenting classes are: H04 (electric communication technique), H01 (basic electric elements), G06 (computing, calculating, counting), C07 (organic chemistry), G01(measuring, testing), and C12 (biochemistry, beer, spirits, wine, vinegar, microbiology, enzymology, mutation or genetic engineering).

2.4. Alternative explanations

Another hypothesis that Kortum and Lerner (1999) investigated is the regulatory capture view which suggests that the changes in the legal environment may be taken advantage of disproportionately by the major patentees that have been most active in patenting in the past, such as large enterprises. Is the increase in patenting largely confined to LMEs in China, or is it also occurring among less established firms and other types of patentees? As a matter of fact, in the year 2007, LME patenting accounted for only about one quarter of domestic patenting. During the observation period between 2001 and 2007, the share of LME patenting among all industrial enterprises has stayed around 55%, except for a blip in 2004. Both patterns suggest that the regulatory capture view cannot be the explanation for much of the increase in Chinese patenting. In addition, the fraction of patent filings from universities and research institutes seems to have also increased along with the increase in Chinese patenting over the last decade.

The empirical observations also cast doubt on the three other explanations examined by Hu and Jefferson (2009). In addition to R&D intensification and the pro-patent legal change, these authors argue that the driving forces of the jump in Chinese patenting include three other factors: the inflow of foreign direct investment (FDI), an increase in the number of non-state enterprises that are more active in patenting, and a shift in industrial structure toward industries with higher patent propensities. It is possible that FDI inflow can increase technological opportunities for domestic firms to imitate and innovate, and induce Chinese firms to use patenting as a tool for countering competition from foreign firms. Previous studies have often considered FDI as a factor contributing to firms' innovation performance (Zhang and Rogers, 2009). In this study, however, it is difficult, if not impossible, to argue that FDI could influence innovation and patenting by scientists from universities and research institutes. Likewise, the increase in more pro-patent non-state firms in China seems to have no relation with patenting from universities and research institutes. Finally, it is true that propensity to patent varies greatly across industries (Arundel and Kabla, 1998; Brouwer and Kleinknecht, 1999; Cohen et al., 2000; Levin et al., 1987). A shift in industrial composition toward pro-patenting industries can potentially drive up the overall level of patenting. However, the nearly equal rate in pro-patenting and other IPC classes discussed above shows that this is not likely the case in China.

In summary, although the various forces examined contribute to the recent patenting growth, together they provide an incomplete, if not unsatisfactory, explanation for the Chinese patent upsurge. Several distinctive features emerged in China's patent growth and have to be taken into account. Any valid explanation of the patent upsurge in China must address these concerns. Before proceeding to explore an alternative hypothesis, a brief review of these features is in order. They include:

(a) Chinese resident patent applications to China SIPO, EPO and USPTO have all jumped. Although domestic patenting began to surge in the year 2000, Chinese patenting to USPTO took off one year earlier.
(b) Patents have surged in all types of organizations. Universities and research institutes have both experienced a patent explosion, while industrial enterprises account for a larger share of patent growth. Such a dramatic increase is found among individual inventors as well.
(c) Patent filings from all regions have dramatically risen. However, patents from provinces in the relatively developed eastern region increased more rapidly, leading to an increased disparity in patenting across provinces.
(d) More importantly, Chinese patents from industrial enterprises, universities and research institutes have all been increasing at a faster rate than R&D expenditure. It also holds true for Chinese patenting both domestically and abroad.

3. A region-level institutional explanation

After a review of previous explanations and hypotheses, it is obvious that these factors cannot explain why Chinese filings to EPO and USPTO have suddenly surged, why universities and research institutes are becoming so active and aggressive in patenting, and why the regional disparity in patenting has been increasing. To answer these questions, I propose an examination of region-level institutions. More specifically, I argue that the province-level policy initiatives (patent subsidy programs) underlie the recent Chinese patent jump.

In 1999, the municipal government of Shanghai launched an important policy initiative to encourage and stimulate local patentees to file patent applications both domestically and abroad. It established a special fund to subsidize costs and fees normally incurred during patent application, substantial examination, and maintenance. Individual and organizational inventors who are either living or registered in the Shanghai jurisdiction are all eligible for this subsidy as long as the proof of filings from either the Chinese SIPO or the patent offices in other countries is provided. In 2000, five other provinces and cities including Guangdong, Beijing, Tianjin, Jiangsu and Chongqing, launched similar programs and set up their own funds to subsidize patent filings from firms, universities and research institutes, and residents in their jurisdiction. By the end of 2007, 29 out of 30 provinces in mainland China had launched a patent subsidy program (Fig. 2). It is noteworthy that, although local governments usually review and revise these programs on a regular basis, most provinces continue to subsidize patenting year after year. The incentive provided by these subsidies is therefore not one-off.

The budget available for patent subsidies and the rules for reimbursement differ across provinces. Some local governments rebate patent fees in full, and others reimburse only part of the costs. Beijing allocated one million RMB for subsidizing patents in 2000, whereas Chongqing had only a budget of 200 thousand RMB to subsidize patent applications. Patentees in Shanghai and Guangdong could obtain full reimbursement of application fees, while Tianjin only reimbursed patent applicants a set amount. Thus the monetary incentives provided by these subsidy programs differ across provinces; however, they share some common features. First, all of these subsidy programs support only the patent applications registered in their own jurisdictions. Individual inventors usually receive the same support as firms, universities and research institutes. Second, they all encourage inventors to patent abroad. The amount of subsidy for patent filing in foreign countries is usually larger than that for domestic filings to the Chinese SIPO. In Tianjin, for example, in 2003 patent filings to foreign patent offices were subsidized 2000 RMB per filing, while the subsidy for domestic applications was only 800 RMB per filing. In Shanghai, an issued patent by a foreign patent office is eligible for a subsidy of 30 thousand RMB per country (up to two countries), which is also much higher than the subsidy to domestic patents.[13] Third, in most cases, these programs do not discriminate inventor applications by technology class. Subsidies are also independent of the qual-

[13] At the sub-region level, there also exist such preferential subsidies to patent filings in foreign patent offices. In the city of Shenzhen, for example, each patent issued by USTPO, EPO or the Japan Patent Office is subsidized up to 50 thousand RMB apiece, while subsidies for patents issued in other foreign countries is only 30 thousand RMB apiece.

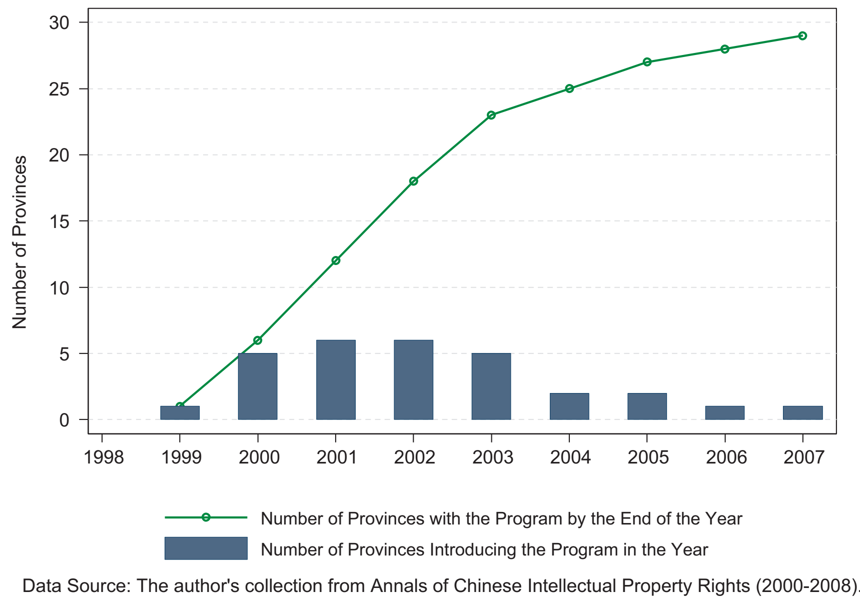

Fig. 2. Diffusion process of patent subsidy programs among Chinese provincial regions.

ity or potential economic value of inventions, requiring only that they be the same patent type and filed to the same patent office, although the amount of subsidy usually differs across inventions, utility models and designs.

For potential patentees, patent subsidies largely reduce the cost of seeking patent protection and therefore increase the overall return of patenting. They are particularly favorable for firms patenting strategically and patentees from university and research institutes who are less likely to appropriate the benefit of patenting from commercializing their patented technologies. In this sense, patent subsidies are able to not only encourage frequent applicants to file more applications, but also attract a lot of filings from those inventors who had never applied for patents before. Given the weak protection of intellectual property and the low commercialization rate of patented inventions in China, the incentive brought about by such subsidies is quite remarkable. In practice, despite the differing details for patent subsidies across provinces, they have greatly stimulated enthusiasm for patenting among Chinese inventors. In Shanghai, for example, there were only 573 invention applications in 1998. In September of 1999, when the patent subsidy program was enforced, the number of invention applications almost doubled and increased to 1047. The growth of invention applications accelerated even more dramatically in 2000. The number more than quadrupled within one year and jumped to an unprecedented level of 4713. Between 1999 and 2000, although individual patent applications increased by only 35%, patent applications from both universities and research institutes more than tripled. The increase rate of patenting from industrial enterprises was by far the most noticeable. The number of enterprise invention applications rapidly jumped to 3374 from 469, a more than 6-fold upsurge within one year. Surprisingly, almost 80% of the applications in 2000 were contributed by one biotech firm which began to file for patents only after 1999.

The features of such patent subsidy programs are actually consistent with the growth pattern of Chinese patenting as shown in the previous section, which helps resolve the puzzle. First, all these programs encourage inventors to apply for patents in foreign countries. Some even have preferential rules for patent filings to foreign patent offices. The special stipulations provide an explanation as to why Chinese patenting in USPTO and EPO has also increased so rapidly. Second, the fact that patent subsidies are available to all types of patentees explains why patent applications from universities, research institutes, and individuals have all increased dramatically. Finally, the increasing regional disparity in patenting could probably be attributed to the difference in launch time, total budgets and specific rules of subsidy across provincial-level regions.

Available findings and the reasoning above seem to suggest that the enforcement of the patent subsidy program is an alternative explanation for the recent patent upswing in China. However, solid evidence is scant and still needed. In particular, if the speculations about the impact of patent subsidy programs on Chinese patenting are correct, there should be a significant increase in patent propensities among all types of patentees after the launch of a patent subsidy program in a province. Furthermore, since it takes time for information about such a program to diffuse among inventors,[14] its impact on patent propensity should start increasing after the launch of the program and become stabilized gradually. In the next section, I will present an empirical test to examine whether these speculations are valid.

4. Empirical evidence

4.1. Data and methodology

In order to test the patent subsidy hypothesis, the impact of patent subsidies on patenting propensity is empirically estimated for four types of patentees: individuals, LMEs, universities, and research institutes, at the province level.[15] The estimate is based on a comprehensive dataset constructed from multiple official sources. Specifically, the exact year of launch for patent subsidy programs for each province was gleaned from the series of Annuals of Chinese Intellectual Property Rights which record important policies and practices of intellectual property management every year for each local government. Table A1 in the Appendix reports

[14] According to media coverage, during the first year of patent subsidy programs, the budget was not used up in several provinces, mainly because many inventors did not know the availability of subsidies.

[15] Since R&D data and patent information are not available for small enterprises, I consider only a special group of industrial enterprises, LMEs, in this analysis.

the launch year for each province in detail. University patents and R&D data aggregated at province-level were mainly drawn from Compiled Books of University Science & Technology Statistics. For the other three types of applicants, patent information was collected from a series of Annual Reports on Patent Statistics published by the Chinese SIPO. Information on R&D expenditures was gathered from the series of Chinese Science & Technology Statistical Yearbooks. The remaining data were collected from Chinese Statistical Yearbooks which provide rich information on province-level GDP per capita, population, FDI inflows, and country-level export and direct investment in China.

As noted briefly before, it is implausible that the effect of patent subsidies is instantaneous and constant. It is more likely that any positive or negative effect starts increasing after the actual date of launch and finally stabilizes at a certain level. Given that a province launches its patent subsidy program in year t_0, for the sake of simplicity, I assume that the impact of patent subsidy programs on patent propensities in year t can be expressed as: $\exp[\beta_1 - \beta_2/(t - t_0 + 1)]$. As t increases, it will approach a stable level. Accordingly, two variables were constructed to capture the impact. The first variable, $PSP1_{it}$, is a dummy which takes a value of 1 if province i launches its patent subsidy program in year t or before, and 0 otherwise. The second variable, $PSP2_{it}$, takes the value of $-1/(t - t_0 + 1)$, where t_0 is the year when the province first launches the program.

As discussed in Section 2, the intensification of R&D investment is one important factor contributing to the recent patenting surge. Following the econometric literature on estimating the relationship between R&D and patents (Crépon and Duguet, 1997; Hausman et al., 1984; Li, 2008), I used contemporaneous and lagged R&D expenditure as controls for the effect of R&D. In order to avoid the loss of too many observations, I considered only one-year and two-year lags. With respect to individual patentees for whom there is no R&D information available, I drew from Furman et al. (2002) and used two other province-level variables, Gross Domestic Products per capita (*GDPPC*) and total populations (*POP*), as the control for the capitalized knowledge stock which is accessible for individual inventors.

The change in the Chinese legal environment is a second force that has fostered the Chinese patent upsurge. To control for its impact on patenting, I incorporate a constructed variable, *IPENV*, in the estimation. Since a pro-patent legal change should stimulate patenting from both domestic and foreign inventors, I used the information on foreign patenting to construct this variable. Specifically, I assume that foreign inventors' propensity for seeking patent protection in China is strongly related to the Chinese legal environment. As the patent law changes, the willingness to file patent applications in China will change accordingly. Therefore, the following ratio equation can be estimated to capture the impact of the patent law change:

$$E\left[Log(RTO_{it})\right] = \alpha + \sum_{t=1996}^{2007} \gamma_t \cdot YD_t + \beta_1 \cdot Log(DIC)_{it} + \beta_2 \cdot Log(EXPC)_{it} \qquad (1)$$

where RTO_{it} is the ratio of the number of patent applications in the Chinese SIPO from inventors of country i in year t to the count of total applications in the home country patent office. DIC_{it} and $EXPC_{it}$ are the amount of direct investment in China and total export to China from country i in year t, respectively. These two variables are included to control for the effect of multinational corporations and international trade, which should presumably influence total foreign patenting as well. YD_t are year dummies. The estimation of Eq. (1) was based on panel data containing patent information from 1995 and 2007 for the 21 countries that have the most filings to the Chinese SIPO in 2007. The estimated coefficients of these year dummies, γ_t, from a fixed-effect panel regression were taken as a proxy indicator of time-varying legal changes.[16]

Hu and Jefferson (2009) hypothesized that the increasing inflow of FDI has contributed to patenting from Chinese firms. In order to account for this factor, I included FDI stock at the end of the previous year in each province as an additional control variable. It was constructed with the perpetual inventory method suggested by Hall and Mairesse (1995) and the depreciation rate of FDI was set at 15%. Except for *IPENV*, all other control variables take a log form in estimation.

Regarding model specifications, I took the number of patent applications as the dependent variable and employed the knowledge production function as the underlying theoretical framework. For the analysis of patenting from LMEs and individuals, I used the fix-effect panel regression technique and specified the model as following:

$$E\left[Log(PAT_{it})\right] = \alpha + \beta_1 \cdot PSP1_{it} + \beta_2 \cdot PSP2_{it} + \lambda \cdot X_{it} \qquad (2)$$

In the case of universities and research institutes, since the number of patent applications was rather small for some units of analysis, regression techniques based on a count data model were utilized. Accordingly, the model was specified as:

$$Log\left[E(PAT_{it})\right] = \alpha + \beta_1 \cdot PSP1_{it} + \beta_2 \cdot PSP2_{it} + \lambda \cdot X_{it} \qquad (3)$$

In both equations, PAT_{it} is the number of patent applications in year t from province i. $PSP1_{it}$ and $PSP2_{it}$ are two variables reflecting the impact of patent subsidy programs. X_{it} is a vector of variables containing controls and regional dummies. By construction, β_1 measures the long-term impact of patent subsidy programs, and β_2 captures the short-term adjustment to the long term effect due to information diffusion.

It is noteworthy that the estimated coefficients, β_1 and β_2, from model (2) and (3) are not directly comparable due to the different model specifications. Nonetheless, they can be interpreted in a similar way. Both measure the impact of patent subsidy programs on patent propensity. Table 1 below presents a correlation matrix of variables for different types of patentees.

4.2. Results

In order to account for unit heterogeneity in estimation, a fixed-effect regression technique was employed for individuals and LMEs. In the case of universities and research institutes, a fixed-effect Poisson regression on the count data model was used instead. Since province-level R&D information for LMEs and research institutes is not available until 1998, the time span covered for the four types of patentees are not the same. Estimated coefficients with robust standard errors are given in Table 2 for each type of patentee separately.[17]

As is apparent from the table, the estimated coefficients of *PSP1* and *PSP2* are all significantly positive, although their magnitude varies across four regressions. This confirms my previous argument that patent subsidy programs are an important institutional factor that has bolstered the recent patent upswing.

In terms of the contribution of R&D for LMEs, universities and research institutes, the sum of estimated coefficients, which measures the long term elasticity of patenting with respect to R&D investment, is less than unity in all three cases. This finding lends

[16] For the year of 1995, the proxy indicator was set to 0. The results from this regression are available from the author upon request.

[17] The robust standard errors in the fixed effect Poisson regressions are obtained with the Stata module *xtpqml* developed by Tim Simcoe, as implemented in Hu and Jefferson (2009).

Table 1
Summary statistics and correlation matrices.

Variables	Mean	Sd. dev.	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)
(a) Individuals (number of observations: 358)										
1. Log(PAT)	5.89	1.11	2.77	8.71						
2. PSP1	0.46	0.50	0	1	0.44**					
3. PSP2	−0.18	0.28	−1	0	−0.17**	−0.71**				
4. Log(GDPPC)	−0.24	0.63	−1.64	1.64	0.62**	0.51**	−0.21**			
5. Log(POP)	8.10	0.79	6.19	9.34	0.61**	0.05	−0.03	−0.12*		
6. IPENV	0.88	0.40	0.37	1.49	0.43**	0.72**	−0.29**	0.49**	0.03	
7. Log(FDI)	5.20	1.81	−0.44	8.62	0.77**	0.27**	−0.13*	0.63**	0.48**	0.14**
Variables	Mean	Sd. dev.	Min	Max	(1)	(2)	(3)	(4)	(5)	
(b) LMEs (number of observations: 240)										
1. Log(PAT)	4.86	1.59	0.69	9.74						
2. PSP1	0.68	0.47	0	1	0.41**					
3. PSP2	−0.27	0.30	−1	0	0.02	−0.61**				
4. Log(R&D)	11.81	1.43	7.17	14.94	0.91**	0.33**	−0.01			
5. IPENV	1.08	0.33	0.52	1.49	0.43**	0.50**	0.04	0.35**		
6. Log(FDI)	5.37	1.75	−0.24	8.62	0.70**	0.30**	−0.08	0.76**	0.07	
Variables	Mean	Sd. dev.	Min	Max	(1)	(2)	(3)	(4)	(5)	
(c) Universities (number of observations: 385)										
1. PAT	224.44	475.02	0	3417						
2. PSP1	0.43	0. 50	0	1	0.41**					
3. PSP2	−0.17	0.28	−1	0	−0.05	−0.72**				
4. Log(R&D)	−0.02	1.85	−5.32	3.74	0.56**	0.41**	−0.18**			
5. IPENV	0.81	0.45	0	1.49	0.46**	0.72**	−0.34**	0.40**		
6. Log(FDI)	5.14	1.82	−0.51	8.62	0.43**	0.28**	−0.14**	0.72**	0.18**	
Variables	Mean	Sd. dev.	Min	Max	(1)	(2)	(3)	(4)	(5)	
(d) Research Institutes (number of observations: 240)										
1. *PAT*	112.05	243.42	0	1782						
2. *PSP1*	0.68	0.47	0	1	0.14*					
3. *PSP2*	−0.27	0.30	−1	0	0.04	−0.61**				
4. *Log(R&D)*	12.11	1.29	9.18	16.01	0.70**	0.19**	0.02			
5. *IPENV*	1.08	0.33	0.52	1.49	0.16*	0.50**	0.04	0.18**		
6. *Log(FDI)*	5.37	1.75	−0.24	8.62	0.32**	0.30**	−0.08	0.59**	0.07	

* $p < 0.05$.
** $p < 0.01$.

Table 2
Regression results with constructed legal change variable (IPENV) included.

Variables	Individuals	Large & Medium Sized Enterprises	Universities	Research Institutes
PSP1	0.394***	0.576***	0.681***	0.291*
	(0.115)	(0.203)	(0.222)	(0.172)
PSP2	0.372***	0.668***	0.613***	0.355***
	(0.117)	(0.227)	(0.163)	(0.132)
$Log(GDPPC)_{-1}$	0.749***			
	(0.200)			
Log(POP)	1.871**			
	(0.687)			
Log(R&D)		0.326*	0.569***	0.430***
		(0.170)	(0.091)	(0.099)
$Log(R\&D)_{-1}$		0.119	0.175**	0.354***
		(0.178)	(0.087)	(0.126)
$Log(R\&D)_{-2}$		0.391**	0.188***	−0.326***
		(0.170)	(0.057)	(0.095)
IPENV	0.151	0.383	0.704***	0.468***
	(0.137)	(0.275)	(0.199)	(0.128)
Log(FDI)	0.115	−0.020	0.284	0.279*
	(0.097)	(0.133)	(0.178)	(0.158)
Period	1995–2007	1998–2007	1993–2007	1998–2007
Observations	358	240	385	240
Number of regions	30	30	30	30
R^2	0.83	0.77		

Robust standard errors are in parentheses.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

additional support for the prior argument that R&D intensification cannot entirely account for the upsurge of Chinese patenting.

Regarding the impact of the pro-patent legal changes, the estimated coefficients of *IPENV* for individuals and LMEs are not statistically significant, while they are significant for universities and research institutes. This result implies that the change in patent laws has a distinct impact on patenting across different inventors. That is, universities and research institutes benefit more from the stronger protection provided by patent laws; whereas individuals and LMEs seem to not benefit. To better understand this counterintuitive result, it is useful to take a close look at the specific changes enacted in the second patent law amendment.

One of the most important changes in the amended patent laws is that state-owned patenting organizations such as universities and research institutes could now claim for ownership of patent rights, in line with the previously held rights of private or collective enterprises. Prior to the legal change, however, they were considered as mere holders of patent rights. This Bayh–Dole style change amounts to a great incentive for such organizations to patent aggressively. Moreover, the new patent laws have a special article stipulating that inventors from state-owned organizations should be awarded appropriately, which further evokes patenting enthusiasm among scientists and researchers. Because almost all research-intensive universities and important research institutes are state-owned and funded by the government in China, one should not be surprised to find that the most important influence that the new patent laws have is on universities and research institutes. The reason why LMEs seem to not benefit from the pro-patent legal changes is probably because most actively patenting firms in the LME group are not state-owned, such as Huawei and ZTE. The change in patent laws has a moderate effect on these firms. As a result, the impact of the legal change on LMEs as a whole may not be able to manifest itself.

In addition, if foreign inventors conclude that the amended patent law is less beneficial to them than to Chinese inventors, the variable *IPENV* as constructed from Eq. (1) may not fully capture the pro-patenting legal changes.[18] This offers an alternative explanation to the insignificance of *IPENV*.

In terms of the impact of FDI stock, it was found to be statistically insignificant for the three types of patentees except for research institutes in which it was only marginally significant. These findings demonstrate that the inflow of foreign investment is unlikely to be an important force underlying the Chinese patenting surge. In fact, it is rather difficult to justify why FDI should have a noticeable impact on university and research institute patenting.

In order to show how the impact of patent subsidy programs on patent propensity changes as time elapses, the multiplier of patent propensity, $\exp[\beta_1 - \beta_2/(t - t_0 + 1)]$, was computed from the estimated coefficients, β_1 and β_2, and plotted as a function of time in Fig. 3. Since different model specifications were used, I contrasted individuals with LMES, and universities with research institutes, separately. It can be clearly seen that the magnitude of the impact is much larger for LMEs than for individuals, and it is more remarkable for universities than for research institutes. The disparate impacts are actually in accordance with the fact that universities and LMEs are the main innovators in Chinese regional innovation systems (Li, 2009). They also partially explain why the fractions of LME and University patenting have both increased.

From the estimated coefficients and the fitted figure, one may notice that the first year multiplier on patent propensity is less than 1 for both LMEs and Research institutes. It seems to suggest a temporary hold-off effect during the first year that the subsidy program is launched. Although it is possible that some inventors may wait and postpone filings until assured that the subsidy is real, an alternative explanation could be the limitations of the data which cover a rather short period from 1998 to 2007 in the case of LMEs and research institutes. Because the two-year lagged R&D variable was used, the regressions were actually based on observations starting from 2000. By the end of 2000, however, seven provinces, which were the most aggressive in patenting, had already launched the program. As a matter of fact, the growth of patenting in regions other than the seven provinces was not so dramatic. In this sense, the hold-off effect may well be an artifact of data limitations.

Finally, it may be interesting to quantify the effects of the two other significant factors, R&D intensification and the legal change, and set them against those of patent subsidy programs. In order to do so, I first normalized the number of patent applications as unity in 2001 and examined the extent that changes in *Log*(*R&D*) or *IPENV* contributed to the rise in applications for each year from 2001 to 2007, given all other factors being set at their level in 2001. Next, I assumed that a patent subsidy program was launched in 2001 and estimated the multipliers of patent propensity for the subsequent years. The results are juxtaposed and tabulated in Table 3.

From the table, it can be concluded that, for all three types of organizations, the R&D intensification effect dominates in the long run, suggesting that R&D intensification is a crucial factor that sustains the long-term growth of patenting. Nevertheless, the effect of patent subsidy programs is rather remarkable when compared to those of the two other factors. For example, the effect of patent subsidy programs on LMEs is comparable to that of R&D intensification within a short period of two or three years. In the case of universities, the importance of patent subsidies is always more prominent than that of the pro-patent legal change. For research institutes, patent subsidy programs have a larger impact than the legal change in patent laws during the first three to four years. This comparison, although rather preliminary, demonstrates that patent subsidy programs represent one of the important economic forces underlying the recent Chinese patent growth that cannot be overlooked.

4.3. Robustness check

In order to check for the robustness of the estimation reported above, I have also tried several different specifications. In Table 2, the variable *IPENV* was measured with the estimated coefficients of year dummies from a regression of foreign patents in China. As discussed above, one may worry whether it is a valid indicator of the changing legal environment in China. To investigate whether and how this variable has influenced the estimation, I replaced *IPENV* with a group of year dummies to capture the time-varying effect related to the Chinese legal environment. The estimated results are presented in Table 4.

Because year dummies have captured part of the common fluctuation in patent propensity, the magnitude of estimated coefficients are not directly comparable with that listed in Table 2. Nonetheless, the statistical significance of coefficients from this specification still reveal a very similar pattern of patent subsidy impact, except for the case of research institutes where the estimated coefficient of *PSP1* is no longer significant. Even in this case, the significant coefficient of *PSP2* also suggests a noticeable time-varying effect that can be attributed to patent subsidies.[19]

[18] The author is grateful to one anonymous reviewer for suggesting this caveat.

[19] Hall et al. (1986) showed that contemporaneous R&D is almost as good as the sum of the lags in explaining patent applications. As an additional check, I estimated the models in the case of LMEs, universities and research institutes with only contemporaneous R&D incorporated. The results, which are available from the author upon request, are similar to those presented in Tables 2 and 4.

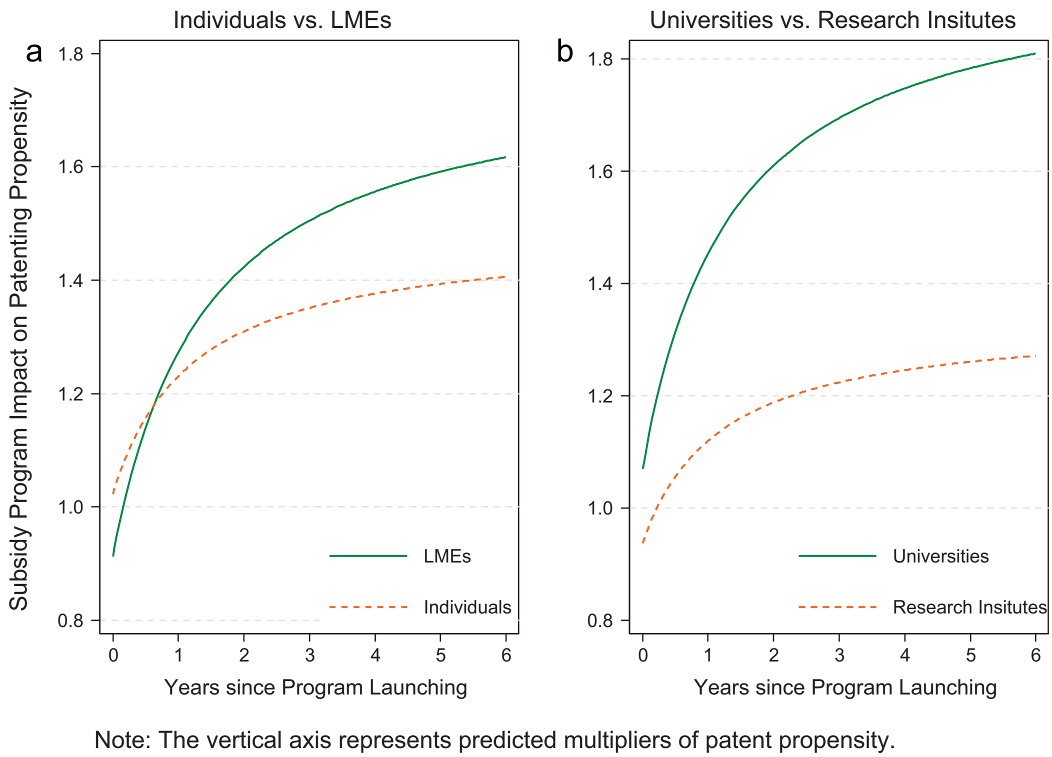

Fig. 3. An illustration of time effect of patent subsidy programs.

Table 3
A comparison of predicted impact across three factors.[a]

Year	Large & Medium Enterprises[c]		Universities			Research Institutes		
	Subsidy Program[b]	R&D	Subsidy Program[b]	R&D	Legal Change	Subsidy Program[b]	R&D	Legal change
2001	0.91	1	1.07	1	1	0.94	1	1
2002	1.27	1.24	1.45	1.22	1.09	1.12	1.28	1.06
2003	1.42	1.46	1.61	1.51	1.09	1.19	1.48	1.06
2004	1.51	1.74	1.70	1.77	1.32	1.22	1.45	1.20
2005	1.56	2.07	1.75	2.19	1.49	1.25	1.52	1.30
2006	1.59	2.48	1.78	2.47	1.64	1.26	1.55	1.39
2007	1.62	2.93	1.81	2.84	1.61	1.27	1.65	1.37

[a] Figures represent the imputed number of patent applications, with the number in 2001 being unity and all other factors being set at their level in 2001.
[b] Assuming that a patent subsidy program was launched in 2001.
[c] The legal change is not a significant factor in the case of LMEs.

Alternatively, I estimated model (2) and (3) with a third measure of the IP environment which was constructed from an ANOVA analysis as suggested by Kortum and Lerner (1999, pp. 8–9).[20] Again, the results do not change much and suggest a similar conclusion.

Overall, the robustness of estimation affirms the argument that patent subsidy is an important economic force that accelerates the growth of Chinese patenting. In the meantime, it has contributed to the increasing disparity in patenting across regions.

5. Discussions and implications

5.1. Impact on patent quality

As corroborated by empirical evidence, the launch of patent subsidy programs represents an important and favorable change in regional institutional arrangement that has stimulated the rapid upswing of patenting in China. Since patent subsidies result in a lower cost for patent filings by inventors, one may worry if this would attract a large number of low-quality filings with lower potential economic value, and therefore lead to a decline in the quality of patent applications. A careful analysis of the resulting impact on patent application quality is certainly beyond the scope of this analysis. Nonetheless, available data can provide a clue to this important issue.

[20] Specifically, the number of applications by inventors from a source country for patent protection in another destination country in each year can be decomposed into nine sets of effects and analyzed with a common ANOVA procedure. A log-linear regression of the exponentiated fitted values of patent numbers, obtained from the ANOVA procedure, was next run on the nine sets of effects. Based on the estimated parameters obtained from the log-linear regression, the magnitude of time-varying China-destination effect over the sample period can be calculated and regarded as an alternative proxy measure of the IP environment. For a detailed discussion of the modeling strategy and its limitations, see Kortum and Lerner (1999). The results are available from the author upon request.

Table 4
Regression results with year dummies included.

Coefficient	Individuals	Large & Medium Sized Enterprises	Universities	Research Institutes
PSP1	0.395***	0.449**	0.302**	0.173
	(0.115)	(0.210)	(0.135)	(0.175)
PSP2	0.390***	0.558**	0.372***	0.260*
	(0.120)	(0.225)	(0.101)	(0.135)
$Log(GDPPC)_{-1}$	0.641			
	(0.888)			
Log(POP)	1.743*			
	(0.906)			
Log(R&D)		0.244	0.287***	0.196
		(0.204)	(0.084)	(0.155)
$Log(R\&D)_{-1}$		0.126	0.084	0.275***
		(0.144)	(0.065)	(0.082)
$Log(R\&D)_{-2}$		0.354**	0.113*	−0.233
		(0.142)	(0.066)	(0.142)
Log(FDI)	0.137	−0.039	0.070	0.197
	(0.110)	(0.142)	(0.236)	(0.164)
Period	1995–2007	1998–2007	1993–2007	1998–2007
Observations	358	240	385	240
Number of regions	30	30	30	30
R^2	0.84	0.78		

Coefficients for year dummies are not reported for brevity. Robust standard errors are in parentheses.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

In effect, if this is the case, one would expect that the ratio of applications that eventually get granted should drop, provided that the criteria used to assess the non-obviousness and novelty of patenting remain unaffected. To check out this possibility, I searched the patent database of the Chinese SIPO and tabulated the number of invention patent grants by application and grant year in Table 5. The last column of Table 5 lists the ratio of patent applications that have been granted patent rights by the end of 2008. From the grant ratios, it was found that a larger fraction of applications had been approved since the year 2000. For instance, although the grant ratio for applications filed in 2000 was only 14.2%, 42.5% of the applications filed in 2004 were granted patent rights within the next four years, despite a truncation effect. This evidence contradicts the hypothesis that patent subsidies induce more low-quality patent filings. On the contrary, it seems to suggest an increase in the quality of patent applications. Unless the bar set to assess the quality of applications has been lowered, one cannot conclude a decline in patenting quality.

A close look at the patenting process suggests an explanation for the increase in grant ratio. According to Chinese patent laws, if the applicant does not apply for a substantial check within three years of the announcement of the application, the application is considered legally withdrawn. Some applicants do terminate the patenting process at this stage because of the expensive fee required at the time that the substantial check is requested. Patent subsidies for the substantial check fee help lower the withdrawal rate of domestic patenting and prompt a larger fraction of applications going through a substantial check, which will certainly cause an increase in the number of patent grants.

It is worth noting that what I have checked so far is only the grant ratio of patent applications. The argument that there is no decline in patent application quality is conditional on constant criteria in patent examination. If the criteria vary as the number of applications increases, however, it is still possible that there is a decline in quality of issued patents, in spite of the increasing grant ratio. Hall (2007) pointed out that as the number and the complexity of applications grow, patent examiners will not be able to keep pace with the increased workload. In this case, there will be a dilution of grants and the quality of patents will suffer. This may well be the case in China. Thus, further evidence is necessary for a firm conclusion on the change in patent quality.

5.2. Implications for policy

Patent subsidy programs initiated by local governments have unambiguously given a great impetus to domestic patenting. They

Table 5
Number of invention patent grants issued by application and grant year.

Application year and number of applications		Grant year and number of grants									Grant ratio (%)
		2000	2001	2002	2003	2004	2005	2006	2007	2008	
1998	10975	52	212	311	410	121	15	14	9	5	10.5
1999	13183		75	451	826	418	43	47	16	33	14.5
2000	20698			120	1133	1092	253	191	90	50	14.2
2001	23259				364	1942	704	996	272	195	19.2
2002	32823				25	1701	1659	3441	1496	1148	28.9
2003	46638					215	1517	8443	4326	3124	37.8
2004	55573						92	8029	8998	6483	42.5
2005	75937							1048	10064	13412	32.3
2006	100024								1069	12832	13.9

Data source: The author's calculation from the patent database of China SIPO.

have also proved crucial in widening the patenting disparity across regions. The analysis and discussion presented above suggests important implications for policy makers to ensue.

First, appropriately designed patent subsidies are an effective policy instrument for stimulating patenting. By lowering the application cost and increasing the overall return of patenting, patenting subsidies amount to an offset to the weak protection of intellectual properties in developing countries. Following the same logic, the associated cost of patenting seems to be an important obstacle that inhibits some inventors from seeking patent protection. Since by now almost all provincial governments have launched patent subsidy programs, some critics argue that it is better for the central government to lower the various fees incurred while applying for patents. Evidence from this study implies that this might be a beneficial and feasible initiative.

Second, it is sensible to make a distinction between applicants when distributing subsidies, given that the impact of subsidies varies across different types of applicants. In effect, for innovating firms which have already been patenting aggressively and those who patent mainly for a strategic purpose, it is questionable whether or to what extent patent subsidies improve social welfare. By contrast, some patent applicants, such as small firms, are particularly vulnerable and sensitive to high costs in the course of applications. It may be worthwhile to give them preferential treatment when granting subsidies. As a matter of fact, the Chinese central government recently set up a special fund for subsidizing small and medium-sized enterprises that apply for patents in foreign countries,[21] taking an important step in this effort.

Third, as preliminary evidence on patent quality illustrates, the incentive provided by patent subsidies does not necessarily cause patenting bubbles, as long as the examination process remains unaffected by the increased number and complexity of patenting. This finding points to another important policy issue that is worth noting. As the number of patent applications surges, the increased workload and complexity of patenting may create a great challenge for patent examiners. It would be wise for patent offices to either increase the number of patent examiners or reorganize its process of dealing with applications. On the other hand, local governments can help maintain the quality of patent applications by appropriately designing the allocation scheme of patenting subsidies. Some provinces, such as Anhui and Hubei, grant patent subsidies after a patent right is issued. If only patentable inventions are encouraged in this way, there would be no reason to believe that patent subsidies would threaten the quality of applications.

5.3. Implications for research

Patent upsurge is not a unique phenomenon to China. Japan, the United States and Korea have all experienced a patenting surge in the past. Previous studies have proposed many hypotheses to explain the rapid growth of patenting. After a thorough examination, none of them was found to be compatible with the distinctive growth pattern of Chinese patenting. The alternative explanation presented in this study is in accordance with this pattern of patent growth. Empirical evidence shows that it is indeed a valid and essential factor underlying Chinese patenting growth. The analysis thus is an important complement to prior studies and largely enriches the research on patenting surge.

Under the analytical framework of innovation systems, institutions are regarded as a basic component for regulating innovation activities (Edquist, 2005; Lundvall, 1992). Since the launch of patent subsidies at the provincial level represents an important institutional change within the respective regional innovation systems, this study in effect makes a contribution to studies on regional innovation systems by demonstrating and confirming the relevance and importance of institutions as a system constituent.

The more pronounced impact of patent subsidies on LMEs and universities seems to imply that inventors who are proactive and intensive in regard to innovation are likely to benefit more from subsidies, because they have more technological inventions ready to be patented. No matter how much a patent is subsidized, no one is able to file an application without a development in new technology or knowledge. The question as to whether patent subsidies stimulate innovation is worth more attention and neglecting the effect on innovation will lead to an underestimation of their importance in bolstering patenting. Although it has been shown that patent subsidies result in an increase in patenting, it is still much less clear whether and to what extent they will encourage innovative activities. In this regard, patent subsidies share something in common with the changes in patent laws. As Hall (2007) once summarized, favorable changes in the legal environment such as lengthening the patent term, broadening patent scopes, and improving enforcement, stimulates an increase in patenting and encourages the use of patenting as a strategy tool by firms. This is to be expected, but it is not clear whether it will lead to an increase in innovation activities. Sakakibara and Branstetter (2001), for example, presented a case where expanding patent protection in Japan in 1988 did not significantly affect R&D activity in Japanese firms. Apparently, both patent subsidies and legal changes stimulate patenting, but do not necessarily lead to more innovations. Furthermore, besides giving an impetus to patenting, the subsidies may affect the direction of technological innovation. Moser (2005) showed that the adoption of patent laws redirects innovation activity toward inventions that are patentable and away from those that could be better protected by secrets. It is speculated that patent subsidies may have a similar effect, because patenting becomes easier and cheaper with subsidies. Therefore, future research should address the impact of patent subsidies on innovation activity and its changes together.

In terms of methodology, I not only estimate the long-term effect of patent subsidies in this study, but take into account their diffusion process as well. The methodology employed may provide a template for future research on other similar issues.

6. Conclusions

There has been a dramatic growth of patenting by Chinese inventors, roughly concurrent with an amendment to the patent law and China's accession to WTO. This confluence of events provides an unprecedented opportunity and a major challenge for innovation scholars to evaluate science and technology policy. Intrigued by such an upsurge of patenting, I embarked on an investigation and exploration of the underlying reasons that have propelled the rapid increase of Chinese patenting.

Taking the growth pattern of Chinese patenting as a reference point, I first examined several alternative hypotheses proposed in prior works that have been regarded as valid and convincing, such as the intensification of R&D investment, the pro-patent legal change, and the emergence of fertile technologies, among others. Although each may serve as a contributing factor, together they cannot satisfactorily explain why the upsurge encompasses different types of patentees, and different patent offices. Enlightened

[21] It was reported in People's Daily online on October 13, 2009. According to this program, each patentable invention will be subsidized in not more than five countries or regions with up to 100,000 RMB.

by the increasing disparity in patenting across different regions, I argue that an institutional change at the provincial level, the launch of patent subsidies programs, is one influential but unfortunately also neglected factor in the recent patent growth. This argument is supported and validated with empirical evidence based on a comprehensive dataset gleaned from multiple official sources. Moreover, the concern as to whether these subsidies will lead to a decline in patent quality is also addressed. Based on an examination of grant ratios, preliminary evidence shows that the fraction of patent applications that were finally approved has also been increasing since 1999. The increase of approvals implies that the sheer volume of patent applications does not necessarily cause a decline in patent quality, as long as the criteria used in the patent examination process remain unaffected.

This research contributes to at least two lines of research. On the one hand, it presents a novel and complementary explanation to the recent patent growth and enriches our understanding of factors that influence inventors' patenting behavior. On the other hand, it amounts to an annotation on the importance of institutions in regulating knowledge production and diffusion at the regional level, as the work in the strand of innovation systems always suggests.

Nevertheless, it should be noted that this study is not without limitations. In particular, I have not examined the impact of patent subsidy programs on patenting in foreign patent offices, especially USPTO and EPO. In addition, because of data limitations, no insight has been given concerning small firms, although both cases are very interesting. In fact, patent subsidy programs are only part of the initiatives that local governments have launched in order to stimulate residents and organizations to patent.[22] This neglect of other incentives will probably confound the estimated effect of patent subsidies. The diffusion model that has been used to contrast *PSP1* and *PSP2* in this analysis is simple and unconventional in effect, which may lead to a difficulty in interpretation. It is therefore advisable for readers to bear in mind these caveats in interpretation, and think of this study as an addition or a complement to previous understanding of the Chinese patenting explosion.

Finally, a couple of issues are particularly interesting and worthy of further exploration in future research. With detailed individual level data, one could employ difference in difference and/or matching methods to give an accurate estimation of the effect of patent subsidy programs. More importantly, how patent subsidies could encourage and stimulate R&D and innovation activity is a second interesting issue that should be on the research agenda of innovation scholars. It is hoped that this study could help other scholars advance our knowledge further in this field.

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Appendix A. Appendix

See Table A1.

[22] According to media coverage, for example, the municipal government of Shanghai stipulated later that a firm cannot be officially declared or designated as high-tech if it has no registered intellectual property rights. After being officially designated as being high-tech, the firm will be able to enjoy preferential tax exemption and preferential loan treatment from state-owned banks.

Table A1
Launching time of patent subsidy programs in each province.

Year	Provinces that introduced a patent subsidy program	Cumulative number of provinces with a patent subsidy program
1999	Shanghai	1
2000	Beijing, Tianjin, Guangdong, Jiangsu, Chongqing	6
2001	Zhejiang, Heilongjiang, Guangxi, Hainan, Sichuan, Shaanxi	12
2002	Fujian, Jiangxi, Henan, Guizhou, Neimenggu, Xinjiang	18
2003	Shanxi, Anhui, Shandong, Yunnan, Tibet,	23
2004	Jilin, Hunan	25
2005	Hebei, Qinghai	27
2006	Liaoning	28
2007	Ningxia	29

Data source: The author's collection from Annals of Chinese Intellectual Property Rights (2000–2008).

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