Losses from Trade: The Case of China's Pro-innovation Subsidy Program

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Abstract

With pro-innovation subsidy programs in selected sectors, gains from patent trade - emphasized in the existing literature - can be more than offset by trade-enabled losses in welfare. We study such welfare effects in the context of China's largest pro-innovation subsidy program (InnoCom). Patent trade creates two sources of efficiency loss: (a) firms not eligible for subsidy may produce low-quality patterns which they sell to subsidy-eligible firms, and (b) firms that are subsidy-eligible but low-value users of patents may buy them from high-value but subsidy-ineligible users. Our estimation suggests that the overall welfare effect of the program is likely to be negative, and the trade-enabled welfare losses are substantially greater than the direct loss from subsidy-eligible firms producing low-quality patents.

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1 Introduction

That trade improves welfare and that a positive externality can be corrected by a subsidy are two old and powerful ideas in economics. Applying them to intellectual property rights (IPRs), the existing literature has highlighted welfare improvement from trade in patent. In particular, when initial innovators and best users of a patent are not the same entities, patent trade can eliminate the initial mis-allocation of innovations (see Akcigit et al. (2016); Serrano (2010)). Separately, recognizing that offering a temporary monopoly through patent protection is not insufficient, most countries also provide a direct subsidy to innovation including tax deduction for patentable innovations. [1] In this paper, we study possible welfare losses enabled by patent trade in such innovation subsidy programs. We use data from the largest pro-innovation program in China, the InnoCom program, to quantify these effects.

When subsidizing patents, it is common to allow for acquired patents through patent trade to also qualify for subsidy as those developed in house. For example, the patent box policy in more than 10 countries do not distinguished purchased versus self-developed patents for the purpose of subsidy. A rational may be that the social value of a patent is in its commercialization, not innovation itself. If the same subsidy program can inspire more firms to engage in comercializable innovation, including firms that do not directly compete for subsidy, it is considered a desirable outcome of the program. The Chinese InnoCom program also allow subsidy-competing firms to use purchased patents the same way as self-developed patents.

We show that such feature may introduce additional welfare loss since bureaucrats usu-

[1] A type of subsidy with growing popularity is called "patent box", which is a term for the application of a lower corporate tax rate to the income derived from the ownership of patents. This instrument has been introduced by more than 50 countries since 2000. This tool is different with the widely used instrument: R&D tax credit. The latter one is an ex-ante incentive targeting a firm's innovation input, whereas the first one is ex-post and will only be used when innovation has been patented.

ally can only count patents but cannot differentiate quality. Importantly, allowing patents acquired through patent trade may amplify the welfare loss by spreading subsidy-induced production of low quality patents from subsidy-competing firms to a bigger set of firms.

It is generally hard for government officials to discern the true quality of an innovation. Subsidy programs targeting ex-post innovation outcome (i.e. patents) in practice are often conditional on some quantity indicators such as the number of patents a firm holds.[2] While subsidies based on bean counting can cause subsidy-eligible firms to produce low-quality patents, trade in patents may exacerbate the welfare loss by creating two more channels of efficiency losses. The first is production of low-quality patents by firms/individuals not eligible for pro-innovation subsidy, as long as they expect to be able to sell patents to subsidy-eligible firms. The second channel is an additional mis-allocation when a high social-value user of a patent that is not eligible for subsidy sells the patent to a subsidy-eligible but low social value user. We show in our sample that the trade-enabled welfare losses is very significant, and sometimes is even greater than the direct loss from low-quality patents produced by subsidy-eligible firms.

Our empirical assessment focuses on the Chinese InnoCom program, by far the biggest pro-innovation program in the country in terms of budgetary outlay.[3] Established in 2008, the program is meant to encourage production of intellectual property rights (IPRs) in eight designated industries that the government regards as "industries of future".[4] IPRs generally include patents and software copyrights in these industries. The bureaucrats use a grading

[2]For instance, since the patent box subsidizes revenues generated from patents, it may encourage firms to patent solely in order to receive subsidy. As Klemens (2016) points out, "The patent box gives new life to zombie patents".

[3]Figure 1 plots the central government's annual budgets of various Chinese pro-innovation policies in 2015. As we can see, the budget of InnoCom program dominates other pro-innovation programs.

[4]These eight industries are the pharmaceutical manufacture (CSIC 27), the special equipment manufacture (CSIC 36), the transportation equipment manufacture (CSIC 37), the communication equipment & computer manufacture (CSIC 40), the precision instrument manufacture (CSIC 41), computer service (CSIC 61), software service (CSIC 62) and environmental protection industry (CSIC 80).

system to decide which firms to subsidize. The more IPRs a firm holds (up to 6 IPRs), the greater the likelihood of receiving a subsidy. Once the IPR count reaches 6, additional IPRs would not increase the grade any more. Note that the bureaucrat does not distinguish between self-developed IPRs and externally purchased IPRs.[5] Hence the policy gives a strong incentive for firms to increase their IPRs up to 6, either through self-development or purchasing from others.

We are able to obtain several unique firm-level and patent-level data sets associated with the InnoCom program in a large city and will focus our empirical work on that city. We separate all IPRs (patents/software) holders into two groups: subsidy-competing-enterprises (SCEs), which satisfy the basic eligibility of the InnoCom program (such as having a sufficiently high ratio of R&D expenditure to total expenditure and within 8 designated industries), and non-competing-entities (NCEs), which are firms, individual innovators, or other institutions that are not eligible for the program (such as with a low ratio of R&D/total expenditure or outside the eight designated industries.).[6] For each type of enterprise, we construct their IPRs portfolio and merge it with their financial information (conditional on they are indeed firms). Within the IPRs portfolio, we know more information about patents than software copyrights, such as whether patents have been traded (including both buyer and seller information) or renewed. Since this data limit, we mainly focus on patents through out the paper.

We document six salient facts from the data. First, for firms competing for the InnoCom subsidy, there is an increase in the number of patents they hold (beyond a linear trend predicted from pre-2008 data). Importantly, the increase is especially great for those firms whose initial number of IPRs is fewer than six. Our main identification comes from a unique

[5]This policy design may be based on the bureaucrat's understanding that patent trade could solve an initial mis-match between the initial inventors and the best users of the patents.

[6]We call all IPRs holders as "firms". However, some NCEs are individuals or institutions.

feature of the program: since the InnoCom has a numerical kink in the evaluation scoring formula - the subsidy does not increase for firms with the IPR count going beyond six.

Second, the average quality of the patents held by subsidy-competing firms has declined following the InnoCom program. We use three different proxies for patent quality: 3-year out forward citation count, renewal decision by firms holding the patents, and the difference in profit between a firm holding with a patent and another one without patent after controling for other factors that affect profit. All three proxies yield the same result: a decline in patent quality after the InnoCom. Importantly, we also show the growth in patent count above the trend is entirely explained by a growth in low-quality patents. High-quality patents have declined relative to the trend.

Third, the InnoCom program has changed the patent trade pattern. After the launch of the program, the annual patent trade has increased by 18%. Patents sold by NCEs to the SCEs with an initially low IPR count has also risen as a proportion of all patent sales.

Fourth, the quality decline is the greatest for those patents developed by non-subsidy-competing firms sold to subsidy-competing firms. This confirms that the subsidy program has altered the incentives faced by firms not directly competing for the subsidy.

Fifth, an analysis of the proprietary data on bureaucrats' scores on InnoCom applicant firms reveals that the bureaucrats count the number of IPRs but cannot tell the difference in the quality of the innovations. That is, while a higher number of patents pushes up the firm score, a proxy for patent quality by their ex post citation count or ex post renewal rate does not predict a higher score. In addition, whether a patent is purchased or developed in house does not affect the score.

Lastly, as a key justification for the subsidy is possible knowledge spillover in the patent production, we estimate the size of the spillover. We find that a 1% increase in the number of patents in the same industry raises the industry-wide productivity by 0.01%. In other

words, the knowledge spillover is positive but modest.

Inspired by these six facts, we build an equilibrium model to quantify the welfare impact of the InnoCom program. There are three additional channels that the policy can affect the welfare, besides the knowledge spillover of more innovations. The first is a direct effect - the SCEs may develop more low-quality patents in order to qualify for subsidies. The second is a trade-induced spillover effect - InnoCom has encouraged NCEs to produce more low-quality patents that can be sold to SCEs to compete for InnoCom subsidies. The third is a trade-enabled mis-allocation effect - InnoCom may induce a socially inefficient trade that assigns a patent from a high-value NCE user to a low-value SCE user. Both the second and third welfare loss are induced by the patent trade.

Based on our calibration, we find that InnoCom has greatly increased low-quality patents in share of total patents. The aggregate welfare that the IPRs can create declines by more than 1.9 billion RMB per year, which is about 57% of the total subsidy in the InnoCom program. Our model also suggests that trade-enabled welfare loss is quantitatively important - contributing to 1/3 of the total welfare loss associated with the program.

In the last two decades, very few countries can rival China in terms of the rates of growth in patent count. Even though China's income per capita is still below the world average, its annual count of new patents, granted by domestic patent office, has exceeded all countries in the world since 2019.[7] Thus possible distortions from the the largest pro-innovation program, which is the focus of this paper, may have a significant aggregate implication.

Our paper contributes to three sets of literature. First, While the existing literature on patent trade focuses on its benefit, this paper highlights a potentially "dark" side of the trade. In the existing literature, patent trade improves welfare as it allows firms to specialize in what they are best at. For instance, Gans and Stern (2000) and Serrano (2010) point out

[7]https://www.reuters.com/article/us-usa-china-patents/in-a-first-china-knocks-u-s-from-top-spot-in-global-patent-race-idUSKBN21P1P9.

the gains from patent trade when different firms have a different ability to commercialise the patents. Galasso et al. (2013) show the potential of patent trade to resolve commercial disputes without resorting to courts. Since there are gains from trade, frictions in trade may reduce welfare. Shapiro (2010) and Lemley and Shapiro (2005) argue that the patents are reallocated to entities that have the capacity to extract excessive royalty fees by holding up rivals. Akcigit et al. (2016) and Serrano (2018) highlight search frictions in the patent trade market. In most cases, lower frictions in trade raise welfare. In our case, lower frictions in patent trade reduce welfare due to distortions in patent subsidy programs.

Second, the paper contributes to the literature on the design of pro-innovation subsidy programs. Bloom et al. (2019) reviews a menu of common policy incentives and argues that the efficiency of various policies are very different. Subsidies in the tax code is common, especially for R&D activities. Bloom et al. (2002) and Wilson (2009) study the impact of the tax credit on the level of R&D investment in US. A special feature of the InnoCom policy is that it targets the IPRs rather than the R&D expenditure directly. Interestingly, many EU countries use patent boxes (tax cut on revenue linked to a patent), which bears some resemblance to the InnoCom policy. Although different countries have various designs of patent boxes, the literature find that the policy provides a chance for firms manipulate stated revenues from patents to minimize their tax burden, hence may not be so efficient (Griffith et al. (2014); Gaessler et al. (2021)). Our paper shares a similar view: firms manipulate IPR count to maximize subsidies thus the InnoCom program creates distortions. Importantly, our paper suggests that the "idea market" may greatly amplify the welfare loss.[8]

Third, we enrich the literature on Chinese pro-innovation industrial policy by pointing

[8]Bösenberg and Egger (2017), Ciaramella (2017) and Gaessler et al. (2021) also examine the patent trade under the patent box. They find that the policy generally can stimulate the trade, although the effect varies across countries. And they do not directly link the efficiency of patent box to the patent trade.

out new channels of the welfare effects of the subsidy programs. Wei et al. (2017) emphasize a direct channel of welfare loss: while innovation come mostly from non-state-owned firms, the pro-innovation subsidies go mostly to state-owned firms. Chen et al. (2021) document the direct resource waste by firms competing for subsidies from re-relabelling non-innovation expenditures as R&D expenditure. König et al. (2020) study how frictions in input markets affect innovation. We add two new elements: the lack of ability to distinguish patents quality when subsidizing patent holders may generate welfare loss, and the patent trade market can amplify the loss.

Second,

The paper is organized as follows: Section 2 introduces the background of the InnoCom program and the data sets used in the paper. Section 3 provides documents four stylized facts on impacts of the InnoCom. The empirical patterns also motivate key assumptions used in our model that is laid out in Section 4. Using the calibrated result, Section 5 performs a number of counterfactual analyses. Finally, Section 6 concludes the paper.

2 Background and Data

2.1 The Chinese InnoCom Program

The InnoCom program, introduced by the Chinese government in January of 2008, is intended to encourage innovation. The program awards subsidies in the form of a substantial reduction in corporate income tax (from 25% to 15% for three years) to approved firms in "industries of future." Firms can apply for a new award once an existing one expires.

As a form of industrial policy, the program covers 8 industries (see footnote 2). Firms in these industries with high R&D intensities (which we call SCEs) can apply to the program.[9]

[9]Appendix A lists all the eligibility conditions to participate this program.

In determining which firms will receive an award, a government committee (an office jointly established by local tax department and local bureau of science and technology) evaluates SCEs by assigning numerical scores in four areas: a count IPRs (up 30 points) , an ability to manage R&D (30 points), an ability to commercialize science and technology innovations (20 points), and growth potential (20 points). A subsidy (tax reduction) is awarded to a firm if it receives at least 70 points. While the last three categories are subjectively assessed, the IPR count appears objective. Table 2 explains the grading scheme in this category. If the firm has 6 or more IPRs (one invention patent is considered equivalent to 6 utility or design patents), the firm will get an "A" in this category, and receive 24-30 points.[10] When the IPR count decreases, firms will be marked from letter grade "B" to letter grade "E". Within each letter grade, the point difference is up to 6. Note that an applicant firm would receive the full 30 points when its IPR count reaches 6. Any higher count would not improve its chance of receiving the subsidy. On the other hand, fewer than 6 IPRs can noticeably reduce its chance of receiving a subsidy. Because of the fear that SCEs use old and low-valued patents to apply for the subsidy, bureaucrat only counts IPRs granted within 3 years.

On average, the program each year provides a subsidy to over over 5,000 firms, about 60% of all SCEs, or 20% of all firms in the eight industries. The subsidy (tax reduction) is about 0.62 million RMB per firm-year, or 3.4 billion RMB in total per year.

We conjecture that bureaucrats are not able to tell the quality of IPRs. Some anecdotal evidence suggests that due to the InnoCom subsidy, a lot of agents start to sell service to help firms applying for IPRs. These agents advertises that they will prepare everything, including the ideas of IPRs and all related documents. It only takes a few months and the cost is as low as a few thousands RMB to get an IPR. Using the actual score of firms in the

[10]IPRs include patents and software copyrights. Among three types of patents in China (invention, utility and design), invention is considered most innovative and most difficult to obtain. For the purpose of InnoCom, an invention patent is equivalent to 6 non-invention patents or software copyrights.

InnoCom program, we will confirm that the bureaucrat does not give high quality IPRs a higher score in the next section. Moreover, we will also confirm that the bureaucrat does not value in-house IPRs more than purchased IPRs later.

Compare InnoCom program with patent box

It may be interesting to compare the Chinese innovation subsidy program with similar programs in other countries. The patent box, which becomes more and more popular around the world, shares a number of similarities. Rather than providing a subsidy based on an input into innovation, R&D expense, both attemtp to look at some outcome of innovation activities.

Firstly, the main purpose and challenge are similar. These policy instruments are generally intended to encourage firms to hold qualified patents, since they directly increase benefits of successful R&D investments (patents). However, lacking the ability to distinguish high quality innovations, both policies may be not efficient.[11] For the patent box, in principle, the bureaucrats can tell patents quality if they can separate revenues generated by patents with other revenues. However, in practice, firms have a large room to manipulate (Griffith et al. (2014)).

Moreover, similar with the InnoCom program, patent boxes in more than 10 countries allow purchased patents eligible for tax credits (Gaessler et al. (2021)). Such design in the patent box is to increase patents, especially high quality patents, in the local country.[12] We argue that if the bureaucrat cannot distinguish quality, allowing purchased patents may reduce the efficiency even further.

[11]Bloom et al. (2019) concludes that the patent box is the least effective tool to incentivize innovations.

[12]Bösenberg and Egger (2017) and Ciaramella (2017) find that a 1% increase in the tax rebate associated with the patent box could induce 10% increase in patent trade. But some countries require additional restriction on external patents (such as further development of patented invention). Within these countries, the effect of patent box on trade is not significant.

However, InnoCom program has several distinctive features. First, it has an explicit formula with a kink when counting IPRs. This feature greatly helps us for identifying the impact of the InnoCom program. Second, only new IPRs (granted within 3 years) are counted. So unlike the zombie patents phenomenon in the patent box, if patents are solely used for receiving subsidy, they will be discarded 3 years later. We can use renewal rates of patents 3 years after granted to measure the impact of the InnoCom program on patents quality. Finally, NCEs are excluded from the InnoCom program by nature. Hence a patent trade demand is induced between SCEs and NCEs, which can help us to study the welfare effect from the patent trade.

2.2 Data

We study the program in a large city (for which we have the requisite data). We utilize three data sets: administrative data about the firms from their tax records, patent assignment data and software assignment data. The first data records firm-year level financial information (such as sales, employees, assets and etc.) and the industrial classification of the firms. The second and third data record the ownership of patents and software copyrights and any transfer (i.e., assignment) of the ownership through trade. Using this information, we construct the IPRs portfolio for each firm in each year. Importantly, we know more information about each patent, including whether it is renewed or not, its citation count, and identities of the buyer and the seller if a patent is sold.[13] Unfortunately, we do not have similar information on trade in software.

We use firm names to link up firm-level records in different data sets. To clean and standardize firm names, we follow these steps: (1) We trim all special symbols and punctu-

[13]In China, the patent needs to pay a renewal fee every year before the invalidation date. The fee depends on patent age. Overall, it is about 1,000 RMB per year.

ation marks that are not letters, characters or numbers. (2) We remove various corporate form, such as "limited corporation" or "subsidiary". (3) We convert all full-width letters and numbers into half-width ones. (4) All lower cases are changed in to upper cases.

Using the firm names filtered by the above steps, we merge the IPRs assignment information with the list of the subsidized firms. The overall matching performance is good. In particular, we can find 94% of firms that receive an InnoCom subsidy in 2008 in the patent assignment data. This ratio is comparable to Hu and Jefferson (2009). In the end, we have 90,539 IPRs holders (including patent holders and software copyright holders) in the sample city from 2005 to 2012. In addition, if holders are firms, we have their financial information from 2007 to 2011.

We then separate the IPRs holders into two groups: subsidy-competing-enterprises (SCEs), which satisfy the basic eligibility of the InnoCom program, and non-competing-entities (NCEs), which are firms, individual innovators, or other institutions that are not eligible for the program. Overall, IPRs holders in our sample can be grouped as Figure 2.

The summary statistics of the data variables are shown in Table 2. In the first row, we report the average number of SCEs and NCEs per year before and after 2008. We can find that SCEs count slightly increases after 2008, but NCEs count is nearly doubled. In the next three rows, we report the IPR count (including patents and software copyrights), patent count and share of external patents (within the total patents) per SCE and NCE. Before 2008, neither a typical SCE nor a typical NCE had many IPRs. They typically have fewer than 1 IPR on average. After the the start of InnoCom in 2008, however, one can see a dramatic increase in the number of IPRs, especially for SCEs. An SCE has about 10 IPRs on average, compared to 4.2 IPRs by an NCE.[14] Similar with IPRs, both SCEs and

[14]The medians of IPR count are both 0 for SCEs and NCEs before 2008. However, after 2008, the medians for SCEs and NCEs change to 6 and 4, respectively.

NCEs hold more patents.[15] However, SCE's share of external patents increases from 11.05% to 22.27% after 2008, but this share declines for NCEs. In other words, SCEs' tend to rely more on external patents, comparing to NCEs.

In the following rows, we report summary statistics of patent value. Firstly, we report the firm profit difference between firms with and without patent.(We ignore all non-firms NCEs.) Before the InnoCom program, the profit of firms with patents are higher than firms without patents. The log profit difference is about 0.785 and 0.890 for SCEs and NCEs respectively. However, after the InnoCom program, the profit difference is much lower. The log profit of SCEs with patents is 0.376 higher than that of SCEs without patents. And the profit of NCEs with patents is even smaller than the profit of NCEs without patents. The profit difference here may be driven by an aggregate trend or the entry/exit of firms. So in the next row, we control the firm and year fixed effects, and re-compute the log profit difference between firms with and without patents. Before the InnoCom program, the profit of having at least 1 patent is about 12% or 29% higher for SCEs and NCEs respectively. But the profit difference is much smaller after 2008, only by 2.9% and 7.2% for SCEs and NCEs respectively.

Then we use the renewal rate to measure patent value. The renewal rate is defined as whether a patent still survives 3 years after its initial registration or previous renewal. Whether a firm is willing to pay a fee to renew a given a patent can be interpreted the firm's assessment of the value of that patent. We separate the in-house and external patents. Before 2008, about 89% and 97% of SCEs' in-house and external patents were renewed up to 3 years. In comparison, after 2008, renewal rates of these two types of patents drop to 57% and 75%. External patents usually have a higher renewal rate than in-house patents. This may come from a "selection" mechanism: only good patents can be traded if a positive

[15]The difference between IPR count and patent count is the software copyrights.

transaction cost exists. For NCEs, we find a similar pattern.

3 Six Key Data Patterns

In this section, we document a number of key facts related to the InnoCom program. They will guide our subsequent model development.

3.1 Patent Increase Is Stronger for Subsidy-competing Firms with a Low Initial IPR Count

Since the likelihood of receiving a subsidy is much higher for an SCE with 6 IPRs than one with fewer IPRs, but does not increase further once it reaches 6 IPRs, the policy may encourage firms that otherwise would have fewer than 6 IPRs to reach the count of 6. Figure 3 confirms this conjecture. The left graph of Figure 3 plots the density of the IPRs of those SCEs in 2007. The right graph of Figure 3 plots the density of these firms in 2008. As we can see, a notch point at 6 IPRs is clearly observed for 2008, the year when InnoCom was announced and implemented, but not in year 2007 when there was no InnoCom.

Is the change in IPR count distribution generated by InnoCom program, or other unobserved shocks? We then examine a causal relation between the InnoCom program and change of SCEs' IPR count. Denote Nit as the number of newly acquired IPRs by SCE i in year t. We run the following regression:

$$ln(N_{it}) = \alpha_1 D_{it-1} + \alpha_2 D(t \geq 2008) + \alpha_3 D_{it-1} \times D(t \geq 2008) + s_{it-1} + \mu_i + \epsilon_{it} \qquad (1)$$

where D_{it-1} is a dummy which equals to 1 if both the count of IPR in the prior year

$IPR_{it-1} < 6$ and $\text{Invention}_{it-1} = 0$, and 0 otherwise;[16] $D(t \geq 2008)$ is a dummy that equals to one in 2008 and afterwards, and zero otherwise; $s_{it-1} = 1$ if firm i has obtained a subsidy within the previous 3 years, and 0 otherwise; μ_i is a firm fixed effect, and ϵ_{it} is an iid normally distributed random error.

While α_1 captures any general time-invariant difference in the number of IPRs between the two types of SCEs, α_2 captures any general increase in the number of IPRs after 2008 caused by factors common to all SCEs. The key coefficient of interest is α_3, which measures the difference in the number of newly acquired IPRs between those SCEs that had fewer than 6 IPRs and other SCEs. If those SCEs that had fewer than 6 IPRs in the previous year have a stronger motivation to acquire more IPRs than the other SCEs already with 6 or more IPRs, we would expect $\alpha_0 > 0$.

An InnoCom subsidy is given to approved firms for three years. While applications for InnoCom subsidy are reviewed every year after 2008, those that have previously received a subsidy within three years would not need to apply again. We use s_{it-1} to account for possibly different incentives for such firms to increase IPRs.

In column 1 of Table 3, α_3 is 0.13. This means that the SCEs with fewer than 6 prior IPRS acquire 0.13% more IPRs than other SCEs. In the second column, we change the dependent variable to the number of newly self-developed patents.[17] We can see that these SCEs with fewer than 6 prior IPRs develop 0.04% more in-house innovation than other SCEs. As this number is smaller than α_3 in the first column, it implies that these SCEs also purchase more IPRs from patent trade market than other SCES.

In the third column, we switch back to IPR count. With the year fixed effects, all time-varying aggregate shocks that are common to all firms are controlled for, and D($t \geq 2008$) is

[16]In the following empirical analysis, without further notification, we convert 1 invention to 6 IPRs.

[17]Note that for software, we cannot distinguish in-house innovation and external purchase copyrights.

dropped as it is absorbed by the year fixed effects. Importantly, the estimate of α_3 becomes even larger: those SCEs with fewer than 6 IPRs still increase their IPRs by about 0.22% more than other SCEs.

To check whether the SCEs with exactly 6 IPRs and those with more than 6 IPRs are different, we add a regressor $D(IPR_{it-1} = 6) \times D(t \geq 2008)$ in the fourth column of Table 3. $D(IPR_{it-1} = 6)$ is a dummy, which equals to 1 if the firm i has just 6 IPRs in year $t-1$ and 0 otherwise. The new coefficient compares SCEs with 6 IPRs and SCEs with more than 6 IPRs. While the coefficient on the new regressor is not statistically different from zero, α_3 is the same as before. This provides further confirmation that many SCEs have a strong incentive to reach 6 IPRs to qualify for an InnoCom subsidy, but not beyond.

To see if there is a pre-trend in the observed pattern, we estimate separate α_3 for each year and plot them in Figure 4. The circle-solid line represents the point estimates when the dependent variable is ln(IPR count), and capped spikes represent 90% confidence intervals. Before 2008, α_3 is around 0, implying that the numbers of new IPRs between firms with more or lower than 6 IPRs are similar. However, α_3 begins to rise and becomes significantly greater than 0 since 2008. It means that SCEs with IPRs fewer than 6 starts to get more IPRs than other SCEs with 6 or more IPRs since 2008. This information is consistent with column 1 of Table 3.

Overall, α_3 gradually increases since 2008. This implies that incentives to get more IPRs for SCEs with lower than 6 IPRs become stronger over time. A possible explanation of the gradual increase could be the reaction time. Since firms have a short reaction time in 2008, they may not find enough IPRs to apply for the program. So the increase of IPRs at the beginning may not be as large as the increase in the later years.

To confirm our conjecture on "time of reaction", we again estimate α_3 year by year, but use ln(total patents) and ln(in-house patents) as dependent variables. Figure 5 plot α_3 of

these two specifications. The circle-solid line represents point estimates when the dependent variable is total patent count, and the red bar represents point estimates when the dependent variable is in-house patent count. Capped spikes again are 90% confidence intervals. For the total patent count, the pattern is very similar with the Figure 4: the new patent count is significantly higher of SCEs with IPRs lower than 6 after 2008. However, before 2008, the new patent count is not significantly different between these two groups of firms. This again confirms our previous result that the InnoCom encourages firms to hold 6 IPRs.

Interestingly, the in-house patents pattern is different. Overall, the new in-house patents are similar between the two groups of SCEs before 2008. However, in the year 2008, the in-house patent count of SCEs with IPRs lower than 6 is lower than SCEs with 6 or more IPRs. Then since 2009, SCEs with IPRs lower than 6 self develop more patents than other SCEs. In other words, consistent with our "reaction time" conjecture, SCEs in 2008 mainly rely on external patents to increase their IPRs to 6. Since 2009, they gradually catch up, and self develop patents as well.

3.2 Patent Quality Has Declined

We then study the impact of the InnoCom policy on the quality of IPRs. We start from the patents quality since we can observe their renewal rates.[18]. Especially, since the InnoCom program only counts young patents granted in 3 years, we conjecture that a lot of patents granted after 2008 will be discarded after 3 years. Figure 6 confirms this finding, in which we plot the average renewal rates 3 years after granted against the patents grant year from 2005 to 2012 (the renewal rates in 2004 is normalized to 0). We can see that before 2008, the 3 years renewal rate is similar with 2004. However, there is a jump in 2008. The renewal

[18]The idea of using patent renewal rate as a proxy for the value of patents is first explored by Pakes (1986). A large literature follows this idea (Cornelli and Schankerman (1999), Schankerman (1998), Lanjouw (1998), Schankerman (1998), Deng (2007) and Bessen (2008))

rate of patents granted in 2008 becomes significantly lower (-3%) than those granted before 2008. This difference becomes much more pronounced since 2009. On average, a patent granted after 2009 is 13% more likely to be discarded 3 years later than a patent granted before 2008.[19] The decrease from 2008 to 2009 may again reflect the "time of reaction".

A lot of other factors may drive down IPRs quality. We then establish a causal relation. First, instead of only focusing on patents, we try to measure the value of a new IPR as the change of firm profit if IPR count increases (including both in-house or external IPRs). Let i denote an SCE and consider the following regression:

$$\begin{aligned} \ln \text{Profit}_{it} &= \gamma_1 D(\text{New IPR}_{it} > 0) + \gamma_2 D(\text{New IPR}_{it} > 0) D(t \geq 2008) \\ &\quad + s_{it-1} + X_{it} + \mu_i + \mu_t + \epsilon_{it} \end{aligned} \tag{2}$$

where $\ln \text{Profit}_{it}$ is the SCE i's profit in year t. $D(\text{New IPR}_{it} > 0)$ is a dummy, which equals to 1 if the firm i gets a new IPR in year t, and 0 otherwise. Similarly, the dummy $D(t \geq 2008)$ indicates whether year t is after 2008 or not. s_{it-1} is the subsidy status in the last year, which is the same as (1). X_{it} is the firm's observed characteristics, including the total number of workers. μ_i and μ_t are firm and year fixed effects. Hence the coefficient γ_1 measures the change of firm profit after acquiring new IPRs before 2008. γ_2 is our focus, which is the relative difference of firm profit change when acquiring new IPRs before and after 2008. A negative γ_2 means that comparing to the pre-InnoCom period, the firm's profit relatively declines after getting new IPRs when the InnoCom program is implemented. Hence it suggests the quality of IPRs declines.

The first column of Table 4 presents the estimation result. We find that the profit declines by 0.2% ($\gamma_2 = -0.002$) upon acquiring an IPR ater 2008, comparing to the profit change

[19] With citation as the measure of patent quality, we find a similar relation.

before 2008. We also find that if the firm's number of employees increases by 1%, the profit would increase by 0.4%. Hence the value of IPRs declines after 2008.

Would this decline driven by the InnoCom program or other shocks in 2008? In the second column, we restrict our sample to firms which have less than 6 IPRs in the previous year ($D_{it-1} = 1$). The idea is that if the InnoCom subsidy results in IPRs value decline, we should see that this effect is more pronounced among firms with lower than 6 IPRs since they care less about the quality of new IPRs. Column 2 of Table 4 confirms this result. The profit would decline more intensive (0.3%) after 2008.

To strengthen our finding, we switch to evaluating the IPR value at more micro level directly. Since we know more information about the patent, we focus on the patent rather than the software copyrights. Using renewal rate as a firm's self-assessed value of a patent, we study the impact of InnoCom progam on patent quality.

Let indicator variable $V_{ikt} = 1$ to indicate that SCE i chooses to renew patent k in year t. If $V_{ikt} = 0$, then that patent is not renewed. We consider the following regression.

$$V_{ikt} = \beta_1 D_{it-1} + \beta_2 D(\text{OY}_{ik} \geq 2008) + \beta_3 D_{it-1} \times D(\text{OY}_{ik} \geq 2008) + s_{it-1} + X_{kt} + \mu_i + \mu_t + \epsilon_{ikt} \quad (3)$$

where OY_{ik} is the year that firm i obtains the patent k. (If the patent is developed in-house, then it is the year of receiving patent approval. If the patent is purchased from outside, it equals to the transaction year). $D(\text{OY}_{ik} \geq 2008)$ is a dummy, which equals to 1 if the patent k is obtained after 2008. D_{it-1} and s_{it-1} are defined in the same way as in equation (1). X_{kt} is a vector of observed characteristics of patent k, including patent's age, industry classification, and type (invention, utility or design). mu_i and mu_t are firm and year fixed effects, respectively. β_1 and β_2 measure the differences in the renewal rates between treatment group, those firms with fewer than 6 IPRs in the prior year ($D_{it-1} = 1$),

and the control group ($D_{it-1} = 0$), and before and after 2008, respectively.

The key coefficient of interest is β_3, which measures differential change in the renewal rate of the patents owned by the treatment group of firms after 2008, relative to the control group of firms. If additional IPRs are acquired for the purpose of competing for a subsidy, rather than for their intrinsic scientific value, then the new IPRs are likely to be of low quality and would not be worth the extra renewal cost once the InnoCom review process is over. This would imply $\beta_3 < 0$. On the other hand, if the bureaucrats reviewing the InnoCom applications can identify the true quality of patents and take it into account in deciding which firms to award a subsidy, or if firms acquiring IPRs for their true scientific value for any other reason, then there may not be a relative decline in the quality of the patents. In that case, we may see $\beta_3 = 0$.

In column 3 of Table 4, β_3= -0.029 and is significantly different from 0. In other words, the patents owned by the treatment group of firms are indeed less likely to be renewed after 2008 relative to those owned by the control group.

In column 4, we include additional fixed effects for years of obtaining the patent. This allows different vintage of patents to have different quality for reasons unrelated to the InnoCom program. In this case, β_3= -0.045 and is significantly different from zero at the 5 percent level. The quality difference in the patents acquired by the treatment and control groups becomes more pronounced. In other words, the reduced form evidence is consistent with the conjecture that those firms with fewer than 6 prior IPRs tend to acquire low-quality IPRs just to compete for a subsidy from the InnoCom program. Because many of these newly acquired patents do not have a high scientific or commercial value, firms often do not bother to pay a fee to renew them once the InnoCom application process is over.

These findings are consistent with Table 2, which suggests that IPRs/patents quality of SCEs decreases. although the total number of patents increases.

3.3 New Patent Trade Is Driven by NCEs Selling to SCEs

In the absence of patent trade, or if the purchased patent is not recognized in the InnoCom application process, then firms that do not satisfy the minimum eligibility conditions for a subsidy (NCEs) would not be affected by the pro-innovation policy. However, since patent can be traded, and the purchased patents can be used in SCEs' application for an InnoCom subsidy, the pro-innovation industrial policy can generate additional effects beyond a direct effect on the SCEs. Indeed, while the patent trade grew about 40% a year before 2008, the growth rate jumps to 76% a year after 2008.

To see the relative growth rates of patent trade of different seller-buyer types, we decompose the growth in patent trade further based on a seller and buyer's characteristics. Specifically, we separate the trade to 9 groups. Define a trade belongs to group 1 ($g = 1$) if both the buyer and seller are SCEs with fewer than 6 prior IPRs; Define a trade belongs to groups 2 or 3, if both the buyer and seller are SCEs with more than 6 IPRs, or both are NCEs, respectively. We define similarly groups 4 to 9 considering all possible combinations of the seller's and buyer's types.

$$\Delta Trade\% = \sum_{g} Tradesh_g \times \Delta Trade_g\% \tag{4}$$

where $\Delta Trade\%$ is the percentage increase of the total trade from 2007 to 2012. $Tradesh_g$ is the share of trade from group g in 2007, and $\Delta Trade_g\%$ is the percentage change of group g's trade.

The first panel of Table 5 reports the contribution of each source in the annualized trade growth after 2008 ($Tradesh_g \times \Delta Trade_g\%$). We can see that the trade increases about 76% per year (the sum of all numbers in the table). The trade from NCEs to NCEs increases about 20%. This increase may reflect the overall trend. We take it as the benchmark. Comparing

it with other types of trade, we can see that the SCEs with IPRs fewer than 6 purchase most patents (the contribution is about 41% (0.309/0.76)).[20] And these buyers usually purchase patents from either SCEs more than 6 IPRs or NCEs. Their purchase from SCEs with IPRs lower than 6 slightly decrease. Moreover, we can see that the purchase of SCEs with more than 6 IPRs do not increase too much. From the seller side, most trade increase comes from NCEs, and the sale from SCEs with IPRs fewer than 6 nearly do not change. These findings are consistent with incentives of the InnoCom program: the policy gives SCEs with IPRs fewer than 6 strong incentives to purchase patents externally, discourages them to sell patents. Meanwhile, NCEs's patents face an increasing demand to sell.

In the second panel of Table 5, we report the contribution of each source in the annualized trade growth before the policy. We can see that SCEs with IPRs fewer than 6 do not show a strong increase of purchasing patents. Comparing these two panels, we conclude that the InnoCom program changes the patent trade pattern. If a patent flows from a high value user to a low value user, it may induce efficiency loss.

3.4 Patents Sold by NCEs Exhibit the Biggest Quality Decline

Since NCEs can sell patents to SCEs, the InnoCom may change NCEs innovation decisions. We then consider the impacts of the policy on NCEs by estimating the following equation.

$$\begin{aligned} Y_{it} &= \theta_0 PSale_{it-1}^{SCE} \times D(t \geq 2008) + \theta_1 PSale_{it-1}^{NCE} \times D(t \geq 2008) + PSale_{it-1}^{SCE} + \\ &\quad PSale_{it-1}^{NCE} + \mu_i + \mu_t + \epsilon_{it} \end{aligned} \tag{5}$$

where i is an NCE. t is a year. Y_{it} is either the number of new generated IPRs (in log) in year t by firm i, or the quality of new generated patents in t, measured by the average

[20] IPRs are measured as IPRs counts one year before the transaction.

renewal rates of these patents in $t+3$.[21] μ_i and μ_t are firm and year fixed effects, respectively. $PSale_{it-1}^{SCE}$ and $PSale_{it-1}^{NCE}$ are the number of patents sold to SCEs. If an NCE can sell a lot of patents to SCEs in previous years, it is more likely to enjoy a larger demand shock due to the subsidy policy. The effect of the policy on such firm is more pronounced. So we expect θ_0 to be significant (positive if Y_{it} is the IPRs counts and negative if Y_{it} is the renewal rate).

In the above regression, we assume the likelihood that two firms can trade is a persistent characteristics of NCEs. To check this assumption, we estimate the time persistence of the share of patents sold to SCEs: $cor(\frac{PSale_{it-1}^{SCE}}{PSale_{it-1}^{SCE}+PSale_{it-1}^{NCE}}, \frac{PSale_{it}^{SCE}}{PSale_{it}^{SCE}+PSale_{it}^{NCE}})$.[22] We find that the auto correlation is about 0.71.[23]

We then present estimation results of equation (5). Column 1 and 2 of Table 6 represent results for new IPR count and renewal rate. As we can see, if an NCE can sell 1 more patent to SCEs in the last year, its new IPRs increases about 0.13% while the new IPRs' renewal rate declines by 0.07%. However, this pattern is not pronounced when it sells more patents to other NCEs. Hence NCEs generate more low quality IPRs to sell.

However, some other unobserved variables, which coincides with the timing of the Inno-Com policy, may change Y_{it} and the share of patents sold to SCEs at the same time. To address this concern, we define $PSale_{it-1}^{SCE,IPR<6}$ as the number of patents sold to SCEs with

[21] Since some NCEs are not firms, we do not use profit to measure the quality of IPRs. Although the choice of 3 years renewal rate is relatively arbitrary, the result is quite robust to other ways of renewal rate definitions.

[22] $PSale_{it}^{SCE} + PSale_{it}^{NCE}$ is the total patents that are sold by i in year t. So $\frac{PSale_{it}^{SCE}}{PSale_{it}^{SCE}+PSale_{it}^{NCE}}$ is the share of patents sold to SCEs within all patents sold.

[23] A possible reason driving the persistent trade share to SCEs could be that some NCEs are good at producing patents that firms within 8 InnoCom industries need. To confirm this conjecture, we then separate all NCEs to two groups: firms within 8 InnoCom industries (they have low R&D intensity) and firms out of 8 InnoCom industries. Consider an NCE i out of 8 InnoCom industries. If it is good at producing patents which 8 InnoCom industries need, we expect to see it not only sells more patents to SCEs but also NCEs within 8 InnoCom industries. Define $PSale_{it}^{NCE,InnoInd}$ as the patent counts that an NCE i (out of InnoCom industries) sells to other NCEs within 8 InnoCom industries. We find that the correlation between the share of NCE i sells to SCEs, $\frac{PSale_{it}^{SCE}}{PSale_{it}^{SCE}+PSale_{it}^{NCE}}$, and the share of NCE i sells to other NCEs within InnoCom industries, $\frac{PSale_{it}^{NCE,InnoInd}}{PSale_{it}^{SCE}+PSale_{it}^{NCE}}$, is as high as 0.65. Thus the persistency of the share of patents sold to SCEs could be a firm feature.

IPRs fewer than 6. Due to the InnoCom policy, these SCEs are firms that needs IPRs most. Then we compare whether an NCE which sells more patents to these SCEs is more likely to generate low quality IPRs. Column 3 and 4 of Table 6 represent the results. When an NCE can sell 1 more patent to SCEs in the last year, its new IPRs increases about 0.14% while the new IPRs' renewal rate declines by 0.08%. However, coefficients before $PSale_{it-1}^{SCE}$ are not significant any more. In other words, the pattern that NCEs generate more low quality IPRs is driven by the InnoCom policy shock.

Lastly, Chen et al. (2021) show that some NCEs may manipulate their R&D expenditures to pretend to be SCEs. This may bias our estimates of θ_0 since we take NCEs and SCEs as given. In column 5 and 6, we restrict NCEs to individuals and institutions (rather than firms), which is impossible to be subsidized. So they will never pretend to be SCEs. Comparing to column 1 and 2, we can see that coefficients are very similar. Thus we conclude that our finding is quite robust even considering this possibility.

3.5 Bureaucrats Can Count But Cannot Differentiate Quality

For the 2008 subsidized firms, we have the detailed evaluation scores made by the bureaucrats. We conjecture that bureaucrats are not able to tell the quality of patents. We validate this conjecture by examining whether bureaucrats give more points in their review of InnoCom applications for high quality IPRs for a given count of IPRs. We use two different proxies for patents: the subsequent 3 years forward citation count and the renewal rate in 3 years after granted. Both these information are obviously not available to the bureaucrats at the time of reviewing a firm's application for an InnoCom subsidy. If the bureaucrats are able to make an informed judgement about the quality of the patents, they would pick up something that will be correlated with the subsequent forward citation count of the patent. In that case, they might assign a higher score to firms with more high-quality patents. On

the other hand, if bureaucrats are unable to tell the quality of the patents, then their scores assigned to an applicant firm would be uncorrelated with the average quality of the patents in the firm's IPR portfolio.

We regress the points an applicant firm receives on the objective quality proxy of the IPRs portfolio, controlling the firm's observed characteristics (sales in 2007, ownership and industry) and beans of IPR count.[24] Table 7 shows the result. Each observation is a firm that successfully obtains the subsidy in 2008. In column 1, where the left hand side is the firm's point in the IPRs counts category (out of 30). After controlling the letter grade of the IPR count (in terms of the IPR count up to 6, and whether the firm has invention or not), we can see that high cited IPRs do not significantly increase the points in the IPR category. The second column uses firm's total points (the sum of points across four categories) as the dependent variable. As we can see, the bureaucrats do not give more points for firms holding high quality IPRs. In other words, the chance to be subsidized does not significantly increase for firms holding high quality IPRs.

In columns 3 and 4, we do a similar exercise, but measure the IPRs portfolio quality by the renewal rates of patents three years after receiving them. We find similar results. That is, bureaucrats do not systematically assign a higher score to firms with patents that will have a higher renewal rate three years later.

In all regressions, we control for the share of in-house IPRs. As this variable is never significant, we conclude that the bureaucrat does not distinguish between in-house and external purchased IPRs. This validates our understanding of the InnoCom qualification methodology that counts the IPRs an applicant firm owns, regardless of where they come from.

[24]The data is collected by the Municipal Science & Technology Commission of that city. It includes the grading information of the four categories, as well as other firm characteristics.

3.6 Knowledge Spillover Is Positive But Modest

The main motivation of the InnoCom program is to encourage more innovations, hence may increase the aggregate productivity through the knowledge externality. To gauge the welfare effect of the InnoCom program, we need to know to what extent the knowledge externality depends on the quality and quantity of patents. We estimate the knowledge externality as follows.

Let i and j denote two industries. Denote N_{it} as the total patents in industry i, and r_{it} as the average renewal rate (survival rate of patents three years after granted) of the industry i. Define K_{it} as the measure of total patents with which industry i interacts in the aggregate productivity. We call K_{it} as the "knowledge capital" facing by i. Specifically, we distinguish the knowledge capital from the same sector K_{it}^{within}, and from other sectors K_{it}^{other},

$$K_{it}^{within} = d_{ii} N_{it} r_{it},\ K_{it}^{other} = \sum_{j \neq i} d_{ij} N_{jt} r_{jt} \tag{6}$$

where d_{ij} is the knowledge distance between industry i and j, which is measured as the share of patent citations between industry i and j within all patent citations. The above functions imply that high quality patents (high renewal rates) contribute more to the knowledge capital. Meanwhile, the knowledge externality is greater between two industries that cite each other more frequently.

Consider a firm f in industry i_f. We then estimate the following equation

$$\ln \pi_{ft} = \eta_1 \ln K_{i_f,t}^{within} + \eta_2 \ln K_{i_f,t}^{other} + \mu_f + \mu_t + error \tag{7}$$

where π_{ft} is firm f's labor productivity (profit/workers),[25] $K_{i_f,t}^{within}$ and $K_{i_f,t}^{other}$ are the knowl-

[25] Our result is robust to different productivity definitions.

edge capital facing by firm f, and μ_f and μ_t are the firm and time fixed effects. η_1 and η_2 measure the knowledge externality from the same sector and other sectors.

Firm f's own innovation may change K. So we only focus on firms without any patents. To exclude the impact of InnoCom program, we focus on 2000-2007, a sample one year before the InnoCom program.[26]

Some unobserved shocks may affect π_{ft} and industry level innovations at the same time. So we instrument $K_{i_f,t}^{within}$ and $K_{i_f,t}^{other}$ as

$$IV_{it}^{within} = d_{ii}\frac{Patent_{i0}}{TotPatent_0}S_t,\ IV_{it}^{other} = \sum_{j\neq i} d_{ij}\frac{Patent_{j0}}{TotPatent_0}S_t \tag{8}$$

where $Patent_{i0}$ is the patent counts of industry i in 1998, and $TotPatent_0$ is the total patent counts in 1998. S_t is the total subsidy to innovations from Chinese central government. The assumption is that the total innovation subsidy changes patent counts in different industries proportional to the initial patent share across industries. Meanwhile, the total subsidy does not directly change the productivity of firms without any patents.

Table 8 reports the estimation results of η.[27] In the first column, the OLS estimates suggest that when the industry's total patents increase by 1%, the labor productivity of a firm without patents increases by 0.052%. However, if other industry's patents increase by 1%, the firm's labor productivity drops by 0.102%. In the second column, we instrument K and find that η_1 decreases to 0.01, which means that the knowledge externality within the same sector is very small. Meanwhile, the knowledge externality across sectors is slightly negative (-0.012), although not significantly away from 0.[28]

[26]We use Annual Survey of Chinese Manufacture Enterprises dataset since this data covers firms financial information up to 2009. However, in the tax records administrative data, the observation starts from 2007.

[27]In Table 8, we use new patents in year t to measure K_{it}. However, all results are robust when we use the cumulative patents to measure K_{it}.

[28]In the first stage, we find the F statistics is over 2,000.

In the third column, we change the definitions of K by simply counting patent numbers without adjusted by renewal rates. Comparing to column 2, both η_1 and η_2 decrease, and the knowledge externality within the sector becomes not significant. This result suggests that the productivity benefits more from other firms' high quality patents.

Are the knowledge externality in InnoCom industries different from other industries? This question is important when we discuss the welfare of the InnoCom program. In the fourth column, we allow η to be different for InnoCom industries, by introducing a dummy D which indicates whether the industry is targeted by the InnoCom program. The coefficient before $K^{within} \times D_{InnoCom}$ and $K^{other} \times D_{InnoCom}$ reflect the difference of η_1 and η_2 between InnoCom industries and other industries. As we see, we do not detect any significant difference.

Since the patent quality declines after the InnoCom program was implemented, will η of InnoCom industries decrease after 2008? We then restrict the sample to 2008-2009, and estimate a similar equation as column 4. The result is shown in column 5 of Table 8. Comparing with column 4, in terms of non-InnoCom industries, the knowledge externality within the sector is barely unchanged (0.015), and the knowledge externality across sectors decreases but still not significant away from 0. However, the knowledge externality of InnoCom industries decrease both for $\ln K^{within}$ and $\ln K^{others}$, although they are not significant. One reason for any insignificant decline may be that we adjust patent count by renewal rates, which may have captured patents quality decline.

So we conjecture that if K is not adjusted by renewal rates, the externality of InnoCom industries would drop significantly after 2008. In column 6 and 7, we estimate equations similar as column 4 and 5, but do not adjust K by renewal rates. (The sample is before 2008 in column 6, and after 2008 in column 7.) First, comparing column 6 to 4, η_1 slightly declines, which may suggest that high quality patents contribute more to the within sector knowledge externality. Second, we again do not detect a significant difference in η between InnoCom

industries and other industries before the InnoCom subsidy. After 2008, the externality of other sectors are barely not changed (comparing column 7 and 6), but the within sector externality of InnoCom industries significantly decreases. Overall, column 7 suggests that if the patent count increases by 1% in the InnoCom industry after 2008, the labor productivity of other firms in the same industry without patents would decline by 0.004% (0.011-0.015). This result confirms our conjecture: InnoCom program pushes down the patents quality, hence more patents (without adjusting the quality) do not contribute too much to other firms' productivity.

To sum up, a small but positive knowledge externality exists within the sector, but we do not find any significant knowledge externality across sectors. With US data, Lucking et al. (2019) use R&D expenditure to measure K and find that η from 0 to 0.2. Our estimates are significant smaller than theirs. These may be either because the knowledge externality within China is smaller or because we measure K by patent counts. After an innovation is patented, the knowledge spillover would decrease due to the patent protection.

4 Model

We model the market equilibrium under the InnoCom program. Firms first try to develop patentable innovations, and patents trade may take place afterwards.[29] The subsidy policy, which counts the number of patents but does not adjust for quality, affects the aggregate welfare by altering the decisions on patent production and trade. We lay out a model that aims to capture the salient features of the InnoCom program. We calibrate the model to quantify the relative importance of various channels through the program affects the welfare.

[29]We focus on patents and leave out softwares because we do not have data on ownership changes or trading in softwares.

4.1 Environment

Three types of firms are in the economy: SCEs, NCEs in 8 targeted InnoCom industries, and NCEs out of InnoCom industries (including individual innovators and institutions). We denote variables associated with three types of firms with subscripts S, $N(f)$ and $N(i)$. We use subscript N to denote both two types of NCEs (i.e. $N \in \{N(f), N(i)\}$). We normalize the measure of the SCEs to be 1 and denote β and m as measures of $N(f)$ and $N(i)$ respectively. Without loss of generality, we assume that an SCE may receive a subsidy from the InnoCom program if it owns a patent.[30] The measure of NCEs out of InnoCom industries, m, will be endogenously determined. These three types of firms are heterogeneous in terms of their profits $\pi \in \{\pi_S, \pi_{N(f)}, \pi_{N(i)}\}$. Each firm can hold at most 1 patent. Patents can differ by quality, denoted by x.

The model has three stages. In the first stage, each firm tries to develop a patentable innovation in-house. It chooses the success rate of innovation θ (with probability θ the firm will have a patent), and targets a patent quality distribution distribution $G(x;\lambda)$. We assume that G is a Bernoulli distribution: $x = x_H$ with probability λ; $x = x_L$ with probability $1-\lambda$; and $x_H > x_L$. Parameter λ governs the likelihood that an innovation is of high quality, and is assumed to be a choice variable for a firm. The innovation cost $C(\lambda, \theta)$, is increasing and convex in both λ and θ, and $C_{\lambda\theta} > 0$. The last inequality suggests that the marginal cost of increasing θ is higher for high quality patents. The innovation cost could be different between SCEs and NCEs, denoted by C_S and C_N, respectively.[31] This assumption captures the possibility that the minimum eligibility requirements of the InnoCom program distinguishes firms' innovation abilities. At the end of the first stage, some firms fail to achieve a patentable invention on their own.

[30] This means we condense the 6-patent requirement under InnoCom to one patent (such as an invention patent) in the model.

[31] For simplicity, we do not distinguish the innovation costs between two NCEs.

In the second stage, a market in patent trade opens. All NCEs with patents enter the market as sellers, and those SCEs without a patent enter the market as buyers.[32] They will randomly meet with each other with a transaction cost of $\sigma \geq 0$. If the joint surplus of the trade (after considering the transaction cost) is positive, a trade will take place.

In the last stage, those SCEs with a patent (regardless of the quality) will be subsidized with probability ρ. The subsidy is $T\pi_S$, where T is the subsidy rate (tax cut) of the InnoCom program. After receiving the subsidy, firms decide whether to renew patents at cost $c + \varepsilon$, where c is a constant which captures the common renewal cost of all patent holders. ε is an unobserved individual shock, which follows a normal distribution with mean 0 and standard deviation Ω_ε.

For a firm within InnoCom industries (S and $N(f)$), its profit, $\pi \in \{\pi_S, \pi_{N(f)}\}$, equals to Az, where z is the individual firm productivity $z \in \{z_S, z_{N(f)}\}$ and A is the endogenous aggregate productivity of the InnoCom industries, which depends on the total innovation in the economy. However, any individual firm takes A as given. That is, A captures the positive externality of innovation. Explicitly, we assume $A = A_0 K^\eta$, where A_0 is a constant, K is the aggregate knowledge capital, which will be explained later. $\eta \geq 0$ is the parameter of the knowledge spillover. An active patent x can bring in an additional profit, πx, to the patent holder.

Inspired by our empirical findings in Table 8, we assume that other NCEs cannot enjoy the knowledge spillover from targeted industries. Their profit is $\pi_{N(i)} = z_{N(i)}x$ with an active patent, but 0 without an active patent. If this NCE is a non-firm entity, $\pi_{N(i)}$ can be interpreted as the utility of holding a patent.

The timing of the model is summarized in Figure 7.

[32]Motivated by the previous empirical findings, we assume NCEs will not buy patents from SCEs. Meanwhile, since SCEs are homogeneous, and can hold 1 patent at most. An SCE will not trade with another SCE in the model.

4.1.1 Production

We perform backward induction starting from the last stage. The value of a patent with quality x holding by firm with profit π is

$$V(\pi, x) = E_\varepsilon (\pi x - \varepsilon - c)^+, \quad \pi \in \{\pi_S, \pi_{N(f)}, \pi_{N(i)}\} \tag{9}$$

where $(.)^+$ equals to 0 if the value in the bracket is negative. E_ε means the expectation is taken over ε. Equation (9) implies a cutoff for the patent renewal decision: if the patent quality is bad enough, the firm will not renew the patent and the extra benefit from the patent is 0. Hence the renewal probability is $\Phi(\frac{Azx-c}{\Omega_\varepsilon})$, where Φ is the CDF of a standard normal distribution.

With probability ρ, the SCE with a patent can receive subsidy. ($\rho = 0$ before InnoCom is implement.) If an SCE has a patent, its total expected value (patent value + profit from other business+subsidy), is $V(\pi_S, x) + \pi_S + \rho T \pi_S$. Without a patent, the firm's total value is simply π_S.

For NCEs within targeted industries, they do not have chance to be subsidized. The firm value with and without patent is $V\left(\pi_{N(f)}, x\right) + \pi_{N(f)}$ and $\pi_{N(f)}$. Notice that all firms in the InnoCom industries can benefit from innovations of other firms in the same sector through aggregate productivity A.

Finally, for other NCEs, the firm value is $V\left(\pi_{N(i)}, x\right)$ with a patent, and 0 without a patent. They do not enjoy the knowledge spillover from targeted industries.

4.1.2 Patent Trade

In the patent trading market, an SCE and an NCE are randomly matched. The measure of SCEs without a patent (buyers) is $1 - \theta_S$, where θ_S is the self-innovation success rate of

SCEs. Similarly, the measure of NCEs with a patent is $\beta\theta_{N(f)} + m\theta_{N(i)}$, where $\theta_{N(f)}$ and $\theta_{N(i)}$ are success innovation rates of NCEs. The buyer-seller ratio is

$$\delta = \frac{1 - \theta_S}{\beta\theta_{N(f)} + m\theta_{N(i)}} \tag{10}$$

Denote an SCE meets an NCE with probability $q_S(\delta)$ and an NCE meets an SCE with probability $q_N(\delta)$, where $q_S' < 0$ and $q_N' > 0$. Hence an SCE will randomly meet two types of NCEs.

When an SCE (buyer) meets an NCE with patent quality x and profit $\pi_N \in \{\pi_{N(f)}, \pi_{N(i)}\}$, the trade surplus is

$$S(\pi_S, \pi_N, x) = V(\pi_S, x) + \rho T\pi_S - V(\pi_N, x) - \sigma \tag{11}$$

where σ is the random transaction cost, which is drawn from an exponential distribution with mean ϕ. We denote the CDF of σ as $F(\sigma)$. The trade will happen if $S(\pi_S, \pi_N, x) \geq 0$. An efficient is defined as the case $V(\pi_S, x) - V(\pi_N, x) > \sigma$. That is a trade that can really improve the value of the patent without any subsidy. When $\rho > 0$, some inefficient trade (a trade to increase the chance to be subsidized, though the patent value declines) will happen.

The expected joint surplus is denoted as

$$S^+(\pi_S, \pi_N, x) = \int [V(\pi_S, x) + \rho T\pi_S - V(\pi_N, x) - \sigma]^+ dF(\sigma)$$

where $(.)^+$ indicates that the trade will happen iff $S(\pi_S, \pi_N, x) \geq 0$.

If the trade does not happen, the value of NCE and SCE is $V(\pi_N, x) + \pi_N$ and π_S. After trade, we assume that $S^+(\pi_S, \pi_N, x)$ is split equally between the buyer and the seller. Hence upon their meeting, the expected value of NCE and SCE would both increase by

$\frac{1}{2}S^{+}(\pi_S, \pi_N, x)$.

4.1.3 Innovation stage

Firms are assumed to try to develop a patentable innovation in house before considering acquiring a patent externally. Consider the optimization problem for an SCE. It chooses quality of innovation λ_S and probability of innovation success θ_S to maximize its expected value w_S,[33]

$$w_S = \max_{\lambda_S, \theta_S} \theta_S \int V(\pi_S, x)\, dG(x; \lambda_S) + \theta_S \rho T \pi_S + (1 - \theta_S) TV_S + \pi_S - C_S(\lambda_S, \theta_S) \qquad (12)$$

where TV_S is the value of purchasing patents for SCEs.

$$\begin{aligned} TV_S &= q_S \frac{\beta\theta_{N(f)}}{\beta\theta_{N(f)} + m\theta_{N(i)}} \int \frac{1}{2} S^{+}\left(\pi_S, \pi_{N(f)}, x\right) dG\left(x; \lambda_{N(f)}\right) + \\ & \quad q_S \frac{m\theta_{N(i)}}{\beta\theta_{N(f)} + m\theta_{N(i)}} \int \frac{1}{2} S^{+}\left(\pi_S, \pi_{N(i)}, x\right) dG\left(x; \lambda_{N(i)}\right) \end{aligned}$$

The explanation of equation (12) is as follows. The first four terms are the value of having a patent. With probability θ_S, the SCE achieves a patent by itself. The quality of patent is drawn from distribution $G(x; \lambda_S)$. So the expected firm production value is $\int S^{+}(\pi_S, \pi_N, x)\, dG(x; \lambda_S)$ (the first term). Meanwhile, with probability ρ, the firm will be subsidized by $T\pi_S$ (the second term). The next term is the value if it purchases a patent externally: with probability $1 - \theta_S$, the SCE does not have an in-house patent and needs to purchase it. With probability $q_S \frac{\beta\theta_{N(f)}}{\beta\theta_{N(f)} + m\theta_{N(i)}}$, it will meet an NCE $N(f)$, whose patent quality x is drawn from distribution $G\left(x; \lambda_{N(f)}\right)$. With probability $q_S \frac{m\theta_{N(i)}}{\beta\theta_{N(f)} + m\theta_{N(i)}}$, it will meet an NCE $N(i)$. The patent quality follows a distribution $G\left(x; \lambda_{N(i)}\right)$. The fourth term

[33] We abuse the notation a little here. Although x follows a Bernoulli distribution, we still use integration over the density $G(x; \lambda)$ when we define values.

is SCE's profit π_S from other source which is not affected by the patent renewal decision. The last term, C_S, is the innovation cost of an SCE.

For a representative NCE in targeted industries, it chooses quality of innovation $\lambda_{N(f)}$ and probability of success $\theta_{N(f)}$ to maximize its expected value $w_{N(f)}$.

$$\begin{aligned} w_{N(f)} &= \max_{\lambda_{N(f)},\theta_{N(f)}} \theta_{N(f)} \left[\int V\left(\pi_{N(f)}, x\right) dG\left(x; \lambda_{N(f)}\right) + q_N \int \frac{1}{2} S^{+}\left(\pi_S, \pi_{N(f)}, x\right) dG\left(x; \lambda_{N(f)}\right) \right] \\ &\quad + \pi_{N(f)} - C_N\left(\lambda_{N(f)}, \theta_{N(f)}\right) \end{aligned} \tag{13}$$

With probability $\theta_{N(f)}$, the NCE has a patent. In this case, it can always guarantee to get $\int V\left(\pi_{N(f)}, x\right) dG\left(x; \lambda_{N(f)}\right)$. Moreover, with probability q_N, the NCE meets an SCE. In this case, the NCE receives an extra value from trade $\int \frac{1}{2} S^{+}\left(\pi_S, \pi_{N(f)}, x\right) dG\left(x; \lambda_{N(f)}\right)$.[34] The third term is NCE's profit without a patent and the last term is its innovation cost.

For $N(i)$ firm, its problem is similar with equation (13) except that without a patent, its profit is 0.

$$\begin{aligned} w_{N(i)} &= \max_{\lambda_{N(i)},\theta_{N(i)}} \theta_{N(i)} \left[\int V\left(\pi_{N(i)}, x\right) dG\left(x; \lambda_{N(i)}\right) + q_N \int \frac{1}{2} S^{+}\left(\pi_S, \pi_{N(i)}, x\right) dG\left(x; \lambda_{N(i)}\right) \right] \\ &\quad - C_N\left(\lambda_{N(i)}, \theta_{N(i)}\right) \end{aligned} \tag{14}$$

[34] Our model assumes that the NCEs innovate new patents and then sell to SCEs. A natural question could be that NCEs may directly sell old low value patents to SCEs without making any new innovations. However, in the data, we find that over 80% purchased patents are innovated within 3 years. We have tried to only use traded patents that are innovated within 3 years in the calibration. The results are similar.

4.2 The Equilibrium

We define some useful aggregate variables first. In the last stage, the measure of SCEs with patent x is

$$\begin{aligned} p_S(x) &= \theta_S g(x;\lambda_S) + (1-\theta_S) q_S \frac{\beta\theta_{N(f)}}{\beta\theta_{N(f)} + m\theta_{N(i)}} g\left(x;\lambda_{N(f)}\right) F\left(V(\pi_S,x) + \rho T\pi_S - V\left(\pi_{N(f)},x\right)\right) \\ &\quad + (1-\theta_S) q_S \frac{m\theta_{N(i)}}{\beta\theta_{N(f)} + m\theta_{N(i)}} g\left(x;\lambda_{N(i)}\right) F\left(V(\pi_S,x) + \rho T\pi_S - V\left(\pi_{N(i)},x\right)\right) \end{aligned} \tag{15}$$

where g is the density function of the quality distribution G. The first term is the measure of firms with in-house inventions x. The second and third terms are the measure of firms which purchase patents with quality x. With probability $q_S \frac{\beta\theta_{N(f)}}{\beta\theta_{N(f)}+m\theta_{N(i)}}$(or $q_S \frac{m\theta_{N(i)}}{\beta\theta_{N(f)}+m\theta_{N(i)}}$), an SCE without a patent meets an NCE $N(f)$(or $N(i)$) with patent quality x. Depending on the realization of the transaction cost, the trade happens with probability $F\left(V(\pi_S,x) + \rho T\pi_S - V\left(\pi_{N(f)},x\right)\right)$ (or $F\left(V(\pi_S,x) + \rho T\pi_S - V\left(\pi_{N(i)},x\right)\right)$).

The measure of NCEs in InnoCom industries with a patent x in the last stage is

$$p_{N(f)}(x) = \beta\theta_{N(f)} g\left(x;\lambda_{N(f)}\right)\left[1 - q_N F\left(V(\pi_S,x) + \rho T\pi_S - V\left(\pi_{N(f)},x\right)\right)\right] \tag{16}$$

where the term out of the bracket is the measure of $N(f)$ which innovate patents with quality x, and the term in the bracket is the probability that the patent x can not be sold either because sellers do not meet buyers or the transaction cost is too high.

Similarly, the measure of NCEs out targeted industries is

$$p_{N(i)}(x) = m\theta_{N(i)} g\left(x;\lambda_{N(i)}\right)\left[1 - q_N F\left(V(\pi_S,x) + \rho T\pi_S - V\left(\pi_{N(i)},x\right)\right)\right] \tag{17}$$

So for SCEs, the number of in-house patents is θ_S and the number of external purchased

patents is $\int \left(p_S\left(x\right) - \theta_S g\left(x;\lambda_S\right)\right) dx$. For NCEs, the number of patents is $\int p_{N(f)}\left(x\right) dx + \int p_{N(i)}\left(x\right) dx$.

For SCEs, the renewal rate (including both in-house and external patents) is

$$R_S = \frac{\int \Phi\left(\frac{\pi_S x - c}{\Omega_\varepsilon}\right) p_S\left(x\right) dx}{\int p_S\left(x\right) dx} \tag{18}$$

where $\Phi\left(\frac{Azx-c}{\Omega_\varepsilon}\right)$ is the probability that the SCE with productivity z will renew patent x.

We can further define the renewal rate of SCEs' self-developed patents as

$$R_S^{self-dev} = \frac{\int \Phi\left(\frac{\pi_S x - c}{\Omega_\varepsilon}\right) \theta_S g\left(x;\lambda_S\right) dx}{\int \theta_S g\left(x;\lambda_S\right) dx} \tag{19}$$

where $\theta_S g\left(x;\lambda_S\right)$ is the measure of self-developed patents with quality x.

Similarly, the renewal rate for NCEs is

$$R_N = \frac{\int \Phi\left(\frac{\pi_N x - c}{\Omega_\varepsilon}\right) p_N\left(x\right) dx}{\int p_N\left(x\right) dx}, \quad N \in \left\{N\left(f\right), N\left(i\right)\right\} \tag{20}$$

We now define the equilibrium. To allow for the possibility that innovation can increase knowledge spillover and improve the aggregate productivity, we define the aggregate knowledge capital as

$$K = \int x\left(\theta_S g\left(x;\lambda_S\right) + \beta\theta_{N(f)} g\left(x;\lambda_{N(f)}\right)\right) dx \tag{21}$$

Equation (21) suggests that high quality patents contribute more in the aggregate knowledge capital. It also suggests that innovations from non-InnoCom industries do not contribute to the aggregate productivity of the InnoCom industries.

To close the model, we assume free entry of NCEs out of targeted industries:

$$w_{N(i)} = \kappa \tag{22}$$

where κ is the entry cost.[35]

Given the InnoCom policy ρ and T, an equilibrium is defined as λ_S, θ_S, $\lambda_{N(f)}$, $\theta_{N(f)}$, $\lambda_{N(i)}$, $\theta_{N(i)}$, K, m and δ such that (i) The NCE and SCE's problems (12), (13) and (14) are solved. (ii) Equations (10), (21) and (22) are solved.

4.3 Welfare Decomposition

In this subsection, we first define the aggregate welfare of the economy, and then show that the aggregate welfare can be decomposed into three sources.

The total subsidy is $TS = \rho T \pi_S \int p_S(x)$, where $\int p_S(x)$ is the number of SCEs with a patent. The subsidy may cause distortions on the government budget. We denote $\tau \geq 0$ as the shadow value of 1 unit subsidy on the government's fiscal budget. If $\tau = 0$, it means the government has a deep pocket.

The welfare is defined as the total firm value in the first stage taking out of the subsidy,

$$W = w_S + \beta w_{N(f)} - (1+\tau) TS \tag{23}$$

where we use the fact that the net value of other NCEs is 0 due to the free entry condition.

We can separate SCEs to firms that innovate patents by themselves, and purchase patents from NCEs. The total subsidies received by these three groups SCEs are

[35] In the data, most of new entrants after the InnoCom program is not from targeted industries.

$$TS^{Self} = \rho T \pi_S \theta_S, \quad TS^T = \rho T \pi_S \int \left[p_S(x) - \theta_S g(x; \lambda_S) \right] dx,$$

where TS^{Self} and TS^T denote subsidies to SCEs which self develop patents and purchase patents respectively. $TS^{Self} + TS^T = TS$.

Combining with definitions of w_S,$w_{N(f)}$ and $w_{N(i)}$, we can decompose the aggregate welfare as

$$W = \underbrace{\pi_S + \beta \pi_{N(f)}}_{\text{knowledge externality}} + W_{SCE} + W_{reassignment} + W_{NCE} \tag{24}$$

where

$$W_{SCE} = \underbrace{\theta_S \int V(\pi_S, x)\, dG(x; \lambda_S) - C_S(\lambda_S, \theta_S)}_{\text{(1) value from in-house innovation of SCEs}} - \underbrace{\tau TS^{Self}}_{\text{(2) fiscal cost}} \tag{25}$$

$$W_{reassignment} = \underbrace{2(1 - \theta_S) TV_S}_{\text{(3) surplus from patent trade}} - \underbrace{TS^T}_{\text{(4) subsidy to trade}} \tag{26}$$

$$W_{NCE} = \underbrace{\left[\underbrace{\beta \theta_{N(f)} \int V\left(\pi_{N(f)}, x\right) dG\left(x; \lambda_{N(f)}\right) - {}_N\left(\lambda_{N(f)}, \theta_{(f)}\right)}_{\text{(5) value from innovation of } N(f)} \right]}_{\text{(6) value from innovation of N(i)}} \underbrace{m \left[\theta_{N(i)} \int V\left(\pi_{N(i)}, x\right) dG\left(x; \lambda C_{N(i)}\right) - C_N\left(\lambda_{N(i)}, \theta_{(i)}\right) - \kappa \right]}_{\text{(6) value from innovation of N(i)}} - \underbrace{\tau TS^T}_{\text{(7) fiscal cost}} \tag{27}$$

We can see that the total welfare of the economy first should include the profits of all firms in targeted industries without any patents. This part captures the knowledge spillover from the innovations.

W_{SCE} is the value of SCEs in-house patents. Its change comes from two sources. First, the in-house patent brings an expected benefit $\theta_S \int V(\pi_S, x)\, dG(x; \lambda_S)$ at innovation cost $C_S(\lambda_S, \theta_S)$. Thus term (1) in equation (25) is the net value from in-house innovation. The

term (2) captures the fiscal cost of subsidizing these SCEs.

$W_{reassignment}$ is the value from patents reassignment. Term (3) is the total joint surplus from trade, which includes the subsidy value. Term (4) removes subsidy receiving from patent trade. Hence $W_{reallocation}$ captures the efficiency gain from reallocating patents.

Finally, W_{NCE} is the value of NCEs' patents. It consists three components. Term (5) is the value from innovation of $N(f)$. Term (6) is the innovation value of $N(i)$. Noticing that we consider the entry cost κ as a part of innovation cost since it captures the extensive margin of innovation from NCEs. The term (7) is the fiscal cost from subsidizing traded patents.

To summarize, we can see that the InnoCom program may change the aggregate welfare by: (1) Decreasing the innovation value since firms innovate more low quality patents and decrease the expected value $V(\pi, x)$ (entering W_{SCE} and W_{NCE}); (2) Distorting patent trade ($W_{reassignment}$). There are two opposite forces. On one hand, since inefficient trade ($\sigma > V(\pi_S, x) - V(\pi_N, x)$) may happen, the InnoCom program may decrease the welfare from trade. On the other hand, since more NCEs enter, it becomes easier to find a seller. The total number of trade and the number of efficient trade increase. Hence whether the InnoCom program would increase or decrease the efficiency of patent reallocation depends on which force dominates; (3) Creating fiscal cost; (4) Generating more knowledge spillover. We are interested at which channel dominates in the InnoCom program. Meanwhile, we are also interested at finding out more efficient ways to implement this program.

4.4 Calibration

To calibrate the model, we first impose a few parametric assumptions on some model elements. We assume that the innovation cost has the form

$$C_S(\lambda,\theta)=\frac{v_{0S}}{2}(\lambda_S\theta_S)^2+\frac{v_{1S}}{2}\theta_S^2,\quad C_N(\lambda,\theta)=\frac{v_{0N}}{2}(\lambda_N\theta_N)^2+\frac{v_{1N}}{2}\theta_N^2$$

v_{0S}, v_{1S}, v_{0N} and v_{1N} are parameters that are different between SCEs and NCEs. In the above cost functions, the innovation cost is increasing and convex in θ and λ. Meanwhile, when λ increases, the marginal cost of increasing θ is higher.

The matching function is assumed to be the form

$$q_S=\frac{1-\exp(-b\delta)}{\delta},\ \ q_N=1-\exp(-b\delta)$$

where b is a parameter that measures the matching efficiency.[36]

For simplicity, we assume $x_L=0$, which means that the low quality patent does not bring any extra profit to the holder. Since the measure of SCEs is normalized to 1, we set $\beta=2$ to match annual average number of NCEs in the InnoCom industries over the sample.

To solve the model, we need to know the following parameters: (1) patent quality x_H; (2) the mean and standard deviation of renewal cost c and Ω_ε; (3) firm productivity $z_S, z_{N(f)}$ and $z_{N(i)}$; (4) the innovation cost parameters v_{0S}, v_{1S}, v_{0N} and v_{1N}; (5) the matching efficiency b; (6) the average patent transaction cost ϕ; (7) the entry cost κ; (8) the aggregate productivity parameters A_0 and η; (9) subsidy parameter ρ and T; (10) the fiscal cost parameter τ.

We assign some parameters at the first. For SCEs and NCEs within targeted industries, we can see their profits. So we normalize $z_S=1$ and calibrate $z_{N(f)}=0.9$ to match the

[36]This matching function is widely used in the search literature, such as Petrongolo and Pissarides (2001).

average relative profit between these two groups of firms within the sample.[37] Since a lot of other NCEs are not firms, we can not directly observe their benefits of holding patents. We calibrate $z_{N(i)}$ internally.

For the subsidy policy, we set $\rho = 0.6$ to match the observed subsidy possibility within SCEs. We also set $T = 0.1$ which implies the InnoCom firms enjoy a 10% tax cut.

We calibrate $\eta = 0.01$ to match the elasticity of column 2 of Table 8.[38] Finally, Chen et al. (2021) estimates the cost of the InnoCom program budget with $\tau = 0.2$.[39] Ming (2009) estimates the τ in a reduced form way, and find τ is between 0.2 to 0.4. We set $\tau = 0.2$ in our baseline analysis. We explore the robustness of η and τ later.

Mapping model to the data

For the rest parameters, we fix c and x_H as time invariant. Other remaining parameters are assumed to change before and after the InnoCom program. In sum, we have 22 parameters to calibrate.[40] We calibrate them to match 21 moments in the data. We compute the value of each moment before the policy (2005 to 2007) and after the policy (2008 to 2012).[41]

We start from explaining the identification intuition of time varying parameters. For the innovation cost parameters (v_{0S}, v_{1S}, v_{0N}, v_{1N}), they directly determine patents quality and patent counts. So we calibrate them to match the counts and renewal rates of self-

[37]Hence SCEs are 10% larger than other firms in the same industry.

[38]Notice that K is defined as the patent counts weighted by x In the model. While in Table 8, K is defined as patent counts weighted by renewal rates. In principle, if we have several periods in the model, we can compute the knowledge capital as Table 8, and regress $\ln A$ on it. We then can choose η to make the regression coefficient from the model be 0.01. However, since we only calibrate two periods (before and after 2008) in the model, we cannot do this exercise but simply impose $\eta = 0.01$. We will explore the robustness in Figure 9.

[39]They get this estimate by assuming the utility from public spending is the same between China and US. Using the average tax rate in China to infer the public spending, τ can be estimated.

[40]The parameters to calibrate include 2 time invariant parameters (c and x_H), and 10 time varying parameters (v_{0S}, v_{1S}, v_{0N}, v_{1N}, b, ϕ ,κ, $z_{N(i)}$, Ω_ε and A_0).

[41]The numerical details are provided in Appendix B.

developed patents for SCEs and NCEs. Parameters b and ϕ determines the patent trade market frictions. We calibrate b to match the number of purchased patents of SCEs because it directly changes the number of trade. Meanwhile, since $\phi > 0$, it generates a selection effect that the high quality patents are more likely to be traded. So we calibrate ϕ to match renewal rates of external patents of SCEs, which will reflect the quality of traded patents. The parameter κ is calibrated to match the number of NCEs. Ω_ε, the standard deviation of the renewal cost shock, is calibrated to match the dispersion of renewal rates before and after the policy. Lastly, A_0 and $z_{N(i)}$ can be considered as sector productivity shocks of InnoCom industries and other industries. We then calibrate them to match average before tax profit of Innocom industries and the renewal rate of other NCEs before/after the policy. (Note that we cannot directly observe profits of other NCEs, so we use renewal rates to infer $z_{N(i)}$).

In terms of the 2 time invariant parameters, x_H and c are calibrated to match the profit difference between SCEs with a patent and without a patent before and after 2008. Intuitively, when c increases, more patents will not be renewed. Hence the profit with and without a patent would decrease.

The parameters and model fit are shown in Table 9. The model value is 100,000 RMB. First, $x_H = 0.14$. It suggests that a high quality patent can increase the firm's profit by 14%, which is consistent with observation in Table 2. Second, the renewal cost c is about 0.81 with standard deviations 6.58 and 6.21 before and after 2008. In China, a patent holder needs to pay about 1,000RMB (0.01 in model value) every year to renew the patent. However, the renewal cost not only include the official renewal fee, but also other indirect renewal cost (such as the legal cost to protect patent rights). So our estimate of c is much greater than 1,000RMB.

Switch to four parameters about innovation cost. First, we can see that SCEs have smaller innovation costs than NCEs in both quality and quantity dimensions (v_0 and v_1) before the

policy. This difference may reflect the fact that pre-requirements of the InnoCom program can select out firms with lower innovation costs. Second, the innovation costs decline after 2008 both for SCEs and NCEs. This may be driven by the trend that China's innovation efficiency increases over time. However, the parameters governing increasing patent quantity v_{0N} and v_{0S} decline much faster than the parameters improving patent quality v_{1N} and v_{1S}. It is driven by the data feature that patent count increases, while the renewal rate decreases. Interestingly, v_{1N} decreases much faster than other innovation cost parameters. In other words, after the 2008, NCEs have a strong comparative advantage of producing low quality patents. The patent trade would push NCEs to specialize on this business, which may amplify the welfare loss since more SCEs would hold low quality patents and can be subsidized.

In terms of two parameters about patent trade, the transaction cost ϕ decreases after 2008. This is driven by the data observation that renewal rate of external purchased patents decreases, which means that the it becomes less selective in the trade. This decline may come from that the more intermediary agents join this trade market. The match efficiency on the trade market, b, declines as well. This means that given a large amount of subsidy, our model suggests that if b does not decline after the 2008, we would see much more trade than the data. One reason why we get b declines may be that the patent trade number after 2008 is under-counted. Usually, the new owner of the patent wants to register its information when the after purchasing a patent. However, if the patent has a low value, and the new owner holds it just to increase the chance to be subsidized, it may not have a strong willing to update the information in the patent office. Hence we may under-estimate b after 2008 given the total number of trade is under-counted. Since we find that a large share of welfare loss comes from the patent trade, our conclusion would be strengthened if b is under-estimated. Moreover, the entry cost κ increases after 2008. The reason is similar with b: our model would expect to see more entrant given other parameters of the model.

Our model allows two productivity shocks. A_0 is the productivity shock of InnoCom industries. Its increase after 2008 is resulted from the data fact that the profit of these industries increase. $z_{N(i)}$ is the marginal value of having a high quality patent of other NCEs. The value does not change too much after 2008, but $z_{N(i)}$ is much lower than A_0. This may be because that we include non-firm inventors in this group.

The model fits the data well except that we under-estimate standard deviation of renewal rates. This may be because that we ignore firm heterogeneity in the model. Table 9 also reports some un-targeted moments, including the relative dispersion of renewal rates between SCEs, NCEs ($N(f) + N(i)$) and other NCEs ($N(i)$). We can see that although our model miss the level of dispersion of renewal rates, the relative ratio between dispersion are quite similar with the data.

5 Welfare and Policy Analysis

To understand the effect of InnoCom better, we focus on the economy after 2008 and consider two scenarios in Table 10. In the first column, we use parameters after 2008 and assume the subsidy does not exist ($\rho = 0$, a "laissez faire" economy). In the second column, we consider an economy after 2008 with the InnoCom program (as the real world). And the third column reports the difference between the InnoCom economy and the "laissez faire" economy. In both scenario, we report the total welfare and decompose it into several sources as equation (24). The first row is the total subsidy, which is about 3.4 billion RMB per year after 2008.[42] The second row is the average patent quality x. Without the subsidy, the average x is about 4.35%. However, it declines to 1.98% with the InnoCom subsidy since firms focus on patent count rather than quality. The third row reports the total innovation

[42]The annual total InnoCom subsidy for this city is about 3.4 billion RMB. In our model, we scale the measure of SCEs to match the total subsidy in the data.

cost, which increases sharply from 3.35 to 16.22 billion RMB since each firm spends more resource on creating patents. The fourth row, $K^{\eta} - 1$, shows the increase of aggregate productivity due to knowledge spillover. Since quality of patents declines, although more patents are created, the aggregate knowledge capital slightly declines, and its contribution to productivity decreases by 0.01%.

The next a few rows reports the aggregate welfare, and four decomposition parts in the welfare equation (24). Row (a) is the aggregate profit of firms in 8 InnoCom industries (without considering the value from holding patents by themselves). Because of the decrease of aggregate knowledge capital, the total non-patent profit decreases by 0.1 billion RMB.

Row (b) is W_{SCE}, the net value of SCEs' in-house patents, which is the SCE innovation value minus the fiscal social cost of TS^{self}. This is the direct welfare effect of the InnoCom program. Since SCEs waste too much resource to produce low quality patents, W_{SCE} declines by 1.3 billion RMB.

Row (c) is value from re-assigning patents from inventors to other patent users. This number declines by 0.27 billion RMB, suggesting that a lot of inefficient trade is induced to receive subsidy.

ROw (d) is the net value of NCE's developed patents, which equals to the NCE innovation value minus the fiscal social cost of TS^{T}. This value declines by 0.36 billion RMB because NCEs waste resource to produce low quality patents to sell.

Overall, we can see that the aggregate welfare decrease by 1.93 billion RMB. Notice that most of the welfare loss, about 67% (1.3/1.93) comes from the direct channel that SCEs innovate low value patents. However, the patent trade market significantly amplifies the welfare loss by about 50% ((0.27+0.36)/1.3).

In other words, the key of the welfare loss is that most new granted patents after 2008 is the low quality patents. Since NCEs are extremely good at producing these low quality

patents, allowing purchased patents eligible for subsidy would push more low quality patents to be produced. Hence this further enhance the welfare loss. We check this insight from the data directly. If our model is right, we expected to see that most new patents after 2008 were low quality patents. Figure 8 confirms this conjecture, in which we plot the counts of new inventions (in log) by grant year.[43] The red solid line (with marker "x") is the total number of new inventions, and the black line is the number of inventions expired in 3 years after granted. For each line, we project its value after 2008 using the average growth rate before 2008 (two dashed lines). As we can see, after 2008, the growth rate of the new patents accelerates. More patents are produced. However, within the new granted patents after 2008, the share of patents that will not be renewed in 3 years significantly increases. In other words, most of new patents after 2008 are low quality patents.

Robustness

In our baseline analysis, we assume that all parameters change after 2008 are purely driven by other exogenous reasons. A concern is that these changes may resulted by the InnoCom program. For instance, if firms have a lot of un-patented ideas before 2008, the value of these ideas may be low so that firms do not apply them for patents. However, after 2008, without spending any research effort, firms change these low quality ideas to patents. In our model, the fast decline of v_{1N} and v_{1S} may reflect this type of changes. Another concern is that our estimate of η is very small comparing to others, while the range of social cost of fiscal subsidy τ is quite large in the literature. Is our conclusion robust to η and τ? To handle these concerns, we run three robustness experiments.

First, in stead of focusing on the economy 2008, we consider the economy before 2008. What happens if we implement the InnoCom program, say with $\rho = 0.6$, before 2008,

[43]To save the space, we only report the result of new inventions. Other types of patents (utility/design) have similar results.

assuming that all parameters do not change? This experiment can be considered as an extreme case that all parameters change after 2008 are driven by the InnoCom program. Column 1 of Table 11 reports the difference between economies with and without the subsidy using parameters before 2008. We can see that the total subsidy is lower, about 3.06 billion, since firm's profit is lower. Meanwhile, the average patent quality declines by 1.51% since firms care more about patent count. Although the innovation cost sharply increases by 10.63 billion RMB, the aggregate productivity barely does not change. Overall, the aggregate welfare declines by 1.87 billion RMB, among which W_{SCE} contributes about 16% (0.29/1.87), while the the patent trade market even amplifies the welfare loss even greater than the baseline. It is because that SCEs's innovation costs are high before 2008. Hence a significant amount of SCEs fails producing patents by themselves, and needs to rely on purchasing patents from NCEs. This makes the trade market exaggerates welfare loss more intensively.

In the second robustness experiment, we switch back to the economy after 2008. We want to compare the post-2008 economy without InnoCom program, while taking into the account that the innovation costs and match efficiency may be changed due to the program. Hence comparing to column 1 of Table 12, we wants to not only impose $\rho = 0$, but also move the InnoCom effect on technologies of innovation and patent trade market. To achieve this, we assume that the fast decline of cost to produce low quality patents (v_{1N} and v_{1S}) after 2008 are driven by the InnoCom program, while the decline of the cost to produce high quality patents (v_{0N} and v_{0S}) reflects the other factors (such as the increase of human capital). We further assume that without InnoCom, the decline of v_{0N} and v_{0S} will be the same as v_{1N} and v_{1S} (i.e. other factors will decrease the innovation costs of high and low quality patents in the same way). Hence We can infer v_{1N} and v_{1S} after 2008 if the InnoCom program was not implemented from the change of v_{0N} and v_{0S}.

Under the new v_{1N} and v_{1S}, we then solve the post-2008 economy without any subsidy.

Column 2 of Table 11 reports the difference with the subsidy (column 2 of Table 12) and without the subsidy (using the new v_{1N} and v_{1S}). As we see, the patent quality decreases by 7.17% after implementing the policy. This decline comes from two sources. The subsidy encourages more low quality patents to produce, and the subsidy decreases the cost of producing low quality patents. Although the patent quality drops with the subsidy, but the number of patents increases. So the aggregate knowledge capital barely does not change. Since the InnoCom program can now reduce the innovation cost, it may improve firm's value. For instance, the NCE's v_{0N} declines most with the InnoCom. So W_{NCE} increases by 0.59 billion RMB if the subsidy policy is implemented. In other words, besides generating positive externality, we give the InnoCom program another advantage to the economy, reducing the innovation cost. In practice, we believe this scenario may not be so realistic. However, the bottom line is even in this case, the InnoCom program still generates 0.98 billion welfare loss.

The aggregate welfare depends on two key parameters: the externality η and the shadow value of the fiscal budget τ. We then explore another robustness check: what is the combination of η and τ that makes the InnoCom program welfare neutral after 2008 (that is the welfare with subsidy (column 2 of Table 10) equals to the welfare without subsidy (column 3 of Table 10)). Figure 9 shows the "welfare break even" τ for any given η, holding all other parameters the same as column 2 of Table 10). When η increases, the knowledge externality increases, so we can suffer a higher fiscal cost τ that makes the subsidy welfare neutral. If τ is above/below the solid line in Figure 9, the InnoCom program generates welfare loss/gain. In the baseline case ($\eta = 0.01$), the InnoCom program will be welfare enhanced only if $\tau \leq -0.37$ (1 dollar subsidy's cost is only 63 cents). Lucking et al. (2019) estimates that the knowledge spillover is bounded above by 0.2. Even in this case, the "welfare break even" τ is still negative. However, according to Chen et al. (2021) and Ming (2009), a reasonable esti-

mate of τ in China is from 0.2 to 0.4, which means that the InnoCom program can generate welfare gain only if η is very large (greater than 0.3), which is very unlikely.

To sum up, we find that the InnoCom program is very likely to hurt the aggregate welfare, and the patent trade market plays a quantitatively important role in the welfare loss.

Alternative subsidy policies

We then consider alternative subsidy policies in Table 11. In each column, we consider an economy after 2008 (parameters are the same as column 2 of Table 10), but subsidizing firms in a different way.

First, given the aggregate welfare loss mainly comes from the external purchase, we consider an alternative policy that only counts self-developed patents. The policy still subsidizes firms with $\rho = 0.6$.[44] The first column of Table 12 reports it. Comparing to column 2 of Table 10), we can see that the total subsidy declines to 2.73 billion, and the patent quality increases to 3.44%. Thanks to the improvement of the patent quality, the aggregate productivity barely does not change, although the innovation cost declines. Overall, the aggregate welfare increases from 365.52 to 366.06. Thus the InnoCom program can be more efficient if only counting the internal patents. However, the welfare is still lower than not subsidizing firms at all (column 1 of Table 10)).

In the second column of Table 12, we consider an policy that NCEs in InnoCom industries ($N(f)$) can also be subsidized with probability 0.6 (such as removing pre-requirements of the InnoCom program). Total subsidy and innovation cost are higher since more firms are subsidized. Meanwhile, the patent quality further declines to 1.72%. However, the aggregate productivity barely changes. In the end, the total welfare declines to 360.48 billion RMB. This large decline mostly comes from W_{NCE}, which now has three components. Besides the

[44]Notice that the patent trade market still opens, but SCEs can get subsidy only with self-developed patents.

NCE innovation value and the social cost of fiscal subsidy to traded patents, there is one more term: the social cost of subsidy to NCEs, which is about 2.15 billion RMB. This is because that NCEs are good at producing low quality patents. They can develop a patent very easily and receive subsidy. Thus the total subsidy is now very large, about 13.73 billion RMB. In other words, this type of subsidy policy is extremely inefficient since we subsidize too much.

In the above two experiments, we fix ρ, so the total budget of the subsidy changes. We then explore similar policy designs as column 1 and 2, but fix the total subsidy to be 3.4 billion RMB. In column 3, we consider the policy that only allows in-house patents to claim subsidy. A fixed budget implies that ρ is about 0.7. Hence more SCEs will be subsidized. The patents quality slightly decreases since SCEs understand that as long as they have a patent, it is very likely to be subsidized. So they sacrifice more on patents quality. However, because more patents are generated, the aggregate productivity increases. In the end, the aggregate welfare, comparing to the old policy design, increases by 0.69 billion RMB (366.21-365.52). Hence by only counting internal patents, the InnoCom program can do better, but it still generates welfare loss.

In column 4, we report the economy when subsidizing all firms in targeted industries but fixing the total budget. This implies that ρ is only about 0.32, much smaller than before. Since the total subsidy is fixed at 3.4, the welfare is higher than column 2. But we can still see that it is worse than only subsidizing SCEs. This is because that NCEs are very good at producing low quality patents. If they have chance to be subsidized directly, they will produce more low quality patents. This will decrease the aggregate productivity, as well as the total welfare of the economy.

Optimal subsidy policies

We then explore whether the InnoCom program can be more efficient by making the program more competitive. The result is in the first column of Table 13. Comparing it with column 2 of Table 10), we search ρ to maximize the total welfare. We find that the optimal ρ is very small, about 0.001. This means that the if the policy is designed as such, it may be not good to subsidize any firms.

The essential reason that the InnoCom program creates welfare loss is that the bureaucrat cannot distinguish high quality patents and low quality patents. To see this point clearly, we then consider a counterfactual experiment that the government can distinguish patents quality. Let ρ_H and ρ_L be the probabilities of being subsidized when holding patents with quality x_H and x_L. We then search ρ_H and ρ_L to maximize the welfare. The second column of Table 13 reports the result. We find that when $\rho_H = 0.50$ and $\rho_L = 0$, the welfare is maximized. In this case, the government does not want to subsidize low quality patents since they cannot improve the aggregate knowledge capital. However, the government wants to subsidize high quality patents more intensively. Comparing to column 2 of Table 10, the total subsidy declines but the patent quality increases. Overall, the aggregate welfare increases by 2.76 billion (368.28-365.52), or about 0.8% of the industry total profit (2.76/364.20). This increase mainly comes from the aggregate knowledge spillover.

In the third column of Table 13, we consider whether it is better to accept purchased patents for the subsidy. Comparing to the previous column, we find that the government slightly increases the ρ_H. It is because SCEs have a relatively high cost of producing low quality patents, hence are more likely to have high quality patents. This point is also reflect on the average x, which increases from 4.07% to 5.15%. However, due to fewer patents are produced, the aggregate productivity and the total industry profit (without patents) declines slightly. Overall, we can see that the total welfare increases, which mainly comes from the

increase of W_{NCE}. This change comes from the way we model the trade market. We assume that the trade market is a random search-match market with a free entry condition. Thus the well-known congestion effect exists: the entry of new NCEs would reduce the probability of incumbent NCEs to sell their patents. If the bureaucrat does not count external patents, fewer NCEs will enter the market hence this excess entry problem can be alleviated. So in our model, it is better only counting internal patents even the bureaucrat can tell quality difference.

6 Conclusion

In this paper, we study how the patent subsidy policy, the InnoCom program, change the aggregate welfare. We show that the subsidy policy decreases the value of patents either through declining the quality of new granted patents or through the inefficient trade of patents. Overall, we find the InnoCom program can reduce the aggregate welfare, and the patent trade market can amplify the welfare loss significantly. Thus it is important to consider the patent trade market when we design a pro-innovation policy which directly subsidizes patent holders.

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Tables and Figures

Table 1: Grading Scheme of the IPR Counts

Letter Grade	Points	Criteria
A.	30-24	6 or more IPRs (or at least 1 invention)
B.	24-18	5 IPRs
C.	18-12	4 IPRs
D.	12-6	3 IPRs
E.	6-0	1-2 IPRs
Notes: Both purchased and self-developed IPRs are counted.		

Notes: This table explains the grading scheme of the IPR counts in the InnoCom program.

Table 2: Summary Statistics of the SCEs and NCEs before and after 2008

	2005-2007		2008-2012	
	SCEs	NCEs	SCEs	NCEs
Firm counts	5,530	49,028	5,682	85,009
Per-firm:				
IPRs	0.949	0.852	9.980	4.195
Patents	0.389	0.403	2.636	1.909
Share of external patents	11.05%	2.73%	22.27%	1.15%
Δ ln(Profit) w/o patents	0.785	0.890	0.376	-0.331
Δ ln(Profit) w/o patents (firm/year FEs)	0.123	0.286	0.029	0.072
Citations	1.297	1.019	0.963	1.005
Renewal rate of:				
In-house. patents	0.887	0.803	0.567	0.425
External patents	0.973	0.961	0.635	0.709

Notes: This table shows the summary statistics of SCEs and NCEs before and after 2008. Δ ln(Profit) with patents is the profit (in log) difference between firms with and without patents.

Table 3: Number of New IPRs in Relation to the Timing of InnoCom Policy

	(1)	(2)	(3)	(4)
	ln(IPR)	ln(Self-dev.patent)	ln(IPR)	ln(IPR)
$D_{it-1} \times D(t \geq 2008)$	0.129**	0.043*	0.217***	0.213***
	(0.043)	(0.024)	(0.027)	(0.047)
$D(IPR_{it-1} = 6) \times D(t \geq 2008)$				-0.046
				(0.053)
$D(t \geq 2008)$	Y	Y		Y
D_{it-1}, s_{it-1}	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y
Year FEs			Y	Y
Obs.	10,477	10,407	10,477	10,477
Adj. R2	0.75	0.78	0.77	0.77

Notes: This table presents the estimation results of the equation (1) of SCEs. The observation is at firm-year level. N_{it} is the new obtained IPRs of firm i in year t. $D_{it} = 1$ if $IPR_{it} < 6$ and invention$_{it} = 0$. $s_{it} = 1$ if the firm is subsidized within three years. Standard errors are reported in the parentheses and clustered at the firm-year level. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Value of New Obtained Patents in Relation to the Timing of InnoCom Policy

	(1) $\ln(\text{Profit}_{it})$	(2) $\ln(\text{Profit}_{it})$	(3) V_{ikt}	(4) V_{ikt}
$D(\text{New IPR}_{it-1} > 0) \times D(t \geq 2008)$	-0.002*	-0.003**		
	(0.001)	(0.001)		
$\ln \text{Worker}_{it-1}$	0.004***	0.001		
	(0.001)	(0.001)		
$D_{it-1} \times D(\text{OY}_{\cdot ik} \geq 2008)$			-0.029**	-0.045**
			(0.015)	(0.022)
$D(\text{OY}_{\cdot ik} \geq 2008)$			-0.024**	
			(0.011)	
$D(\text{New IPR}_{it-1} > 0)$	Y	Y		
Restrict sample ($D_{it-1} = 1$)		Y		
Firm FEs/Year FEs	Y	Y	Y	Y
s_{it-1}	Y	Y	Y	Y
D_{it-1}			Y	Y
Patent char			Y	Y
OY. FE				Y
Obs.	4,103	614	159,510	159,510
Adj. R2	0.72	0.5	0.42	0.51

Notes: This table presents the estimation results of the equations (2) (column 1-2) and (3) (column 3-4) of SCEs. For column 1 and 2, the observation is at the firm-year level. $D(\text{New IPR}_{it} > 0) = 1$ if the firm acquires new IPRs in year t, and 0 otherwise. $D_{it} = 1$ if $IPR_{it} < 6$ and $\text{invention}_{it} = 0$. $s_{it} = 1$ if the firm is subsidized within three years. For column 3 and 4, the observation is at firm-patent-year level. $V_{ikt} = 1$ if the firm i renews patent k in year t, and 0 otherwise. $\text{OY}_{\cdot ik}$ is the year of obtaining patent k. $D(\text{OY}_{\cdot ik} \geq 2008) = 1$ if the patent k is obtained after 2008, and 0 otherwise. Patent characteristics include patent age, industry classification and type (invention, utility or design). Standard errors are reported in the parentheses and clustered at the firm-year (column 1-2) or firm-patent-year (column 3-4) level. *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Decomposition of the Annual Patent Trade Growth

Seller \ Buyer	SCEs IPRs<6	SCEs IPRs≥6	NCEs
	2007-2012		
SCEs IPR<6	-0.010	0.001	0.002
SCEs IPR≥6	0.130	0.032	0.042
NCEs	0.300	0.078	0.202
	2006-2007		
SCEs IPR<6	0.108	-0.002	-0.017
SCEs IPR≥6	0.055	0.016	0.091
NCEs	-0.151	-0.001	0.331

Notes: This table decomposes the annual patent trade growth into 9 categories based on buyers' and sellers' characteristics.

Table 6: Spillover Effects to NCEs of the InnoCom Policy

	(1) $ln(IPR_{it})$	(2) $Renewal_{it}$	(3) $ln(IPR_{it})$	(4) $Renewal_{it}$	(5) $ln(IPR_{it})$	(6) $Renewal_{it}$
$PSale_{it-1}^{SCE} \times D(t \geq 2008)$	0.129**	-0.066***	0.046	-0.071	0.110**	-0.070***
	(0.045)	(0.018)	(0.061)	(0.041)	(0.048)	(0.020)
$PSale_{it-1}^{NCE} \times D(t \geq 2008)$	0.025	-0.019	0.023	-0.020	0.009	-0.027
	(0.046)	(0.013)	(0.045)	(0.013)	(0.048)	(0.023)
$PSale_{it-1}^{SCE,IPR<6} \times D(t \geq 2008)$			0.147*	-0.075**		
			(0.080)	(0.026)		
$PSale_{it-1}^{SCE}$, $PSale_{it-1}^{NCE}$	Y	Y	Y	Y	Y	Y
$PSale_{it-1}^{SCE,IPR<6}$		Y		Y		
Firm/Year FEs	Y	Y	Y	Y	Y	Y
Individual NCEs					Y	Y
Obs.	22,486	22,486	22,486	22,486	12,987	12,987
Adj. R2	0.60	0.35	0.60	0.35	0.60	0.34

Notes: This table presents the estimation results of number and citation of new patents (equation (5)) of NCEs. $PSale_{it-1}^{SCE}$, $PSale_{it-1}^{NCE}$ and $PSale_{it-1}^{SCE,IPR<6}$ are the number of patents sold to SCEs, NCEs and SCEs with IPRs fewer than 6, respectively. Standard errors are reported in the parentheses and clustered at the firm-year level. *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Correlation between Evaluation Points and IPRs Quality

	(1) Points in IPRs No.	(2) Tot. points	(3) Points in IPRs No.	(4) Tot. points
Ave. citation	0.030	0.085		
	(0.034)	(0.061)		
Ave. renewal rate			-0.158	-3.916
			(0.557)	(2.516)
In-house IPR sh.	0.031	-0.087	-0.186	0.885
	(0.028)	(0.047)	(0.479)	(0.591)
Letter grades FEs	Y	Y	Y	Y
Other firm char.	Y	Y	Y	Y
Obs.	2,470	2,470	2,470	2,470
Adj. R2	0.62	0.16	0.58	0.18

Notes: This table shows the correlation between 2008 subsidized firms' patents quality and their evaluation grades by the bureaucrat. Average citation is the accumulated citation per patent in 2008. Average renewal rate is the patent's renewal rate 3 years after granted. In-house IPR share is the share of self-developed IPRs. Letter grades is defined in Table 2. Firm characteristics include firm size (measured by 2007 annual sales), ownership, and industry.

Table 8: Knowledge Externality of Patents

	(1) $\ln(laborprod)$	(2) $\ln(laborprod)$	(3) $\ln(laborprod)$	(4) $\ln(laborprod)$	(5) $\ln(laborprod)$	(6) $\ln(laborprod)$	(7) $\ln(laborprod)$
$\ln K^{within}$	0.052***	0.010*	0.009	0.011*	0.015*	0.010	0.011
	(0.012)	(0.006)	(0.008)	(0.007)	(0.008)	(0.008)	(0.013)
$\ln K^{other}$	-0.102***	-0.012	-0.013	-0.011	-0.024	-0.013	-0.009
	(0.025)	(0.016)	(0.017)	(0.019)	(0.017)	(0.019)	(0.026)
$\ln K^{within} \times D_{InnoCom}$				-0.005	-0.013	-0.004	-0.015*
				(0.008)	(0.009)	(0.008)	(0.009)
$\ln K^{other} \times D_{InnoCom}$				0.008	0.003	0.007	0.004
				(0.009)	(0.009)	(0.009)	(0.009)
Firm FE	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y
IV		Y	Y	Y	Y	Y	Y
K: Renewal rate adj.	Y	Y		Y	Y		
Sample after 2008					Y		Y
KP Wald F stat		2175.70	3017.11	5929.45	1500.00	4594.17	1400.04
Obs.	1,120,443	1,120,443	1,120,443	1,120,443	373,074	1,120,443	373,074
Adj. R2	0.65	0.65	0.65	0.65	0.67	0.65	0.67

Notes: This table reports the estimates of knowledge spillover within and across sectors (equation (7)). The dependent variable is the log of labor productivity (profit/worker) of a firm without patent. The $D_{InnoCom} = 1$ if the firm is in an InnoCom industry and 0 otherwise. In column (3), K is not adjusted by the renewal rate. The IV of column (2) to (7) is defined in equation (8). "KP Wald F stat" refers to Kleibergen-Paap Wald F-statistic in the first stage estimation. Standard errors are reported in the parentheses and clustered at the firm-year level. *** p<0.01, ** p<0.05, * p<0.1.

Table 9: Parameters and Model Fit

Param.	Value	Moments	Data	Model
x_H	0.14	Profit dif of SCEs with and without patents bef. policy	0.112	0.123
c	0.81	Profit dif of SCEs with and without patents aft. policy	0.022	0.029
Before policy				
v_{1N}	41.65	No. of NCE self-develped patents	0.346	0.346
v_{0N}	75.77	Renewal rate of NCE patents	0.803	0.734
v_{1S}	36.42	No. of SCE self-develped patents	0.392	0.392
v_{0S}	71.59	Renewal rate of SCE patents	0.887	0.872
b	0.18	Trade per SCE	0.043	0.243
ϕ	4.99	Renewal rate of SCE in-house patents	0.852	0.857
κ	0.11	NCE/SCE	6.866	6.866
A_0	48.91	Ave. profit	47.090	47.090
$z_{N(i)}$	1.23	Renewal rates of other NCEs	0.712	0.705
Ω_ϵ	6.58	Sd of renewal rates	0.151	0.034
After policy				
v_{1N}	7.20	No. of NCE self-develped patents	1.887	1.887
v_{0N}	70.96	Renewal rate of NCE patents	0.425	0.550
v_{1S}	16.64	No. of SCE self-develped patents	2.049	2.049
v_{0S}	69.57	Renewal rate of SCE patents	0.567	0.591
b	0.07	Trade per SCE	0.587	0.574
ϕ	3.71	Renewal rate of SCE in-house patents	0.482	0.600
κ	0.40	NCE/SCE	12.961	12.961
A_0	62.17	Ave. profit	60.100	60.100
$z_{N(i)}$	1.25	Renewal rates of other NCEs	0.401	0.544
Ω_ϵ	6.21	Sd of renewal rates	0.162	0.018
		Untargeted moments		
		renewal rates sd of SCEs/NCEs bef. policy	0.229	0.630
		renewal rates sd of SCEs/NCEs aft. policy	1.594	1.578
		renewal rates sd of other NCEs/NCEs bef. policy	1.033	1.105
		renewal rates sd of other NCEs/NCEs aft. policy	0.886	0.904

Notes: This table reports the parameters and model fit by comparing the moments in the model and the data. The moments before and after the subsidy are computed using data from 2005-2007 and 2008-2012 respectively.

Table 10: Welfare Decomposition

	(1) Laisse Faire $\rho = 0$	(2) InnoCom $\rho = 0.6$	(2)-(1) Difference
Subsidy	0	3.40	3.40
Ave. quality x	4.35%	1.98%	-2.33%
Innovation cost	3.35	16.22	12.87
$K^{\eta} - 1$	6.83%	6.82%	-0.01%
(a) Industry Profit: $Az + \beta A z_{N(i)}$	364.21	364.20	-0.01
(b) W_{SCE} ((b.1)+(b.2))	0.89	-0.41	-1.30
(b.1) SCE innovation val.	0.89	0.12	-0.77
(b.2) Fiscal social cost $-\tau T S^{self}$	0	-0.53	-0.53
(c) $W_{reassignment}$	0.01	-0.26	-0.27
(d) W_{NCE} ((d.1)+(d.2))	2.35	1.99	-0.36
(d.1) NCE innov val.	2.35	2.14	-0.21
(d.2) Fiscal social cost $-\tau T S^{T}$	0	-0.15	-0.15
Welfare ((a)+(b)+(c)+(d))	367.45	365.52	-1.93

Notes: This table reports the economy in two scenarios: the economy before 2008 without InnoCom program (column 1), and the economy after 2008 with InnoCom program (column 2). W_{SCE}, $W_{reassignment}$ and W_{NCE} are defined as equation (24). All numbers are in billion RMB, except the average x has not unit.

Table 11: Welfare Impact of the InnoCom: Robustness

	(1) Bef. 08' $W_{\rho=0.6} - W_{\rho=0}$	(2) InnCom induces decline of low quality patents innov. cost $W_{\rho=0.6} - W_{\rho=0}$
Subsidy	3.06	3.40
Ave. x	-1.51%	-7.17%
Innovation cost	10.63	13.89
$K^{\eta} - 1$	0.00%	0.00%
(a) Industry Profit: $Az + \beta Az_{N(i)}$	0.00	0.00
(b) W_{SCE} ((b.1)+(b.2))	-0.29	-1.30
(b.1) SCE innovation val.	-0.15	-0.77
(b.2) $-\tau TS^{self}$	-0.13	-0.53
(c) $W_{reassignment}$	-0.83	-0.27
(d) W_{NCE} ((d.1)+(d.2))	-0.75	0.59
(d.1) NCE innovation val.	-0.27	0.74
(d.2) $-\tau TS^{T}$	-0.48	-0.15
Welfare ((a)+(b)+(c)+(d))	-1.87	-0.98

Notes: This table reports the welfare impact of the InnoCom program in 2 scenarios. Column 1 compares economies with and without the subsidy using parameters before 2008. Column 2 compares economies with and without the subsidy using parameters after 2008. However, assuming that the InnoCom program can trigger the fast decline of low quality patents innovation cost v_1 but cannot change high quality patents innovation cost v_0, column 2 predicts the post-08 v_1 without InnoCom program as pre-08 $\frac{v_1}{v_0} \times$ post-08 v_0. Each cell reports the change of with and without the subsidy. W_{SCE}, $W_{reassignment}$ and W_{NCE} are defined as equation (24). All numbers are in billion RMB, except the average x has not unit.

Table 12: Impacts of Alternative Subsidy Policies

	(1) Only Inhouse patents $\rho = 0.6$	(2) Subsidize all in 8 ind. $\rho = 0.6$	(3) Only Inhouse patents with a fixed budget	(4) Subsidize all in 8 ind. with a fixed budget
Subsidy	2.73	13.73	3.40	3.40
Ave. x	3.44%	1.72%	3.33%	2.61%
Innovation cost	5.21	33.89	5.63	27.13
$K^{\eta} - 1$	6.82%	6.82%	6.85%	6.80%
(a) Industry Profit: $Az + \beta Az_{N(i)}$	364.20	364.20	364.74	363.05
(b) W_{SCE} ((b.1)+(b.2))	-0.50	-0.47	-0.89	0.62
(b.1) SCE innovation val.	0.04	0.07	-0.21	0.76
(b.2) $-\tau TS^{self}$	-0.55	-0.54	-0.68	-0.13
(c) $W_{reassignment}$	0.01	-0.13	0.01	-0.01
(d) W_{NCE} ((d.1)+(d.2)+(d.3))	2.35	-3.13	2.35	1.30
(d.1) NCE innovation val.	2.35	-0.92	2.35	1.84
(d.2) $-\tau TS^{T}$	0.00	-0.06	0.00	-0.01
(d.3) $-\tau TS^{NCE}$	0.00	-2.15	0.00	-0.54
Welfare ((a)+(b)+(c)+(d))	366.06	360.48	366.21	364.96

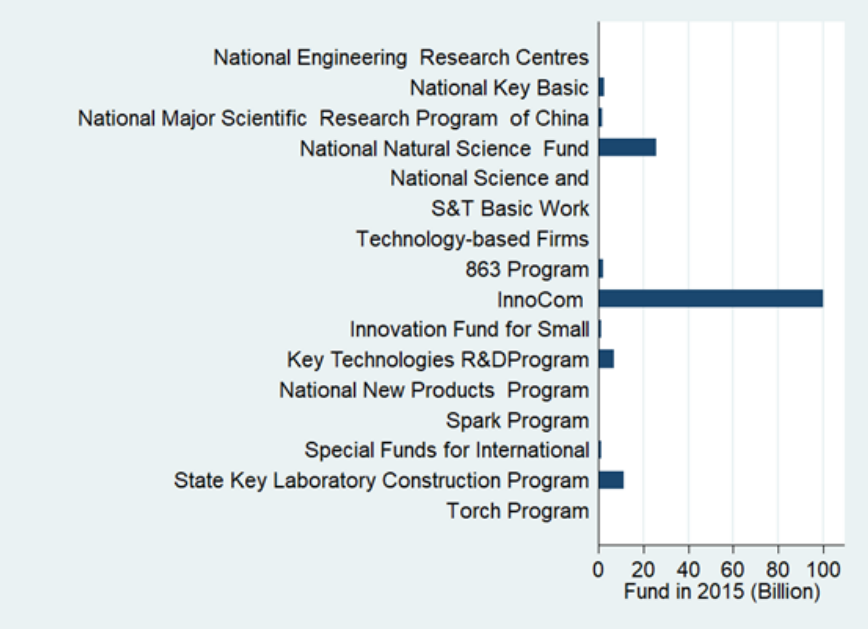
Notes: This table reports the economy with parameters after 2008 in 4 different policies: only subsidizing in-house patents with $\rho = 0.6$ (column 1), subsidizing all firms from 8 InnoCom industries with $\rho = 0.6$ (column 2), only subsidizing in-house patents with a fixed fiscal budget (column 3) and subsidizing all firms from 8 InnoCom industries with a fixed fiscal budget (column 4) . W_{SCE}, $W_{reassignment}$ and W_{NCE} are defined as equation (24). All numbers are in billion RMB, except the average x has not unit.

Table 13: Optimal Subsidy Policies

	(1) Optimal subsidy wo. SEP. patents quality $\rho = 0.001$	(2) Optimal subsidy if SEP. patents $\rho_H = 0.50$, $\rho_L = 0$	(3) Optimal sub. if only SEP. in-house patents quality $\rho_H = 0.53$, $\rho_L = 0$
Subsidy	0.00	1.04	0.92
Ave. x	4.31%	4.07%	5.15%
Innovation cost	3.38	5.26	4.15
$K^{\eta} - 1$	6.83%	7.02%	7.01%
(a) Industry Profit: $Az + \beta A z_{N(i)}$	364.20	365.43	365.40
(b) W_{SCE} ((b.1)+(b.2)) W_{direct}	0.89	0.55	0.55
(b.1) SCE innovation val.	0.04	0.89	0.73
(b.2) $-\tau T S^{self}$	-0.55	0.00	-0.18
(c) $W_{reassignment}$	0.01	-0.01	0.01
(d) W_{NCE} ((d.1)+(d.2))	2.35	2.31	2.36
(d.1) NCE innovation val.	2.35	-0.92	2.35
(d.2) $-\tau T S^{T}$	0.00	-0.02	-0.01
Welfare ((a)+(b)+(c)+(d))	367.45	368.28	368.32

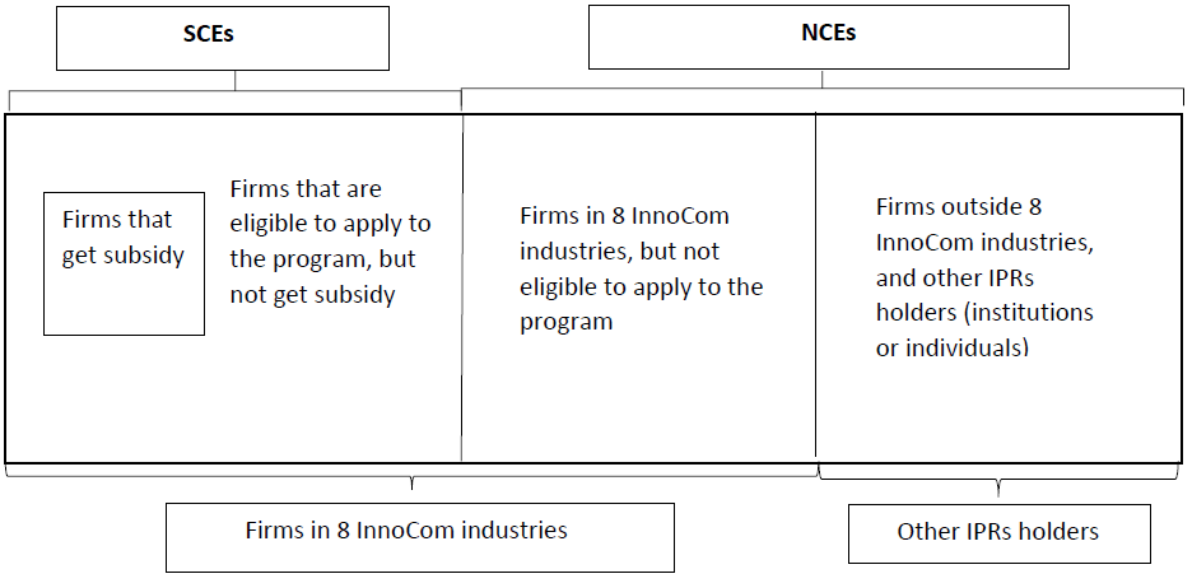
Notes: This table reports the economy with parameters after 2008 in 3 different policies. Column 1 assumes that the bureaucrat cannot tell patents quality, and search ρ to maximize welfare. Column 2 assumes that the bureaucrat can tell patents quality, and search subsidy intensity for high and low quality patents ρ_H and ρ_L to maximize welfare. Column 3 assumes that the bureaucrat can tell patents quality but does not count purchased patents for subsidy, then search subsidy intensity for high and low quality in-house patents. W_{SCE}, $W_{reassignment}$ and W_{NCE} are defined as equation (24). All numbers are in billion RMB, except the average x has not unit.

Figure 1: The Subsidies of Various Pro-innovation Policies by Chinese Central Government



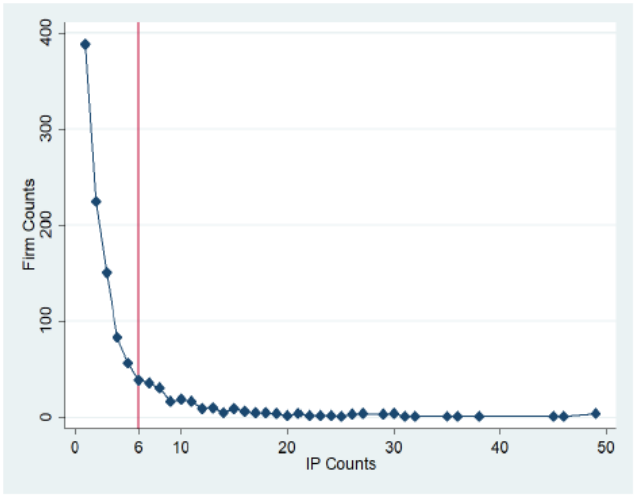
Notes: This figure shows subsidies of various major pro-innovation policies supported by by Chinese Central Government. Source: China Yearbook of Science and Technology 2015.

Figure 2: The Data Structure

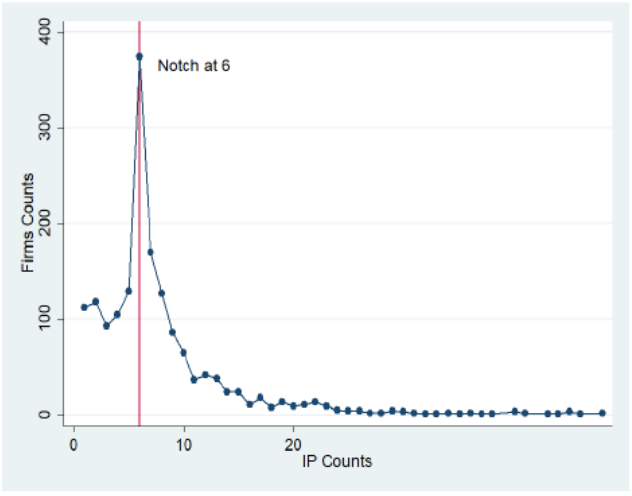


Notes: This figure shows the data structure of the sample.

Figure 3: The IPRs Holding Distribution



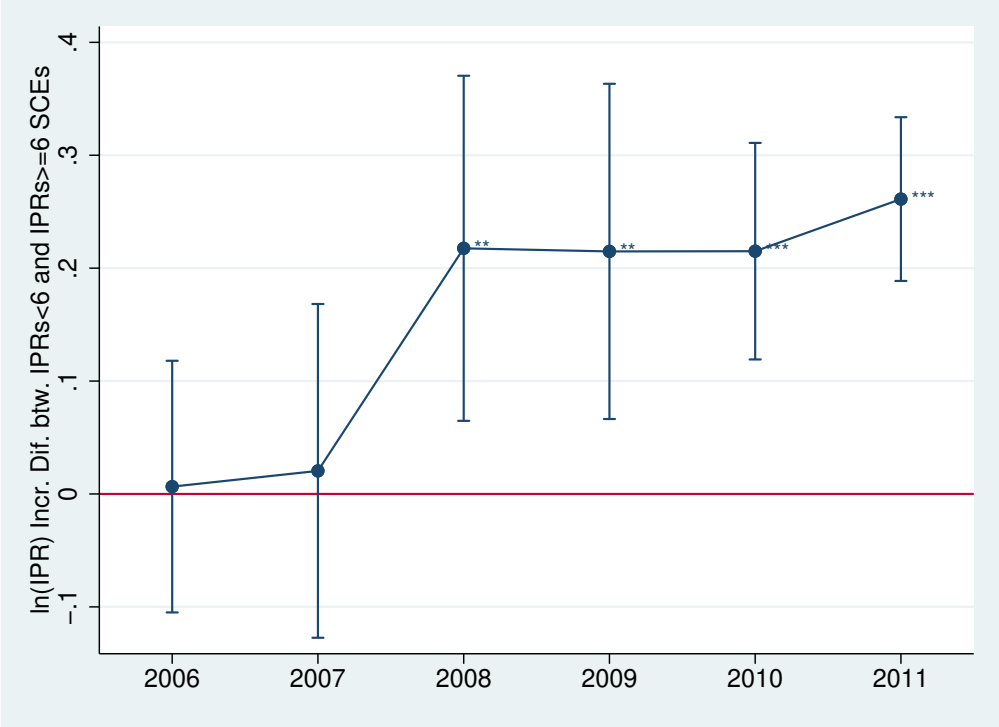
Year 2007



Year 2008

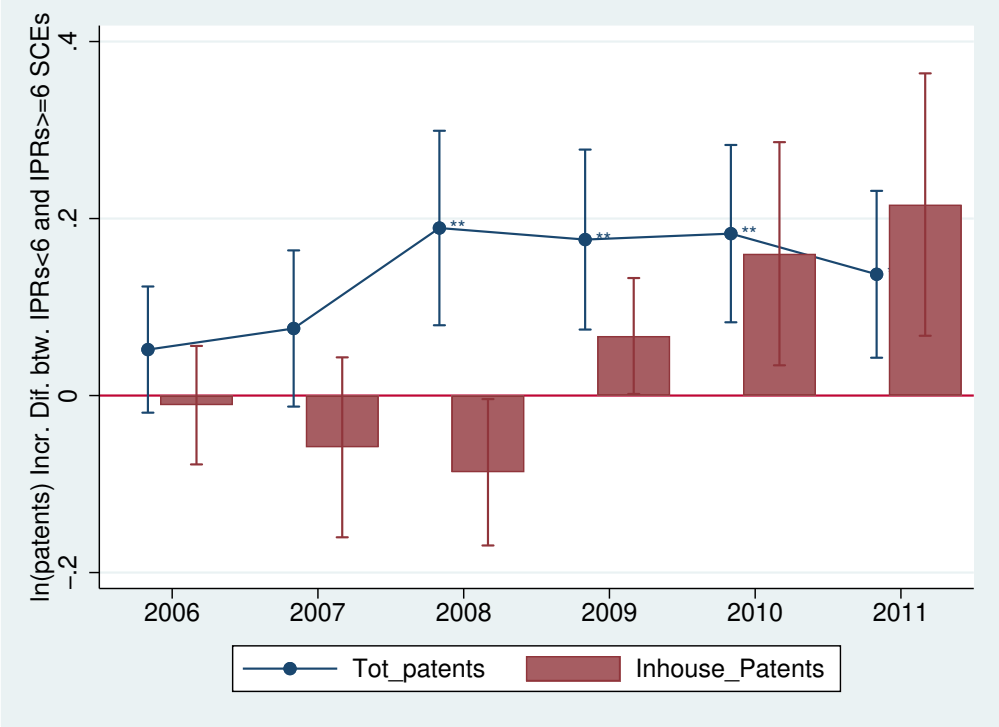
Notes: This figure shows the IPRs (patents and software copyrights) holding distributions of the subsidized firms in Beijing in year 2007 and 2008.

Figure 4: New IPRs of SCEs with IPRs<6 over Years



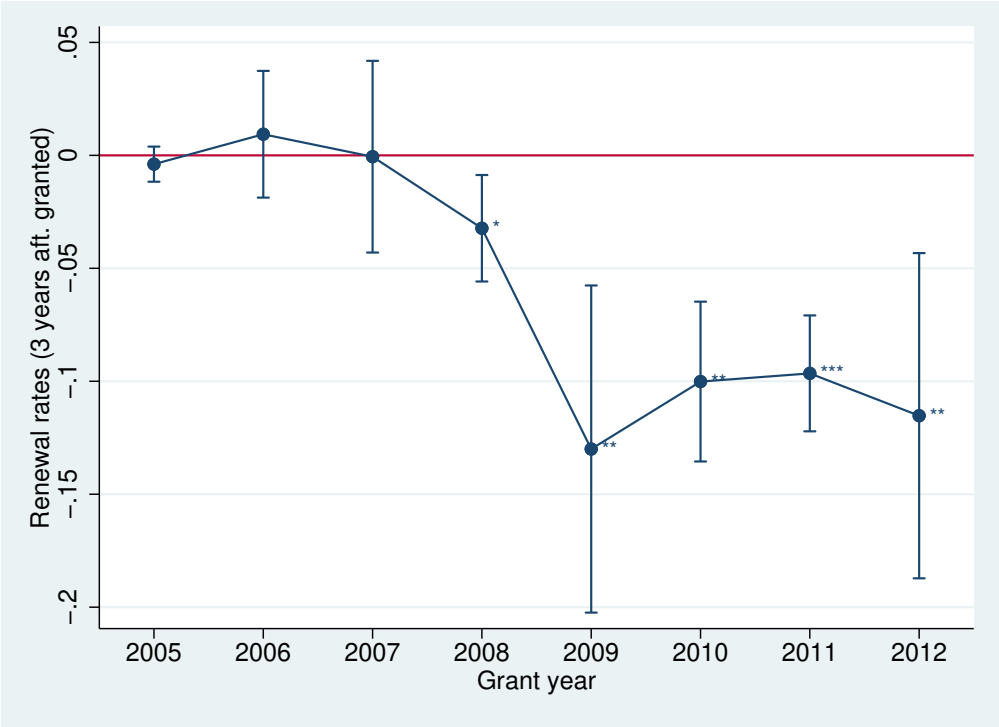
Notes: This figure shows estimates of α_3 in equation (1) by years. The circles indicate point estimates of α_3. New IPRs of SCEs with IPRs$\geq$6 is normalized to 0 in each year. Capped spikes represent 90% confidence intervals.

Figure 5: New (in-house) Patents of SCEs with IPRs<6 over Years



Notes: This figure shows estimates of α_3 in equation (1) by years using $ln(patents)$ (circle) and ln(in-house patents) (red bar) as dependent variables. New patents of SCEs with IPRs≥6 is normalized to 0 in each year. Capped spikes represent 90% confidence intervals.

Figure 6: Renewal Rates of Patents 3 Years after Granted



Notes: This figure shows the average renewal rates of patents 3 years after granted from 2005 to 2012. We have controlled the IPC code and patent types (invention/utility/design) in the estimation. The renewal rates in 2004 is normalized to 0. Capped spikes represent 90% confidence intervals.

Figure 7: Timing

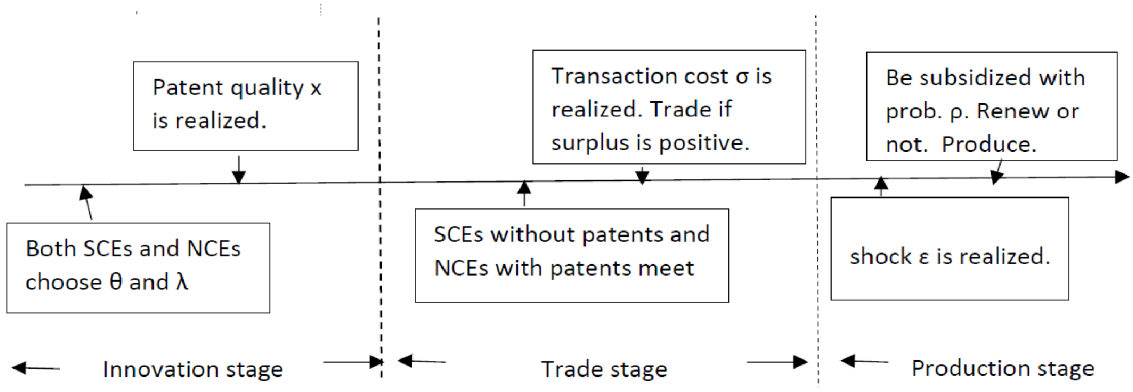
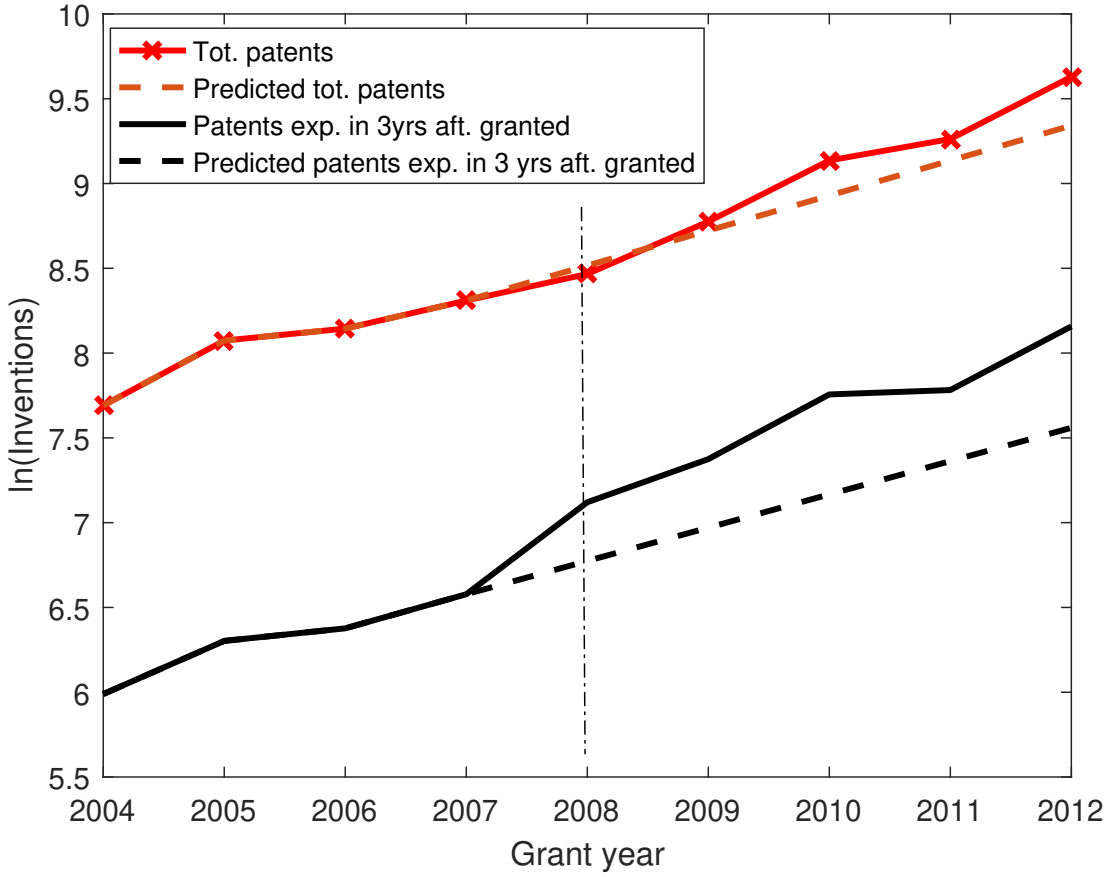
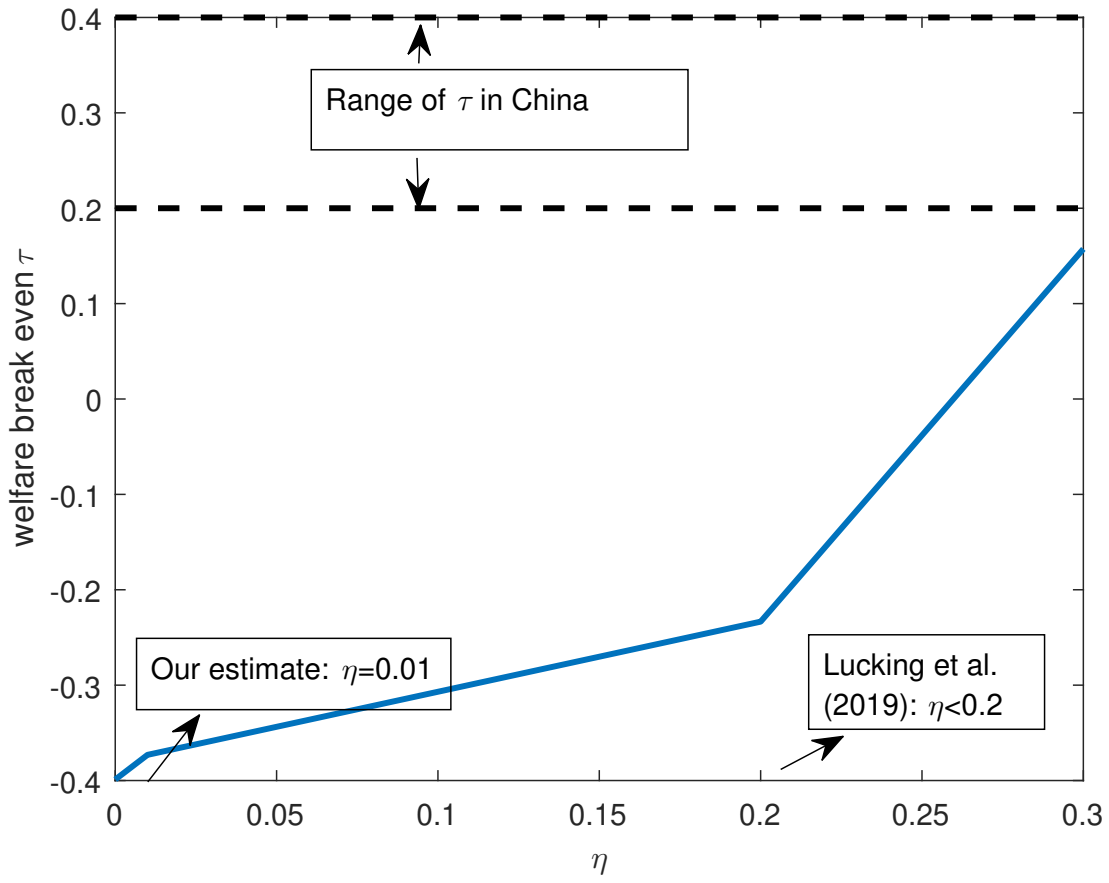


Figure 8: New Granted Inventions across Years



Notes: This figure shows the number of granted inventions from 2004 to 2012. The red line indicates the total number of inventions and the black line indicates the inventions expired in 3 years after granted. The two dashed lines are predicted inventions using pre-2008 trends.

Figure 9: Combinations of social cost of public funding η and technological spillover parameter τ that make InnoCom Program Welfare Neutral



Notes: This figure shows the combinations of knowledge externality parameter η and shadow value of public funding τ that makes the policy welfare neutral (the welfare with and without the policy after 2008 are the same).

Online Appendix (not for publication in print)

A Details of the InnoCom Program

This section has two parts. In the first part, we explains the details on how the InnoCom program evaluates firms. In the second part, we compares the program with other innovation subsidy programs in China.

Table 1 lists the conditions that the firm must satisfy in order to apply for the Innocom program. As we can see, the pre-requirements are based on the R&D-to-sales ratio, the sales of high-tech products, the share of R&D workers, and the number of IP rights (IPRs).

After the application, the local government evaluates the firms based on four parts:the intellectual property rights, the ability to manage R&D, S&T commercialization, and the firm growth. The full marks in the 4 parts are 30, 30, 20, 20 respectively. We explain the grading criteria of the last three categories in Table 2. We can see that for each category, it has 6 levels (A to F). Different levels represent different points the firm can get in that category. The total points of the three categories are 70.

The other 30 points come from the holding of the intellectual property rights. We explain the grading criteria in the first column of Table 2. A noteworthy point is the grading scheme of the IPRs. The firm gets an "A" if they have 6 or more IPRs. Here we emphasize two important points. First, the subsidy program only counts the number of IPRs but does not take into account the quality of the IPRs. Second, the firms do not get any extra points if they have more than 6 IPRs.

Moreover, when the program was first introduced in 2008, the program recognized two ways of holding an IPR: the firm can either be the owner of the IPR (either innovate in-house or purchase from outside) or can hold the IPR under an exclusive license. In other words,

for those patents which the firm borrow from others, the program still count them.

Table 1: Necessary Requirements of the Innocom Program

R&D Intensity	6% if sales $<$ 50 millions of RMB 4% if sales $>$ 50 & sales $<$ 200 millions of RMB 3% if sales $>$ 200 millions of RMB
Sales of High Tech Products	60% of total sales
Workers with College Degree	30% of workforce
R&D Workers	10% of workforce
IP right	Necessary

Table 2: The Grading Scheme of the Innocom Program

Category	Grading Criteria
Ability to transform research projects to business (30 points)	A. Above 4 items (30-24 points) B. 3-4 items (30-24 points) C. 2-3 items (18-12 points) D. 1-2 items (12-6 points) E. 1 item (0-6 points) F. 0 item (0 point)
Research management ability (20 points)	(1) Make research proposals (2) Have R&D expenditure accounting system (3) Co-operate with research institutions (4) Have independent research departments (5) R&D workers' performance evaluation system A. 5 items (16-20 points) B. 4 items (12-16 points) C. 3 items (8-12 points) D. 2 items (4-8 points) E. 1 item (0-4 points) F. 0 item (0 point)
Firm growth (20 points)	Asset growth (10 points) A. $\geq$35% (8-10 points) B. $\geq$25% (6-8 points) C. $\geq$15% (4-6 points) D. $\geq$5% (2-4 points) E. $<$ 5% (0-2 points) F. $\leq$ 0 (0 points) Sales growth (10 points) A. $\geq$35% (8-10 points) B. $\geq$25% (6-8 points C. $\geq$15% (4-6 points) D. $\geq$5% (2-4 points) E. $<$5% (0-2 points) F. $\leq$ 0 (0 points)

B Numerical Details

We assume that x follows a Bernoulli distribution: $x = x_H$ with probability λ and $x = x_L$ with probability $1-\lambda$. And $x_H > x_L$. Furthermore we assume that $C = \frac{v_0}{2}(\lambda\theta)^2 + \frac{v_1}{2}\theta^2$. Then the optimization of the SCE is

$$\begin{aligned} w_S &= \max_{0\leq\lambda_S(z)\leq 1, 0\leq\theta_S(z)\leq 1} \Delta(z)\lambda_S(z)\theta_S(z) + B(q_S,\lambda_N)\theta_S(z) + \frac{q_S}{2}[\lambda_N S^+(z,x_H,\rho) + \\ &\quad (1-\lambda_N)S^+(z,x_L,\rho)] - \frac{v_{0S}}{2}(\lambda_S(z)\theta_S(z))^2 - \frac{v_{1S}}{2}\theta_S^2(z) \end{aligned}$$

where $\Delta(z) = V(z,x_H) - V(z,x_L)$ and $B(q_S,\lambda_N) = V^S(z,x_L) + \rho T(z) - \frac{q_S}{2}[\lambda_N S^+(z,x_H,\rho) + (1-\lambda_N)S^+(z,x_L,\rho)$.

The optimal conditions yield that

$$\theta_S(z) = \max(\min(\frac{B(q_S,\lambda_N)}{v_{1S}}, 1), 0)$$

$$\lambda_S(z) = \max(\min(\frac{\Delta(z)}{v_{0S}\theta_S(z)}, 1), 0) \text{ if } \theta_S > 0; \text{ otherwise } \lambda_S = 0$$

Similarly, the optimization of the NCE is

$$w_N = \max_{0\leq\lambda_N\leq 1, 0\leq\theta_N\leq 1} D(q_N,\theta_S)\lambda_N\theta_N + E(q_N,\theta_S)\theta_N - \frac{v_{0N}}{2}(\lambda_N(z)\theta_N(z))^2 - \frac{v_{1N}}{2}\theta_N^2(z)$$

where $D(q_N,\theta_S) = V(z_N,x_H) - V(z_N,x_L) + \frac{q_N}{2}\sum_z \alpha(z)[S^+(z,x_H,\rho) - S^+(z,x_L,\rho)]$, and $E(q_N,\theta_S) = V(z_N,x_L) + \frac{q_N}{2}\sum_z \alpha(z)S^+(z,x_L,\rho)$. And $\alpha(z) = \frac{(1-\theta_S(z))p(z)}{\sum_z(1-\theta_S(z))p(z)}$ is the share of SCEs with productivity z that are buyers.

Then the optimal conditions of NCE yield

$$\theta_N = \max\left(\min\left(\frac{E(q_N,\theta_S)}{v_{1N}}, 1\right), 0\right)$$

$$\lambda_N = \max\left(\min\left(\frac{D\left(q_N, \theta_S\right)}{v_{0N}\theta_N}, 1\right), 0\right) \text{ if } \theta_N > 0; \text{ otherwise } \lambda_N = 0$$

The free entry condition of NCE can be written as

$$D\left(q_N, \theta_S\right)\lambda_N\theta_N + E\left(q_N, \theta_S\right)\theta_N = C_N\left(\lambda_N, \theta_N\right) + \kappa \tag{28}$$

We can see that an increase of ρ will increase B and E. So $\theta_S\left(z\right), \theta_N$ would increase, and $\lambda_S\left(z\right)$ will decrease. The change of λ_N depends on D. Generally, when ρ increases, D may decrease. So λ_N would decrease.

We can solve the model as follows. For each period, guess δ. Then solve q_S and q_N. Then guess λ_N, solve $\lambda_S\left(z\right)$ and $\theta_S\left(z\right)$. Then we can solve E and D, and we can update the guess λ_N from NCE's optimality policy. Then we can check the NCE's free entry condition to pin down δ. In the end, we need verify the guess of the aggregate productivity.

C Patent trade data

NEED MORE WORK...

Table 3: Budgets of Various Pro-Innovation Policies in China

Programs	Program names in Chinese	Fund in 2015 (Billion)
InnoCom	高新科技企业认定	100
National Natural Science Fund	国家自然科学基金	25.8
State Key Laboratory Construction Program	国家重点实验室	11.5
Key Technologies R&D Program	科技支撑计划	7.0
National Key Basic Research Program of China	国家重点基础研究发展计划（973计划）	2.7
863 Program	863计划	2.0
National Major Scientific Research Program of China	国家重大科学研究计划	1.7
Special Funds for International Technology Cooperation	国际科技合作与交流专项经费	1.4
Innovation Fund for Small Technology-based Firms	科技型中小企业技术创新基金	1.1
National Science and Technology Infrastructure Program	科技基础条件平台专项	0.3
S&T Basic Work	科技基础性工作专项	0.2
Torch Program	火炬计划	0.2
Spark Program	星火计划	0.2
National Engineering Research Centres	国家工程技术	0.1

Table 4: Patent Trade Shares

Seller \ Buyer	SCEs IPRs<6	SCEs IPRs≥6	NCEs
		2006	
SCEs IPR<6	0.008	0.003	0.040
SCEs IPR≥6	0.008	0.001	0.007
NCEs	0.372	0.031	0.533
		2007	
SCEs IPR<6	0.081	0.001	0.016
SCEs IPR≥6	0.045	0.012	0.068
NCEs	0.154	0.020	0.603
		20012	
SCEs IPR<6	0.006	0.001	0.005
SCEs IPR≥6	0.136	0.029	0.056
NCEs	0.328	0.083	0.356

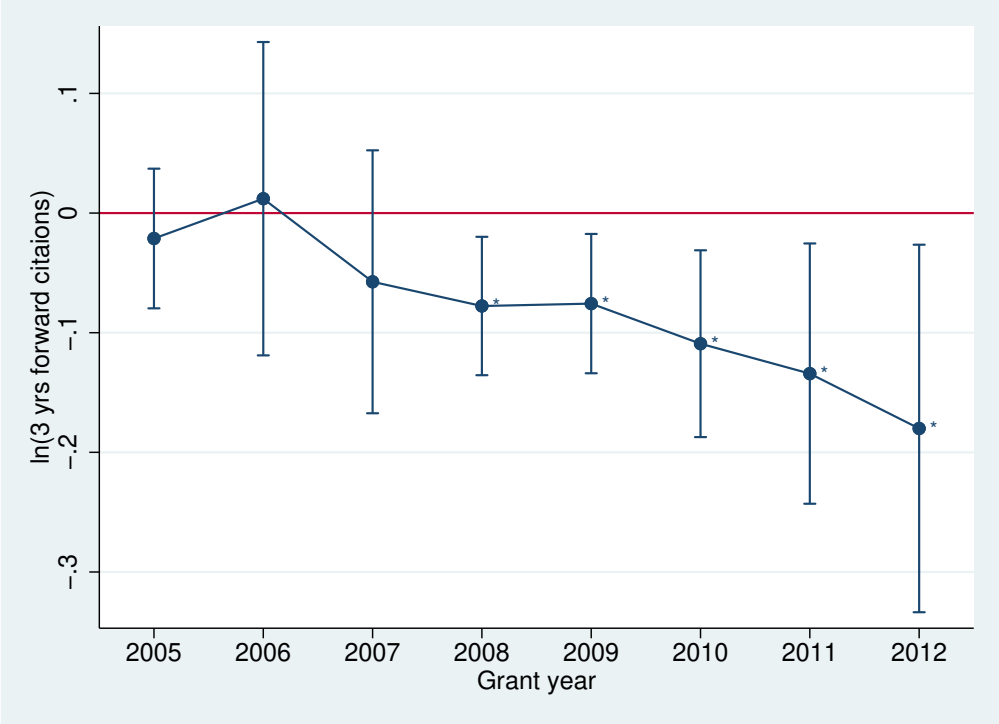
Notes: This table shows the share of patent trade.

Table 5: Coverage of InnoCom Program

Year	No. of new Innocom firms	%. in SCEs	% in 8 Innocom Ind.	Sub. per firm-year
2008	2,470	52%	5%	-
2009	5,167	59%	16%	0.58
2010	6,401	67%	20%	0.53
2011	7,204	72%	33%	0.74
Average	5,860	68%	21%	0.618

Notes: This table shows the number of new InnoCom firms from 2008-2011, and the share of subsidized firms in all SCEs and 8 high-tech industries. The last column shows the annual subsidy (tax return) per InnoCom firm, which is computed using the State Administration Tax Data. The tax information of InnoCom firms in 2008 is missing.

Figure 10: 3 Years Forward Citations of Patents



Notes: This figure shows the average ln(3 years forward citations) of patents granted from 2005 to 2012. The citation in 2004 is normalized to 0. Capped spikes represent 90% confidence intervals.