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PACIFIC TRADE AND DEVELOPMENT WORKING PAPER SERIES

Paper No. YF36-03

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ACKNOWLEDGEMENTS:

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1 Introduction:

On 9 February, 2006 the State Council published the "National Medium- and Long-Term Program for Science and Technology Development (2006 – 2020)", which reflects China's ambition to be transformed into one of the world's most important knowledge sources.[1] In this program, the Chinese government emphasizes the role of indigenous innovation and also the importance of R&D activities performed by business enterprises. The guiding principles for science and technology work over the next 15 years are to "innovate independently, achieve development in selected areas by leaps and bounds, support development and guide the future" (Sun and Du, 2010).

While there exist intricate relationships between education, institutional quality, science and technology performance and economic growth, this paper is focused on one question: how will institutional quality impact on China's innovation performance? This question is fundamentally important. There has long been the debate about how China has grown so rapidly despite its relatively low institutional quality (Huang 2008). While much of the economic growth literature views institutional quality as a fundamental determinant of economic growth and development (Hall and Jone 1999, Acemoglu et al. 2001, 2002, 2005a, 2005b) and views factors such as physical capital accumulation, human capital accumulation and technological progress as growth itself, China's growth performance in the past three decades seems to be an outlier of what the theory predicts. In fact, Allen et al. (2005) regard China as a counter-example to the existing literature on law, institutions, and growth. However, one reason why China has been able to be an outlier in the past thirty years could be that China’s level or stage of development during this period has been one that relies less on institutional quality compared with an economy that is nearer to the world technology frontier and strives to innovate by itself.

[1] Plans related to science and technologies are not new to China. For an introduction to China’s innovation policy, Hutschenreiter and Zhang (2007), Serger and Breidne (2007) and Sun and Du (2010) provide good references.

This paper will add to our understanding of China's innovation prospects by examining how variations in institutional quality within China impact on the R&D efforts of firms located in various provincial regions. The identification strategy exploits regional variation in the quality of institutions to answer the question: how will institutional quality impact on China's innovation performance? More concretely, will firms invest more in R&D in regions where the institutional quality is higher? If the answer is positive, institutional quality will certainly be a key to the realization of China's science and technology take-off. In order to identify the effect of institutional quality, it is necessary to control other factors that could influence firm-level R&D efforts in the analysis. Therefore, in addition to its focus on institutional quality, this study will provide a thorough analysis of the determinants of R&D activities by Chinese firms. While the importance of institutional quality for R&D investment is relatively well understood in the literature as discussed in Study 1, the responsiveness of institutional quality to firms' need to conduct R&D investment is less noticed, yet critical as well. Nee and Opper (2012) argue that "the rise of capitalist economic institutions rests on bottom-up entrepreneurial action. Informal economic arrangement enabling, motivating, and guiding start-up firms provided the institutional foundations of China's emergent capital economic order". Whether institutional quality improvement predates an innovative economy or not has deep implications for the proper policies to be adopted if China hopes to transition from imitation to innovation. This study tackles the issue by taking into account potential endogeneity of institutional quality in the robustness analyses.

In summary, I will examine whether higher institutional quality promotes firm-level innovation empirically by taking into account the potential endogeneity of institutional quality. In the next section, we will first look at how various provinces perform in terms of overall R&D intensity and R&D intensity of large- and medium- sized enterprises. This section will provide us with information about the provincial variation of R&D investment and sets the stage for the firm-level econometric analyses. Section 3 discusses the determinants of firm-level R&D intensity. The way of constructing the data used in this study will be explained in Section 4, followed by the econometric specification and difficulties in the estimation procedure in Section 5. We will then present the baseline results and robustness checks in Section 6. Finally, conclusions will be made in Section 7.

2 R&D investment: provincial variation

As shown in Figure 1, China's national R&D expenditure at current prices has experienced continuous and accelerating growth in the last two decades. While China's annual GDP growth rate during the period 1990-2010 was 10.4 percent (Lin, 2011), the growth of national R&D expenditure has been at a faster rate and therefore the national R&D intensity (share of R&D expenditure in GDP) of China has been increasing as well (Figure 2). The "National Medium- and Long-Term Program for Science and Technology Development (2006 – 2020)" sets an R&D intensity goal of 2.5% by 2020, a level similar to that of the higher-income countries such as the U.S., Japan and South Korea (Fisher-Vanden and Ho 2006).

One interesting angle for examining China's "science and technology take-off'" (Gao and Jefferson 2007) is to look more closely at the performance at the provincial level. Through the analysis of variation in regional R&D performance, one may gain deeper knowledge about the forces behind the changing R&D intensity and thus help identify policies that regions with weaker R&D performance could adopt to boost their R&D performance.

Figure 3 and Figure 4 show the intramural R&D expenditure in China's 31 provincial regions in 1999 and 2010 respectively. While there are considerable variations among the Chinese regions in their R&D expenditure in both years, one interesting observation is that compared with 1999 in which Beijing is the single pole of R&D expenditure, by 2010 several wealthy eastern provinces such as Guangdong, Shandong and Zhejiang had caught up with Beijing, while Jiangsu province had even overtaken it. While Figures 3 and 4 inform us of the changing amount of R&D expenditure in various regions, Figure 5 presents changes in R&D intensity[2] in various regions from 1999 to 2010. During this period, China's national R&D intensity increased by about 1% (Figure 2), but with significant variation across provinces (Figure 5). Tianjin, Zhejiang, Shanghai and Jiangsu realized rapid increases in R&D intensity of about 1.5%. In contrast, the R&D intensity in Hainan decreased and that in Shaanxi barely changed.

China's "National Medium- and Long-Term Program for Science and Technology Development (2006 – 2020)" not only emphasizes the growth of R&D intensity, but also proposes that business enterprises should become increasingly important as the entities that perform R&D. How do the various regions perform in this dimension? To answer the

[2] R&D intensity is calculated as the ratio between provincial intramural R&D expenditure and provincial GDP in a year.

question about business enterprises' R&D performance, I utilize statistics for large and medium-sized enterprises reported in the China Statistical Yearbook on Science and Technology. Figure 6 illustrates the share of large and medium-sized enterprises' intramural R&D expenditure in total regional R&D expenditure in 1999 and 2010 respectively and also the change of the share between these two years. Among the 31 regions, 25 regions saw their large and medium-sized enterprises' intramural R&D become more important in total regional R&D. In Hubei, Tianjin, Henan, Hunan, Inner Mongolia, the share of large and medium-sized enterprises' intramural R&D in total regional R&D grew by more than 20% between 1999 and 2010. In contrast, in Hainan, this share decreased significantly from 50% to 26%; in Ningxia, Qinghai, Guizhou, Fujian and Guangdong, the respective shares began from more than 70% in 1999 and yet shrank from the original high level. Interestingly, large and medium-sized enterprises' R&D share in Beijing was very low at only 13% in 2010 and higher only than the share in Tibet.

In order to have regional R&D intensity and the importance of enterprise R&D grow at the same time, it is fundamentally important that business enterprises will allocate a larger share of resources towards research and development activities. We can see the changes of the R&D intensity of large and medium-sized enterprises from 1999 to 2012 in Figure 7. Due to the fundamental importance of firm-level R&D intensity, the focus of this study is to find out the determinants of R&D intensity of large and medium-sized enterprises in China using a firm-level dataset. Researchers have investigated various factors that may induce Chinese firms to carry out R&D activities (Hu, Jefferson and Qian 2005, Liu and Buck 2007). However, this literature has not provided a rigorous study on the importance of institutional quality of the economic environment where the firms are located on firm-level R&D activities. Hence, this paper examines whether institutional quality plays a critical role in enhancing Chinese firms' R&D intensity.

3 Determinants of firm-level R&D intensity

In this section, we first focus on the channels through which institutional quality of the economic environment a firm operates in can influence firm-level R&D activities. We then explain the determinants of firm-level R&D intensity other than institutional quality.

The channels through which institutional quality influences firm-level R&D activities are as follows. First is the impact of institutional quality on firms' external financing. Some studies show that sound legal systems and efficient financial infrastructures can facilitate firms' access to external finance and thus their ability to fund investment projects (La Porta et al. 1997, Demirguc-Kunt and Maksimovic 1999, Beck and Demirguc-Kunt 2006). Second is the impact of institutional quality on firms' internal financing. Cull and Xu (2005) find that Chinese firms exposed to a greater risk of expropriation by government have a lower reinvestment rate. Lin and Wong (2012) also provide evidence that the provision of good-quality institutions and services by government is positively associated with a firm's investment and sales growth. Third, the characteristics of innovation activities as a form of investment make them particularly sensitive to institutional quality. Jorde and Teece (1990: pp.76) argue that "Innovation...involves uncertainty, risk taking, probing and re-probing, experimenting, and testing. It is an activity in which "dry holes" and "blind alleys" are the rule, not the exception". Kaasa, Kaldaru and Parts (2007) also regard risks and uncertainties as defining characteristics of innovation since technological development is full of unforeseeable contingencies. Hence, they emphasize the importance of formal laws and regulation introduced by the state to help reduce the risk and uncertainty of innovation faced by firms.

One of the key aspects of formal laws and regulation that affects sustained R&D investment and innovation is the strength of intellectual property rights (IPR). It is not clear yet whether the strengthening of intellectual property rights promotes or retards technological progress. The relationship between the strength of a country's IPR regime and technological progress is ambiguous from a theoretical standpoint, reflecting the variety of channels through which technology can be acquired and their differing importance at different stages of development (Falvey, Foster and Greenway, 2006). For example, Furukawa (2007) finds that tightening of IPR decreases the productivity of the final goods sector and the associated demand for innovation. Manca (2010) finds that the tightening of property rights reduces the ability of countries to achieve technological catch-up. And the negative effect is stronger the farther away the countries are from the frontier. Yet, Kwan and Lai (2003) argues that there is an optimal level of IPR that balances out the loss in current consumption and the gain in consumption growth caused by higher investment in R&D in the face of tightening of IPR. Falvey, Foster and Greenway (2006) show that IPR protection is positively and significantly related to growth for low- and high-income countries, but not for middle-income countries.

The rationale for this finding is that although IPR protection encourages innovation in high-income countries and technology flows to low-income countries, middle-income countries may benefit less because of the reduced scope for imitation.

There are also works that support that importance of strengthening IPR to technological progress. For example, in the Romer (1990) model, firms engage in R&D in order to invent new varieties of intermediate goods and obtain their patent rights. When the patent is enforced, the innovation is produced by the inventor under monopolistic conditions and the inventor enjoys monopolistic profit from the innovation output; if the patent is not enforced, the commodity can be imitated and produced by firms on a competitive fringe and, in this case, the innovator receives no profits. While the Romer (1990) model applies to countries at the world technology frontier that rely on innovation for economic growth, there is also a literature that pays attention to how an economy moves from a pure imitation regime to an equilibrium with private R&D. Eicher and García-Peñalosa (2008) show that those countries with initial institutions above a threshold converge to the high-growth/strong-institutions equilibrium with private R&D, and those starting below the threshold will move to the no-growth/ no-IPR protection equilibrium. Moving from the no-growth to the high-growth equilibrium with private R&D is shown to require the adoption of sufficiently strong institutions that overcome the institutional threshold defined by the low growth equilibrium.

Now consider other determinants of firm-level R&D intensity. First, it is recognized in the literature that government subsidy may play a role in firm-level innovation activities. For example, Zúñiga-Vicente et al. (2012) maintain that the use of public funding to foster private R&D activities is common in many countries. They cite the statistics from Eurostat (2009) that the public share in R&D activities from the mid-1990s to the mid-2000s was about 35% in the EU27, 30% in the United States and 18.5% in Japan. A sizable amount of these public R&D funds is actually used to subsidize R&D activities undertaken by private enterprises. Hence, the share of subsidy in industrial sales is a potential determinant of Chinese firms' innovation activities.

Second, the availability of financial funds will impact on R&D activities of firms as well. Financial constraints may be particularly restrictive for R&D investment compared with other forms of investment. According to Unger and Zagler (2003), basic alternatives for innovation financing include internal finance (out of profit) and external finance (credit-based or equity-financed systems). Prior work on investment financing at the firm level has demonstrated that firms first resort to internal funds in order to maintain control rights over their innovations. When additional capital to fund R&D expenditure is needed, they turn to external funds, first accessing bank credit and then equity markets (Maskus, Neumann and Seidel 2012). One reason for the priority of internal finance could be that firms with high R&D expenditure tend to have few tangible assets that can serve as collateral for credit. R&D expenditures largely go to salaries and wages for scientists and researchers, which are human capital investment that cannot be collateralized (Brown et al. 2009). Furthermore, firms may be unable or unwilling to offer sufficient information about their intended R&D programs to potential funding providers due to the need to protect their proprietary information over innovation (Maskus, Neumann and Seidel 2012), which adds to the financial restriction of R&D intensive firms. In order to examine the effect of financial constraints on firms' innovation activities, the share of profit in industrial sales, total debt to total assets ratio and the share of interest payment in industrial sales are included in the regression as potential determinants of firm R&D activities.

Third, closely related to the problems relating to financial constraints are issues about firm size, market structure and firm innovation activities brought into mainstream economics by Schumpeter. He argued that large firms operating in a concentrated market are the main engines of technological progress. Symeonidis (1996) explains the seven reasons behind Schumpeter's argument. They included the ability of large firms to cover the large fixed costs of R&D projects, scale and scope economies in the production of innovations, larger firms' better position to exploit unforeseen innovations, their stronger ability to spread the risks of R&D by undertaking many projects at one time and better access to external finance. As for firms with greater market powers, these firms are in a better position to finance R&D from their own profit. They also have more incentive to innovate because they can appropriate the returns from innovation more easily. In this study, the number of employees, share of firm sales in the total sales of firms in the same four-digit industry and the four-digit industry level Herfindahl Index are included in the regression as proxies for firm size, market power and market structure respectively.

Fourth, there is evidence in the literature that R&D-intensive firms have, on average, higher wages. Mishra and Smyth (2012) list the four possible explanations for how the positive relationship between R&D intensity and wages should be understood: first, there exists a higher demand for workers in particular occupations or with particular skills in firms with higher R&D intensity; second, there exists a higher demand for the innate ability or other unobserved characteristics of more educated workers in firms with higher R&D intensity; third, there exist quasi-rents generated by R&D intensive firms to be shared with workers with certain characteristics; fourth, firm size of R&D-intensive firms is larger since investing in R&D is likely to involve large fixed costs and wage premium is positively related to firm size. Therefore, the average wage of employees of a firm is included in the regression analysis of this study.

Fifth, firm age could exert two distinct impacts on R&D. Although Loderer and Waelchli (2009) are not focused on the relationship between firm age and firm R&D, the two different age effects are clearly explained by them. On the one hand, age could help firms become more efficient since firms discover what they are good at and learn how to do things better over time. On the other hand, older age may also make knowledge, abilities, and skills obsolete and induce organizational decay. On balance, it is therefore unclear whether a higher firm age helps a firm innovate or whether it burdens them –an empirical question I will address in the regression analysis below.

Sixth, a firm's export participation may affect its R&D activities as well. This could be because exporting requires prior R&D innovation (Yu and Dai 2013) and innovation can help a firm maintain a competitive advantage in international markets over potential competitors (Porter 1990). The causality could also be reversed. It could also be because firms that export to international markets are more likely to be exposed to world knowledge stock and enjoy larger knowledge spillovers, which in turn promotes R&D activities within the exporting firms. As one of the largest exporting countries in the world market, the relationship between trade participation and innovation performance is vital for China's growth prospects. This question will be fully addressed in Study 4 where firm-level production data will be merged with transaction-level trade data. In that merged dataset, we will be able to observe firm-level trade activities such as the number of imported intermediate and capital goods, the unit value of imported good, and the geographical diversification of export markets. Hence we will be able to examine the various channels through which trade activities could impact on a firm's innovation performance in the next study.

Seventh, firm ownership may also have an influence on firm-level R&D activities. Earlier empirical studies have identified a productivity gap between the rapidly expanding non-state sector and state-owned firms (Groves, et al., 1994; Jefferson and Rawski, 1994, Brandt, Van Biesebroeck and Zhang, 2012). It is possible that a firm's R&D performance is affected by a firm's ownership type as well. Since there are information externalities associated with discovering the cost structure of the economy and coordinating externalities in the presence of scale economies, private-firms may underinvest in R&D compared with the socially optimal level (Rodrik 2004). Therefore, government interventions such as the adoption of industrial policies are justified given this potential for market failure. If government intervention takes the form of leaning towards state-owned enterprises rather than subsidizing various types of firms universally, then state-owned enterprises may have higher R&D investment compared with other types of firms. Anecdotal evidence suggests that government support for R&D and resources for R&D are more often channeled towards state-owned enterprises than towards private-owned enterprises in China.

One more reason why state-owned enterprises may be more R&D intensive than private entperises is given in Bruche (2010). The author argues that when it comes to firms' technological catch-up strategy, "business groups" in India are a dominant and appropriate organizational form because they help firms overcome shortcomings in the institutional context of developing countries. These shortcomings include immature capital markets, insufficient contract security or underdeveloped labour markets. Bruche (2010) further suggests that state-owned enterprises in China could be a functional substitute for business groups because state organizations support catch-up strategies through soft loans and preferential access to government sponsored research. However, it should be noted that whether state ownership benefits firms' growth or not depends on how the effect of inefficient resource allocation under soft budget and the effect of efficiency gains from substituting lacking institutions balance out.

Another strand of literature that is relevant to the issue of ownership type and R&D is on the relationship between foreign direct investment (FDI) and R&D. In terms of R&D by foreign affiliates, some studies in this literature find that there is little incentive for foreign firms to undertake innovation efforts since foreign firms have access to parent firms' technology (Kathuria 2008, Beers 2004). Others suggest that foreign affiliates will perform adaptive R&D to modify technologies originated in home countries to suit local conditions in host countries (Cassiman and Veugelers 2003). Therefore, considering these two opposing effects, whether foreign ownership enhances firm-level R&D is an empirical question to be examined.

Finally, as will be explained in the next section, the identification strategy to be used involves the estimation of a selection equation and an outcome equation. This identification strategy requires at least one variable that appears in the selection equation but not in the outcome equation. I adopt a dummy for advertisement as the variable that is included only in the selection equation. The dummy for advertisement is chosen because marketing expenses and R&D expenses are two of the key inputs that firms effectively manage to improve their competencies (Andras and Srinivasan, 2003). Spending on advertising and R&D can both be viewed as forms of investment in intangible assets with predictably positive effects on future cash flows and are therefore related – a necessary condition for this variable choice to be valid (Chauvin and Hirschey 1993).

4 Data

The analysis is based on a firm-level panel dataset of the Chinese manufacturing industry for the period 2005-2007. The data were obtained from the Annual Census of Chinese Industrial Firms compiled by the National Bureau of Statistics of China (NBS). This census provides detailed firm-level financial and operational information for state-owned enterprises and all firms with annual turnover of more than five million RMB. The NBS has requested all these firms to report information to the local statistical offices, which then report to the NBS. The NBS has the final responsibility to process the data and produce the census. This census is considered to be the most comprehensive firm-level dataset ever compiled by the Chinese statistical office, accounting for about 90% of total output in most industries. The NBS has endeavored to maintain consistency in data collection across time, industries and regions (Yi, Wang and Kafouros 2013). Tables 1 and 2 provide a description of the R&D activities of the firms in the dataset from 2005 to 2007.

To measure the institutional quality of China's provincial regions, I adopt the NERI Index of Marketization for China's Provinces published by the National Economic Research Institute (NERI) (Fan, Wang and Zhu 2011). The NERI index is an assessment system for relative progress in marketization for China's provinces (Wang, Fan and Zhu, 2004). It assesses marketization performance in five fields by a total of 23 basic indicators. For a certain field, a field index is calculated as the arithmetic average of a few basic indices. And the arithmetic average of the five indices becomes the overall marketization index. The five fields covered are: 1. government and market relations; 2. development of the non-state enterprise sector; 3. development of the commodity market; 4. development of factor markets; 5. market intermediaries and the legal environment for the market. In this study, two measures of institutional quality are used and they are both from the NERI index system. One measure is the overall marketization index from the NERI index system. The other measure is the basic index for the protection of IPR, which is one of the basic indices that compose the field index for market intermediaries and the legal environment for the market in the NERI index system. Specifically, this basic index for the protection of IPR is based on numbers of patent applications and patent grants per technical personnel in various regions.

The two measures of institutional quality are important in their own right. On the one hand, IPR receives much attention in the discussion about firm's incentives for doing innovation. On the other hand, overall institutional quality will affect the whole production process and hence each firm's ability to enjoy the fruit of R&D investment as well. Therefore, these two measures of institutional quality are both examined in the regression analyses below.

5 Empirical specification and estimation

Based on the discussion about the determinants of firm-level R&D intensity in Section 3, we can now conduct the econometric analysis using the firm-level panel dataset constructed in Section 3. The outcome equation we are interested in is as follows and the selection equation differs from the outcome equation only by one variable $dummy\_advertise_{i,j,k,t}$. This variable only appears in the selection equation.

$$R\&Dintensity_{i,j,k,t} = \beta_0 + \beta_1 * size_{i,j,k,t} + \beta_2 * age_{i,j,k,t} + \beta_3 * profitability_{i,j,k,t} + \beta_4 * exportintensity_{i,j,k,t} + \beta_5 * wage_{i,j,k,t} + \beta_6 * marketshare_{i,j,k,t} + \beta_7 * herfindahl_{j,t} + \beta_8 * debtratio_{i,j,k,t} + \beta_9 * k_{i,j,k,t} + \beta_{10} * subsidy_{i,j,k,t} + \beta_{11} * interestpayment_{i.j,l,t} + \beta_{12} * institutionalquality_{k,t} + \varepsilon_{i,j,k,t} \quad (1)$$

where i denotes an individual firm in a certain four-digit industry, j denotes a certain four-digit industry, *k* denotes a certain province, *t* denotes a certain year.

$R\&Dintensity_{i,j,k,t}$ is the share of a firm's R&D expenditure in its total industrial sales. This is a measure of input into the innovation process. Measures of innovative or technological activity can be classified as measures of either innovation input or output. Measures of innovation output include number of patents, number of significant innovations, and various indices of market value of innovations. The most frequently used measures of inputs into the innovation process are R&D expenditure and personnel involved in R&D (Symeonidis 1996). Since there is no information about innovation output in our dataset, R&D intensity is adopted as the measure of innovative activity here.

$size_{ij,k,t}$ is the natural logarithm of the number of employees in a firm.

$age_{i,j,k,t}$ is the number of years of existence of a firm.

$profitability_{i,j,k,t}$ is the share of profit in total industrial sales of a firm.

$exportintensity_{i,j,k,t}$ is the share of export value in total industrial sales of a firm.

$wage_{i.j,k,t}$ is the average wage of the employees in a firm, i.e. the sum of wage compensation and welfare compensation divided by the number of employees in a firm.

$marketshare_{i,j,k,t}$ is the share of the industrial sales of a firm in the industrial sales of all firms in the same four-digit industry.

$herfindahl_{j,t}$ is the four-digit industry-level Herfindahl Index. This is calculated as the sum of squared market shares of all the firms in the same four-digit industry. The range of Herfindal Index is between 0 and 1 with 0 denoting perfect competition where each firm's market share is infinitesimally small and 1 denoting monopoly where one firm takes up the whole market.

$debtratio_{i,j,k,t}$ is the share of a firm's total liabilities in its total assets.

$k_{i,j,k,t}$ is the net value of fixed assets per employee in a firm.

$subsidy_{i,j,k,t}$ is the share of subsidy in a firm's industrial sales.

$interestpayment_{i,j,k,t}$ is the share of interest payment in the industrial sales of a firm.

$institutionalquality_{k,t}$ is the measure of institutional quality (overall or focused on the protection of intellectual property rights) of the province where a firm is located.

$dummy\_advertise_{i,j,k,t}$ is the dummy that takes value 1 if a firm has positive advertisement expenditure and zero otherwise.

The empirical strategy can be summarized as one that relies on provincial variation of institutional quality and locational information of firms to identify the effect of institutional quality on firm-level R&D intensity. Since a firm only reports the location where it registered its capital and there is no information in the dataset about where the R&D activities are conducted, one may argue that a firm may have several subsidiaries across provinces and its R&D activities may be conducted at a different province from where the firm registered its capital. It is possible that what matters for firm's R&D intensity is the institutional quality of the province where R&D activities are performed and not that of the province where the firm registers its capital. If so, without information on the actual site of R&D, the empirical strategy discussed above will not work.

However, I hope to clarify here that this concern is in fact unnecessary and the empirical strategy in this study can address the research question well. The reason is that I am investigating the impact of institutional quality on firm-level R&D intensity from a firm's perspective. The question to be asked is whether the business environment a firm operates in will influence its business strategy about R&D, all other things equal. A firm should be regarded as an organic whole whose R&D investment decisions should be guided by an overall strategy. Wherever a firm locates its R&D activities, the decision of R&D investment is made at the firm level and responds to the business strategy of the firm as a whole. A firm can choose to establish R&D centers in the same province where its headquarter is located or in the most advanced cities such as Beijing, Shanghai, Guangzhou and Shenzhen in order to gain easy access to human capital, business opportunities and information arising because of industrial agglomeration. Furthermore, a firm can also choose to contract its R&D project to universities or public research institutes and even the R&D facilities of other firms. Wherever the location of R&D activities of a firm, the decision is made at the firm - level and serves the profits of the firm as a whole.

Therefore, if we hope to examine how institutional quality could potentially influence firm-level R&D intensity, what matters most is the economic environment that most directly affects a firm's business strategy. The province where a firm registers its capital is undoubtedly the place that most strongly and intensively shapes the firm's business environment. In China, local governments often make efforts to attract firms to register capital and even to establish headquarters and these firms will receive preferential treatments such as import and export convenience and tax exemptions, lower profit tax, subsidized loans and/or cash grants offered by governments. On the one hand, when entering the Chinese market, foreign multinational enterprises will choose in which province to register their capital based on consideration of the local business environment. On the other, large-scale domestic enterprises often move from hometowns and relocate their headquarters to more developed cities and register capital there. Motivated by the ambition to expand market share and to upgrade product quality, such relocation can help a firm tap into developed industrial clusters, communication and infrastructure facilities for commercial and financial activities, science and technology capabilities and market intermediaries. Hence, where to register capital critically determines the business environment a firm will be faced with, which most strongly influence the business strategy about R&D investment Therefore, the empirical strategy in this study is proper and valid.

The difficulty of the estimation of Equation (1) lies in the concentration of the dependent variable $R\&Dintensity_{i,j,k,t}$ on the zero value. It is known that if ordinary least squares (OLS) estimation is used on the non-zero part of the original variable $R\&Dintensity_{i,j,k,t}$, the results could be biased due to the sample selection problem. This problem is made more complex when firms may have unobserved heterogeneity, such as the ability of the entrepreneur. The coexistence of the concentration of independent variable on the zero value and the necessity to take into account firm-level fixed effects requires an estimation strategy that can tackle these two problems at the same time. Previous studies on the determinants of Chinese firm's R&D intensity resort to the random-effects Tobit model for panel data. Although this approach pays attention to the fact that the dependent variable is left-censored at zero value, it also assumes that the possibly omitted firm-specific variables are not correlated with variables included in the empirical specification. This assumption is problematic if, for example, the omitted variable is the ability of the entrepreneur, which influences the R&D intensity of the firm and is potentially correlated with other independent variables such as profitability and market share of the firm.

The estimation strategy suggested by Kyriazidou (1997) solves the sample selection problem and the omitted variables problem due to unobserved firm heterogeneity at the same time and is therefore the strategy adopted here. A two-step procedure is adopted to implement the estimation. In the first step, the coefficients of the selection equation are consistently estimated by the Conditional Logit Estimator. In the second step, the estimates of the coefficients of the selection equation are used to construct the weights needed for the estimation of the coefficients of the outcome equation by weighted least squares. Since the construction of the weights requires a choice about bandwidth, the optimal bandwidth as suggested in Kyriazidou (1997) is adopted. There is no existing command or user written program files available for this estimation strategy and therefore it is necessary that I write it with certain programming software. Since Kyrizaidou (1997) has presented the derivation in matrix form, Mata in Stata is the ideal tool to be used. I write the Mata code for this estimation strategy by Kyriazidou (1997) in the Stata program. The program for estimation in Stata is available upon request.

6 Empirical results

Table 3 presents the descriptive statistics of the sample for the regression. Tables 4 and 5 report the regression results of the empirical strategy explained above. In Table 4, I examine how intellectual property rights protection influences firm-level R&D intensity and in Table 5, the effect of overall institutional quality is considered. It can be seen that the results based on these two different measures of institutional quality are qualitatively similar[3]. Ceteris paribus, a larger firm is more likely to do R&D; a firm that pays higher wages, enjoys higher profitability and has higher export intensity is more likely to do R&D; a firm with a higher debt burden is less likely to do R&D; a firm in which received subsidy is of a larger proportion in the industrial sales is more likely to do R&D; when the protection of IPR (overall institutional quality) is stronger in the province where a firm is located, the firm is more likely to do R&D. Finally, a firm that advertises is also more likely to do R&D.

The influences of these variables on the R&D intensity of a firm that indeed conducts R&D

[3] The only difference is that the coefficient of the variable market_share is significant and negative in Table 4 but not significant in Table 5.

activities are as follows. The larger the size of a firm, the less R&D intensive the firm becomes. If the four-digit industry to which a firm belongs becomes less competitive, the more R&D intensive a firm becomes. The higher the debt burden of a firm, the less R&D intensive the firm becomes. The larger the share of interest payments in the industrial sales of a firm, the more R&D intensive the firm becomes. The larger the proportion of exports in the industrial sales of a firm, the less R&D intensive the firm becomes. The role of the share of subsidy in the industrial sales of a firm is not robust. It is positive and significant at 10% level in Table 4 but insignificant in Table 5. Similarly, the impact of a firm's market share is not robust. It is negative and significant at 5% level in Table 4 but insignificant in Table 5.

Comparing how the variables impact on the likelihood of doing R&D and the R&D intensity of firms, the following four points emerge. First, the market share of a firm, capital intensity of a firm, the industrial concentration of the industry to which a firm belongs and the share of interest payment in the industrial sales of a firm influence the R&D intensity of a firm that conducts R&D activities, but not the decision to do R&D or not. Second, profitability and IPR protection positively influence the likelihood to do R&D but do not significantly impact on the R&D intensity of a firm that has already decided to do R&D. Third, the size of a firm and its export intensity exert the opposite impact on the likelihood of doing R&D or the R&D intensity of a firm doing R&D. Fourth, the wage rate, the debt burden of a firm and the share of received subsidy in industrial sales are three variables that influence the likelihood of R&D and the intensity of R&D in the same direction. Firms that pay a higher wage rate, have less debt burden and receive subsidy are more likely to do R&D and also more R&D intensive once having decided to conduct R&D activities.

Stronger protection of IPR clearly boosts the possibility that a firm will invest in innovation. This finding suggests that China is no exception in terms of the importance of institutions that provide protection for the R&D fruit. If the Chinese government hopes to achieve the goal set in the "National Medium- and Long-Term Program for Science and Technology Development (2006 – 2020)" that firms should become the major agents performing R&D activities, one helpful strategy that the government could adopt is to build up institutions that facilitate the operations of market and strengthen the protection of intellectual property rights (overall institutional quality) that increase the expected return to R&D investment of firms. Interestingly, intellectual property protection (overall institutional quality) does not significantly influence the R&D intensity of a firm that has already decided to do R&D.

This empirical finding suggests that the importance of the protection of IPR probably lies mainly in inducing a phase change of firms from technological imitation to innovation. Once this phase change is completed, the continuous growth of innovative capability may rely on other determinants and dynamics. This finding echoes the empirical result in Stenholm, Acs and Wuebker (2013), who examine how four different dimensions of institutions impact on the rate and type of entrepreneurial activities. They find that the institutional dimensions that determine the rate of entrepreneurial activities (on the quantity side) are distinct from those that determine the type of entrepreneurial activities (i.e., the uality side: replicative entrepreneurship and high-impact entrepreneurship). Innovative, high-quality and high-impact entrepreneurial activities are not positively influenced by regulative, cognitive and normative institutional arrangements but are nurtured by conducive institutional arrangements such as availability of venture capital, access to knowledge spillovers and university-industry collaboration.

As for the relationship between firm size, market structure and firm-level innovation, on the one hand, the findings that a firm of larger size is more likely to do R&D but is less R&D intensive and that a firm's profitability enhances its likelihood to do R&D but not its R&D intensity reflect the complex relationship between firm size, firm profitability and innovation activities; on the other hand, the finding that a firm in a more concentrated industry and a firm with smaller market share are more R&D intensive shows the links between market power and innovation activities. However, the evidence found in this study is not entirely consistent with Schumpeter's argument and it requires further research on the channels behind the results to provide a convincing explanation. While various hypotheses could be made here, I refrain from doing so due to the lack of further evidence about the mechanisms behind the empirical findings.

Regarding the relationship between financial constraints and innovation activities, the finding that a firm with larger debt burden is less likely to do R&D and less R&D intensive supports the hypothesis that internal funds are a critical funding source of firm-level R&D activities. Interestingly, the share of interest payment in the industrial sales of a firm, a variable that reflects the external funding of the firm plays an insignificant role in inducing a firm to do R&D but significantly impacts on the R&D intensity of firms that conduct R&D. The share of subsidy in total industrial sales is found to increase the propensity of a firm to do R&D and to enhance the R&D intensity of a firm that is doing R&D. This finding suggests that the role of government in the "science and technology take-off" of China may be important and how government subsidy influences a firm's investment in innovation and innovation output is a question that is highly relevant in China. Also, the fact that institutional quality matters for engaging firms in R&D activities but not for R&D intensity once firms opt into R&D activities further points to the importance of other potential determinants of R&D intensity.

With regard to the relationship between firm-level exports and innovation, it is found that a firm that has a higher export intensity is more likely to conduct R&D activities although for a firm that is doing R&D, higher export intensity is negatively associated with R&D intensity. In Study 5, I will make an in-depth analysis about the effects of trade participation on firm-level R&D.

Up till now, we have assumed that institutional quality exerts an exogenous influence on firms' R&D activities. However, this assumption may not be valid because institutional quality may be endogenously determined by the need of firms as suggested by Nee and Opper (2012). In this case, firms conduct R&D activities in order to survive in the process of market competition. When more and more firms are engaged in innovation activities, the government's incentive to establish proper institutions to accommodate the changes grows higher. The more active firms are in R&D activities, the higher the institutional quality of the province where the firms are located becomes. Hence, in this process, the endogeneity of institutional quality arises from reverse causality. In order to tackle the potential endogeneity caused by the two reasons discussed above, I resort to an instrumental variable that is correlated with institutional quality but not with firms' decision to do R&D and with regards to R&D intensity.

I follow Li, Wang and Wang (2012) to use the average mortality rate in each province during the great famine in China (1959-1961) as the instrumental variable for institutional quality in the province. As Li, Wang and Wang (2012) argue, a region's inflexible grain procurement policy when faced with the drop in production in 1959 led to a high mortality rate in that region. Furthermore, the inflexibility of policy was related to its weak institutions. Hence, the average mortality rate in the great famine can capture the institutional quality during that time period. Because institutions are path dependent (Acemoglu et al., 2001), a region with weaker institutions in that period (1959-1961) is likely to have a weaker institutions today. Hence, the average mortality rate during the great famine is correlated with institutional quality today.

And unobserved factors that influence firms' R&D activities nowadays should not impact on the average mortality rate at that time. Thus the average mortality rate during the great famine is a valid instrument for institutional quality nowadays.

It is currently not clear how one could make use of instrumental variables to deal with the above endogeneity problem in the estimation strategy of Kyriazidou (1997). In general, the proper way to deal with the endogeneity problem in a censored regression of panel data is not yet mature. Therefore, I resort to cross-sectional data for the year 2007 to examine the endogeneity problem. An instrumental variable Probit model and an instrumental variable Tobit model will be performed on the cross-sectional data of the year 2007[4].

The descriptive statistics of the sample of year 2007 are presented in Table 6. We can see that the descriptive statistics in Table 6 are close to those in Table 3. In Tables 7 and 8, the results of the instrumental variable Probit model are reported. It can be seen that these are similar whether intellectual property rights protection or overall institutional quality is used. In order to deal with firm heterogeneity, the dummies for the four-digit industries and the dummies for the ownership types of firms are included in the model specification. Therefore, the instrumental variable Probit estimation using cross-sectional data for the year 2007 not only provides some evidence about the endogeneity problem but also explicitly shows the effects of ownership types and industry effects on firms' R&D activities. In contrast, we have no information about the influence of ownership types from the main results based on Kyriazidou (1997) because the fixed effects are differenced out both in the selection equation and the outcome equation.

We can compare the second and the third columns of Table 4 (Table 5) with Table 7 (Table 8). Recall that the second and the third columns of Table 4 (Table 5) report the results of the conditional Logit estimation while Table 7 (Table 8) reports the results of the instrumental variable Probit estimation. Hence, the values of the coefficients cannot be directly compared but the signs of the coefficients are comparable. It should be noted that the two measures of

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[4] Probit and Tobit models were also estimated for further comparison. The results are available upon request.

institutional quality are significant and positive in both the baseline estimation and the instrumental Probit model (Table 4, 5, 7, 8). Therefore, the finding that higher institutional quality enhances the likelihood that firms conduct R&D activities is robust across various specifications.

In order to take into account the potential endogeneity problem of the outcome equation, an instrumental variable Tobit estimation is performed on the cross-sectional data of 2007. The deficiency of this approach is that we assume that the selection process and the outcome process are the same. Tables 9 and 10 report the estimation results of the instrumental variable Tobit models. Since the Wald tests of exogeneity of the instrumental Tobit reject the null hypothesis that the ease of doing business index is exogenous at the 1% level, the results indicate that there may be endogeneity problem and the result from instrumental variable Tobit model is reliable. A comparison of these two tables with the fourth and the fifth columns of Table 4 and Table 5 indicates that the two sets of results are not totally consistent since the significance and signs of the coefficients of the variables firm size, age and capital intensity are different. However, we can see that the coefficient of the institutional quality variable is still not significant in the instrumental variable Tobit estimation. This suggests that the finding that institutional quality will not influence the R&D intensity of firms that have already decided to do R&D is a robust one.

The Heckman two-step estimation is the counterpart of the estimation strategy in Kyriazidou (1997) for cross-sectional data. Like the estimation strategy in Kyriazidou (1997), the Heckman two-step estimation involves the estimation for a selection equation and an outcome equation. I perform the Heckman two-step estimation on cross-sectional data of 2007 as a comparison with the Kyriazidou (1997) estimation on panel data. In order to control fixed effects, dummies for industries and dummies for ownership types are included in both the selection equation and the outcome equation in the Heckman two-step estimation.

The results are reported in Tables 11 and 12. The results of the selection equation using Kyriazidou (1997) and those of the selection equation using the Heckman two-step have several discrepancies. However, the results of the outcome equation using Kyriazidou (1997) and those of the outcome equation using the Heckman two-step are very similar. The only two differences are: first, the variable profitability is insignificant for Kyriazidou (1997) (Table 4 and 5) but is positive and significant for Heckman two-step (Table 13 and Table 14);

second, capital intensity is negative and significant in Table 4 and Table 5 but positive and significant in Table 11 and Table 12. When the Heckman two-step estimation is used on cross-sectional data of 2007, it is found that higher institutional quality is significantly and positively associated with the likelihood of firms to do R&D but does not significantly influence the R&D intensity of firms that have already decided to perform R&D. This finding is consistent with the finding of the Kyriazidou (1997) estimation on panel data.

In all the above analyses, the measures of institutional quality in various provinces are from the NERI Index of Marketization for China's Provinces. As a robustness check, I employ the indicator of a business-friendly environment provided by the World Bank Report “Doing Business in China 2008” (the World Bank Group, 2008). This indicator is the ease of doing business index, which is calculated as the simple average of each city’s percentile rankings on each of the four topics covered in the report. These four topics are four areas of business regulation and their enforcement: 1. “starting a business”; 2. “registering property”; 3. “getting credit”; 4 and “enforcing contract”. Therefore, the ease of doing business index can reflect how encouraging regulations are to business activities.

Since the ease of doing business index is for the capital cities in 30 province-level administrative divisions, I need to filter firms located in these 30 capital cities from the original cross-sectional data of 2007. This goal is achieved by using the first three[5] and four digit of the 12-digit address code in the dataset to identify the 30 capital cities.

In both the instrumental Probit and instrumental Tobit model, the coefficient of the ease of doing business index is significant and positive. Since the Wald tests of exogeneity of both the instrumental variable Probit and the instrumental variable Tobit reject the null hypothesis that the ease of doing business index is exogenous at 5% level, the results of instrumental Probit and instrumental Tobit may be more reliable. It should be noticed that the finding that the ease of doing business index is significant and positive in the instrumental Tobit estimation is not consistent with the baseline result. [6]

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[5] In order to identify Shanghai, Beijing and Guangzhou, the first three digits are used. In order to identify the other 27 capital cities, the first four digits are required.

[6] I also performed instrumental Probit, Probit, instrumental Tobit, Tobit and Heckman two-step estimations on the sample of firms in capital cities of in 30 province-level administrative divisions. The instrumental variable used is still the average mortality rate in a province during the great famine. The results are available

One side-product of the above analyses performed on the two sets of cross-sectional data is that we can examine the role of firm ownership type in determining firm R&D activities. Summarizing the findings from various methods performed on the full cross-sectional data of 2007 and the cross-sectional data of firms in the 30 capital cities in 2007, we can see that state-owned enterprises enjoy the highest likelihood to do R&D and the highest R&D intensity. Private enterprises, HMT-owned enterprises and foreign-owned enterprises are less likely to do R&D and are less R&D intensive compared with state-owned enterprises. The finding here support the argument made in Bruche (2012) as discussed above.

7 Conclusion

While some studies argue that China has been able to grow fast despite its relatively low institutional quality (Huang 2008, Allen et al. 2005), the findings in this study suggest that institutional quality is critical for China's innovative performance and hence for the economy's future growth.

This study employed a firm-level panel dataset covering the period 2005-2007 and including all state-owned enterprises and all enterprises with an annual turnover of more than 5 million RMB. Based on the estimation strategy suggested by Kyriazidou (1997), which takes into account the sample selection problem and firm-level fixed effects at the same time, the study shows that higher levels of overall institutional quality and higher levels of IPR protection of the province where a firm is located increase the likelihood that a firm will conduct R&D activities when other potential determinants of a firm's R&D participation are controlled. However, these two measures of institutional quality are not found to be significantly related to a firm's R&D intensity once the firm has already decided to invest in R&D.

These findings suggest that institutional quality at the provincial level positively affects the entry decision of firms into R&D activities. But once firms start to do R&D, the subsequent expansion of firm-level R&D intensity depends on other factors. Therefore, sorting out the domestic institutional quality is just the first step towards the goal of building a knowledge-intensive economy, becoming a global R&D player and contributing to the world

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upon request. The results are mostly consistent with the corresponding estimation results for the cross-sectional data of the year 2007 where the NERI index system is adopted for measures of institutional quality.

pool of knowledge and technology. A better understanding of other factors that influence the R&D intensity of firms after they begin to invest in R&D is important for ensuring continuous growth of the firms' innovative capabilities.

For example, trade-related factors could be very important for the R&D intensity of firms since there are complex relationships between trade and innovation suggested by the existing literature. Although export intensity, the only trade-related factor in this study, is found to enhance a firm's likelihood of doing R&D but reduce the R&D intensity of the firm, we will need more trade-related measures for a complete study on the effects of firm-level trade or innovation. This remains the task of Study 4.

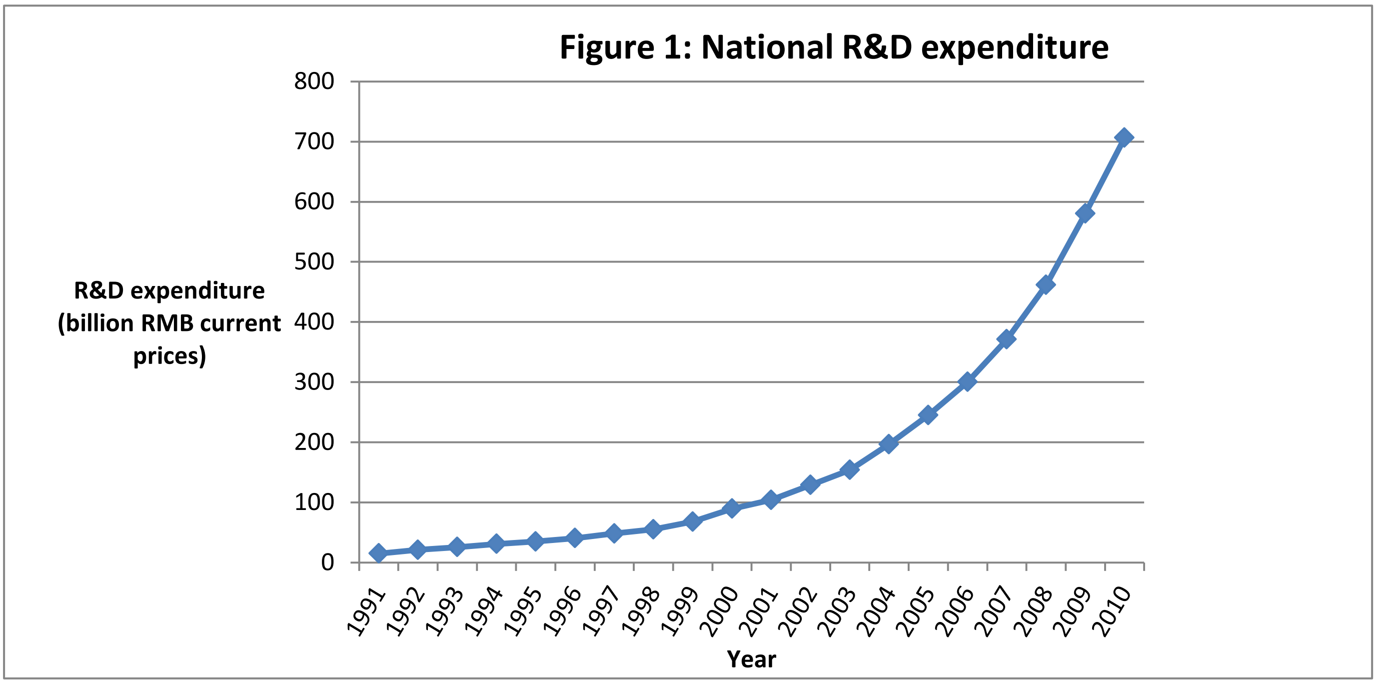


Figure 1: National R&D expenditure

Source: China Statistical Yearbook on Science and Technology (various issues)

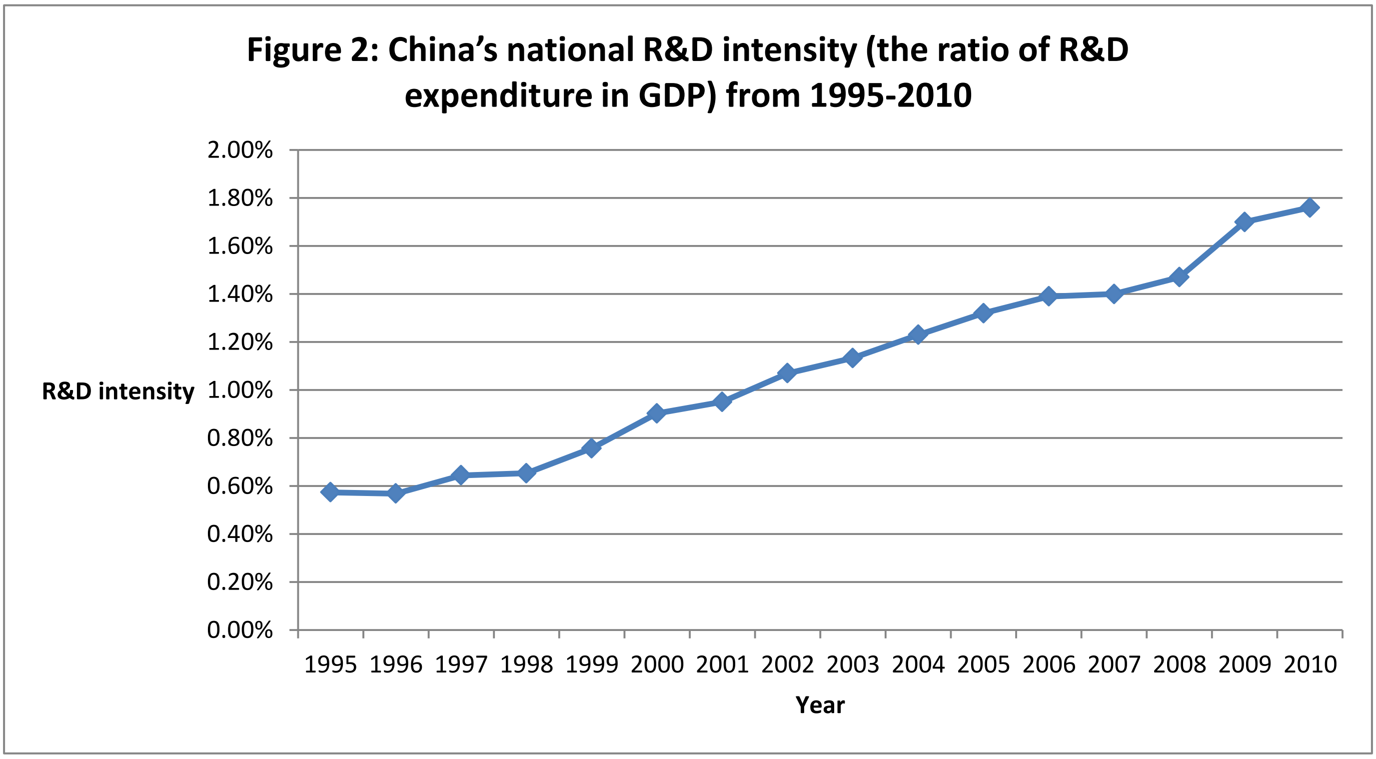
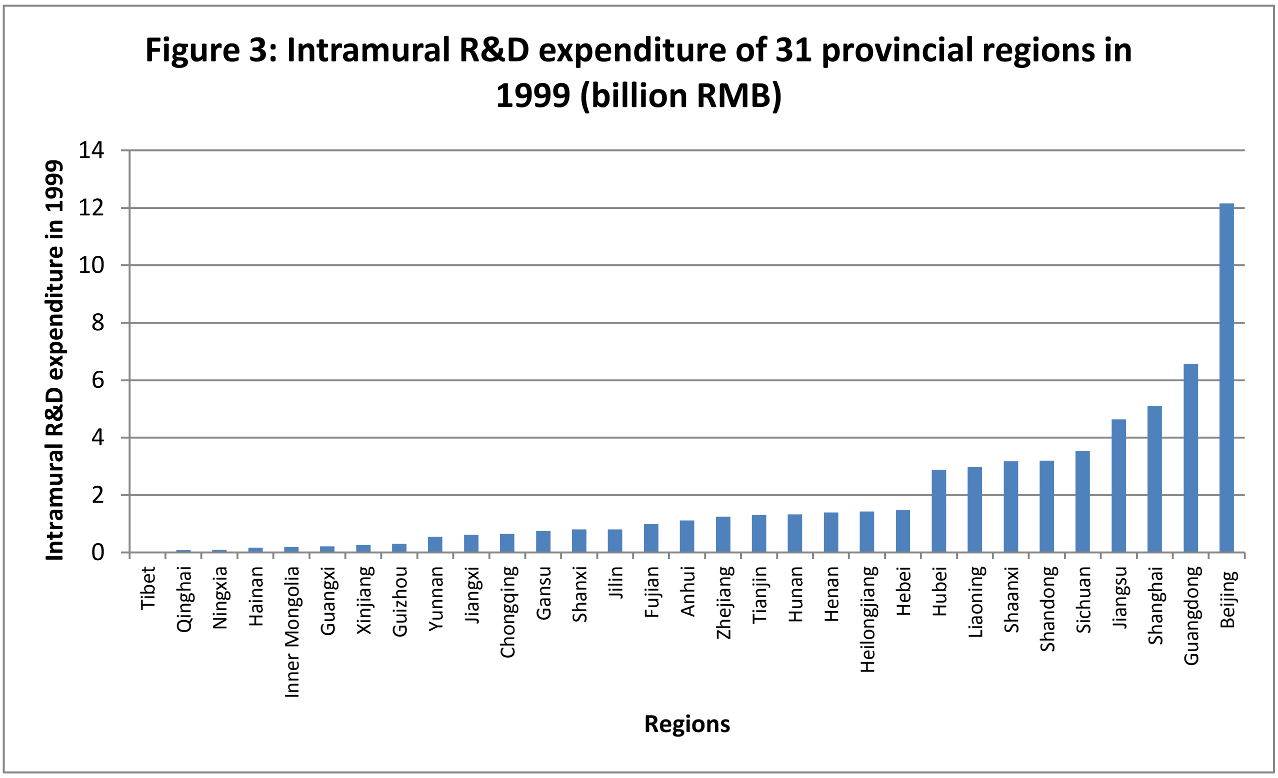
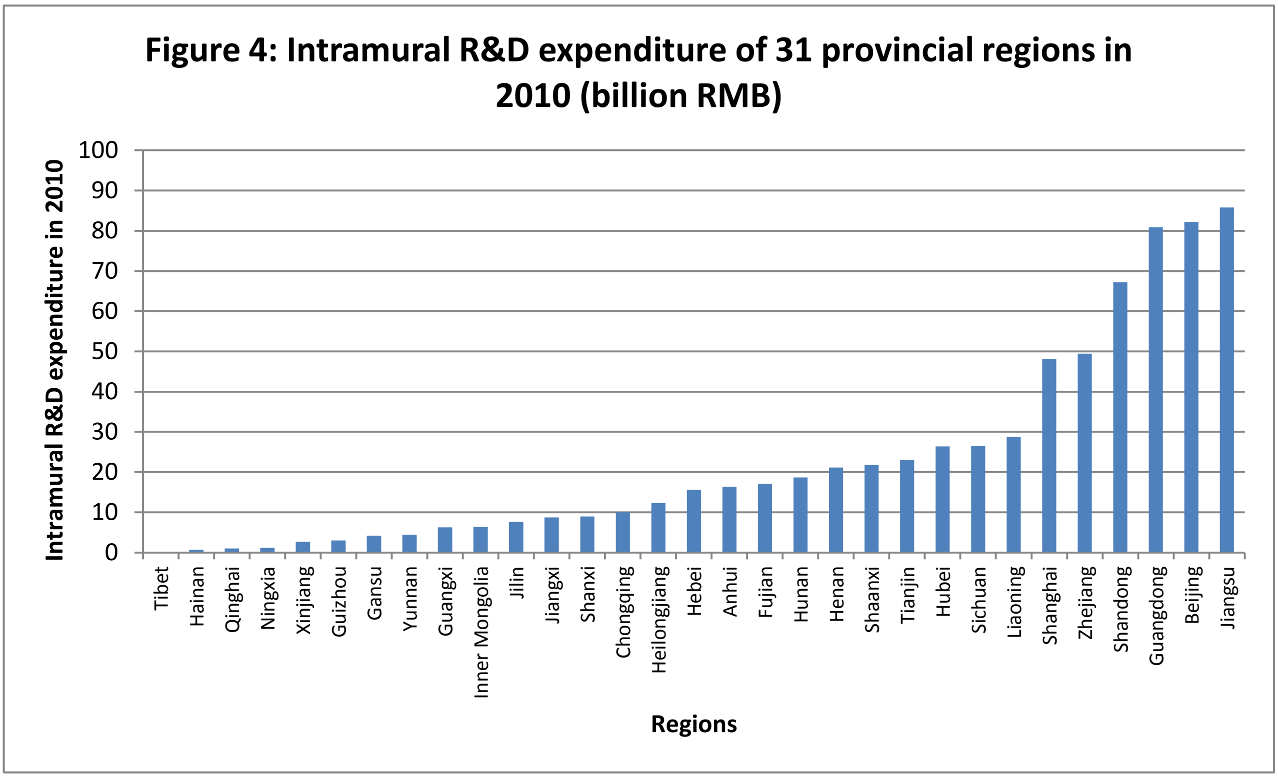


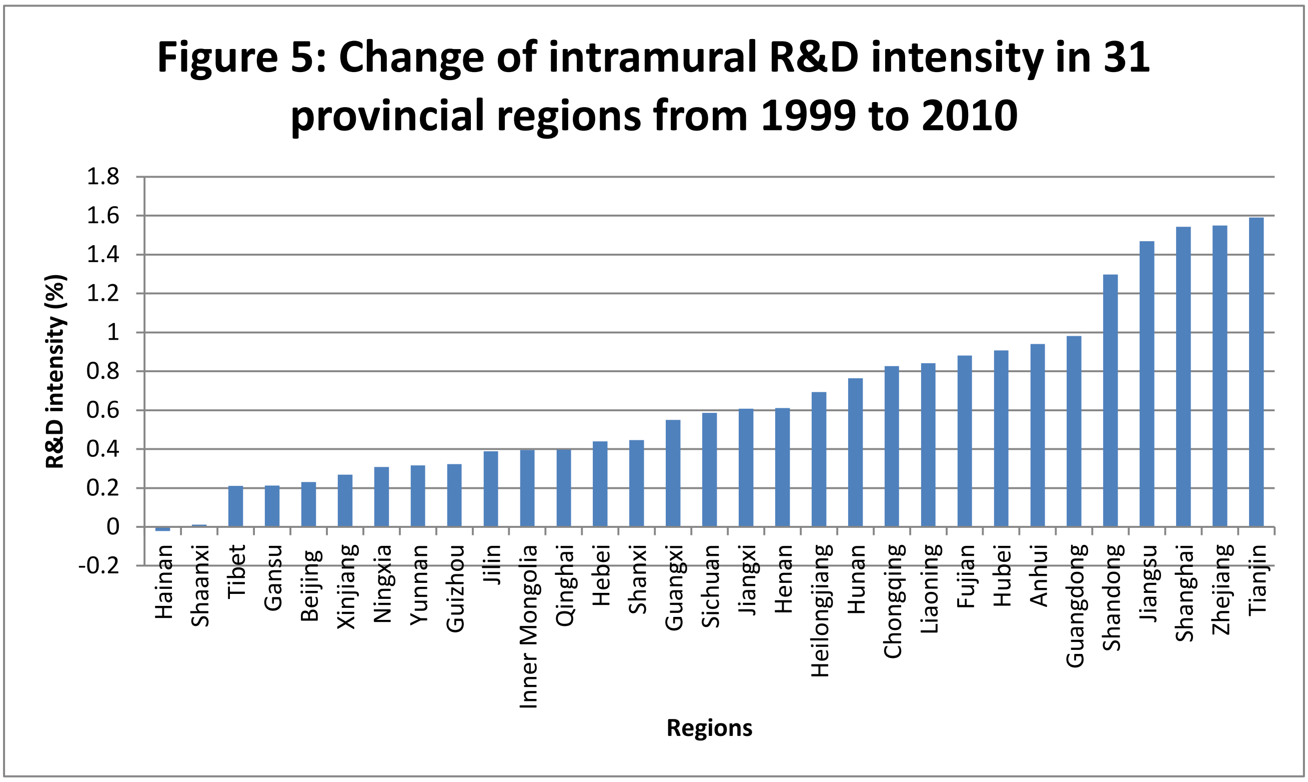
Figure 2: China’s national R&D intensity (the ratio of R&D expenditure in GDP) from 1995-2010

Source: author's calculation based on data from China Statistical Yearbook on Science and Technology (various issues)



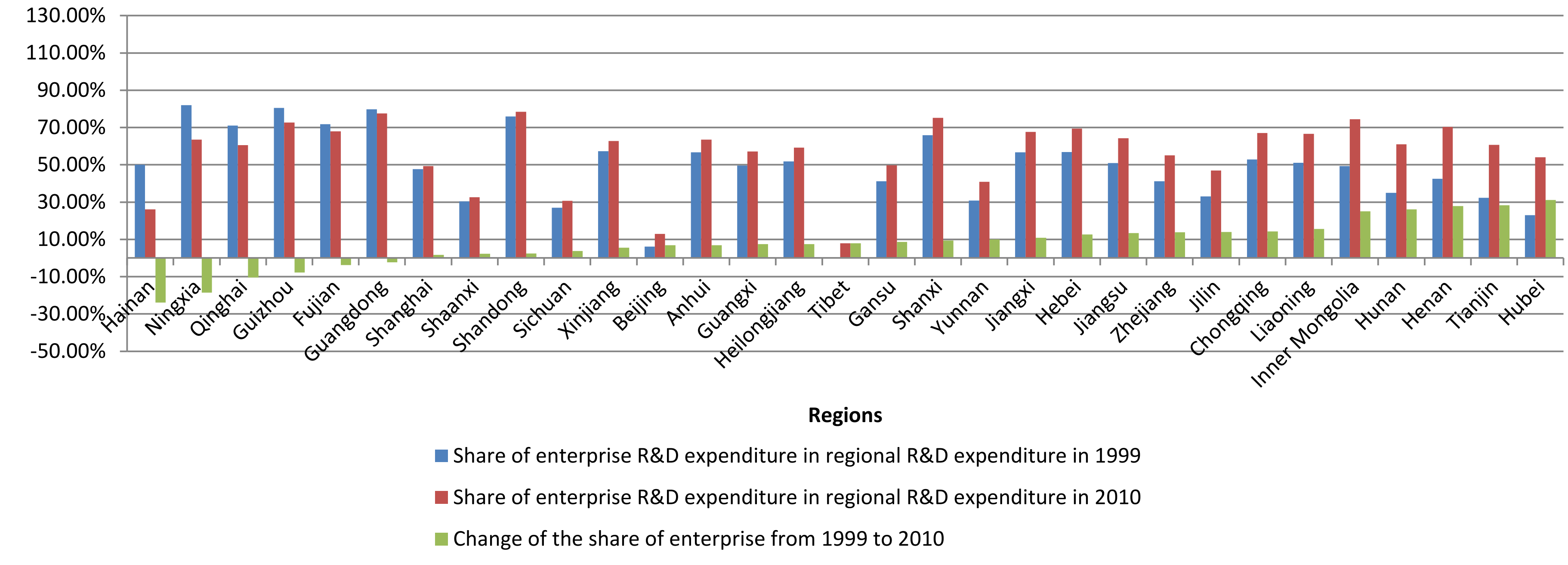


Source: China Statistical Yearbook on Science and Technology (2000, 2011)



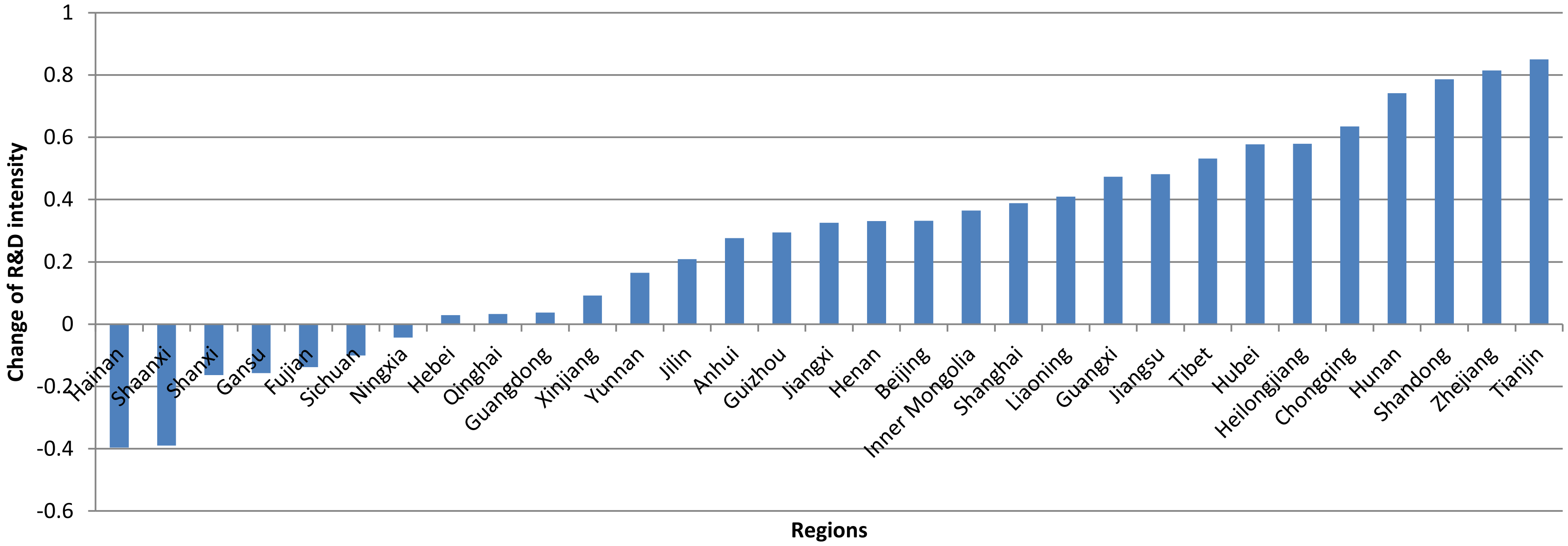
Source: China Statistical Yearbook on Science and Technology (2000, 2011)

Figure 6: Share of large and medium-sized enterprise R&D expenditure in regional R&D expenditure in 1999 and 2010 and changes of this share from 1999 to 2010



Source: China Statistical Yearbook on Science and Technology (2000, 2011)

Figure 7: Change of R&D intensity (share of R&D expenditure in gross output) of large and medium-sized enterprises from 1999 to 2010



Source: China Statistical Yearbook on Science and Technology (2000, 2011)

Table 1: Number of all firms and number of firms that are engaged in R&D expenditure

Year	N	Number of observations with nonzero R&D	Percentage
2005	241,188	24,123	10.00%
2006	267,883	27,848	10.40%
2007	302,526	33,089	10.94%

Table 2: Number of all firms, number of firms that are engaged in R8D expenditure, av
various industries (2005, 2006 and 2007 as a pooled sample)

Code	Industry name	N	Number of obser with nonzero R	Percentage of R&D	R&D intensi	Subsidy a share of product c
13	Food processor	47,934	3,311	6.9%	0.05%	0.35%
14	Food producer	17,392	2,317	13.3%	0.13%	0.25%
15	Beverage	11,541	1,383	12.0%	0.10%	0.32%
16	Tobacco	466	176	37.8%	0.18%	0.69%
17	Textile	74,219	4,094	5.5%	0.05%	0.13%
18	Clothing & Accesso	38,740	1,684	4.3%	0.03%	0.10%
19	Leather and fur clothir	20,080	1,330	6.6%	0.04%	0.10%
20	Wooden products	19,194	700	3.6%	0.02%	0.30%
21	Furnishings	10,470	701	6.7%	0.05%	0.13%
22	Paper producer and p	23,102	1,008	4.4%	0.03%	0.31%
23	Publishing	14,450	720	5.0%	0.06%	0.42%
24	Education and sport	10,741	822	7.7%	0.07%	0.14%
25	Petrochemical	5,957	489	8.2%	0.08%	0.29%
26	Chemical material	60,385	7,991	13.2%	0.18%	0.35%
27	Medicals and pharma	15,538	5,625	36.2%	0.93%	0.44%
28	Chemical fiber prod	4,040	389	9.6%	0.10%	0.18%
29	Rubber products	9,668	988	10.2%	0.13%	0.26%
30	Plastic products	39,545	2,359	6.0%	0.06%	0.19%
31	Nonmetallic produc	64,616	4,480	6.9%	0.08%	0.66%
32	Black metal smelti	19,389	959	4.9%	0.35%	0.24%
33	Nonferrous metal sm	16,600	1,384	8.3%	0.08%	0.62%
34	Metal products	44,889	2,852	6.4%	0.07%	0.16%
35	Industrial machine	66,398	7,647	11.5%	0.19%	0.22%
36	Specialty machine	32,962	5,907	17.9%	0.48%	0.33%
37	Commercial vehicles	36,214	6,205	17.1%	0.29%	0.34%
39	Electrical engineering a	49,370	7,954	16.1%	0.28%	0.24%
40	Computers and telecom	28,205	7,059	25.0%	0.97%	0.35%
41	Meters and instrum	11,399	3,347	29.4%	1.10%	0.41%
42	Other equipment manu	16,616	1,131	6.8%	0.11%	0.20%
43	Recycling	1,477	48	3.2%	0.04%	0.50%

Table 3: Descriptive Statistics of the sample for regression on the three-year unbalanced panel data

	Descriptive Statistics				
Variables	**Mean**	**Medium**	**Standard Deviation**	**Min**	**Max**
RnDintensity	0.0018	0	0.0146	0	0.9906
size	4.7	4.6	1.1	0	12.1
age	9.2	7	9.0	1	180
k	100.2	45.3	383.8	1.1E-03	209520.5
herfindal	0.015	0.0071	0.028	1.0E-03	0.95
market_share	0.0018	3.2E-04	0.0095	1.5E-09	0.98
wage	2.72	2.69	0.57	-5.3	8.6
profitability	0.0093	0.026	8.9	-7710.8	628.8
exportintensity	0.17	0	0.34	0	1.4
debtratio	0.56	0.57	0.31	-7.2	22.9
interestpayment	0.0097	0.0014	0.21	-17.6	158.7
subsidy	0.0029	0	0.038	-0.35	17.2
intellectual property protection	13.2	8.6	10.6	-0.02	41.5
overall institutional quality	8.4	8.6	1.6	0.29	10.9
dummy_advertise	0.5	0	0.5	0	1
average_mortality_rate_during_famine	14.4	13.2	5.8	7.2	38.9

Table 4: Regression Results (three-year unbalanced panel data, intellectual property rights protection)

	Likelihood of conducting R&D activities		R&D intensity (share of R&D expenditure in total industrial sales)	
Regressors	Coefficients	Standard Error	Coefficients	Standard Error
size	0.47***	2.6E-02	-2.4E-03***	8.7E-04
age	-2.1E-03	3.3E-03	9.0E-05	7.5E-05
k	-1.7E-05	4.0E-05	-3.7E-06*	2.1E-06
herfindal	-0.50	7.0E-01	0.12***	3.2E-02
market_share	-1.9	2.1	-0.074**	3.0E-02
wage	0.36***	2.1E-02	5.9E-03***	1.5E-03
profitability	0.073***	2.57E-02	1.1E-03	3.0E-03
exportintensity	0.29***	6.6E-02	-6.5E-03***	1.7E-03
debtratio	-0.17***	4.9E-02	-8.2E-03***	2.8E-03
interestpayment	0.33	2.1E-01	0.067***	3.0E-02
subsidy	0.68***	2.6E-01	0.13*	7.9E-02
intellectual property protection	0.027***	2.6E-03	1.4E-04	1.9E-04
dummy_advertise	1.2***	2.1E-02		
year2006	0.07***	1.8E-02	2.7E-03***	8.4E-04
year2007	-0.63***	2.9E-02	-2.3E-03	1.9E-03

Note: regression results on constants and industry dummies are not reported due to space limit.

***, ** and * indicate significance level of 1%, 5% and 10% respectively.

Table 5: Regression Results (three-year unbalanced panel data, overall institutional quality)

	Likelihood of conducting R&D activities		**R&D intensity (share of R&D expenditure in total industrial sales)**	
Regressors	Coefficients	Standard Error	Coefficients	Standard Error
size	0.47***	2.6E-02	-2.4E-03**	1.1E-03
age	-1.9E-03	3.3E-03	1.0E-04	1.1E-04
k	-1.8E-05	4.0E-05	-6.4E-06*	3.3E-06
herfindal	-0.51	7.0E-01	0.16***	5.3E-02
market_share	-2.1	2.1	0.11	1.8E-01
wage	0.36***	2.1E-02	6.0E-03***	2.2E-03
profitability	0.073***	2.6E-02	7.5E-03	4.6E-03
exportintensity	0.29***	6.6E-02	-8.3E-03***	2.1E-03
debtratio	-0.16***	4.9E-02	-8.3E-03**	3.7E-03
interestpayment	0.34	2.1E-01	0.073*	4.2E-02
subsidy	0.68***	2.6E-01	0.17	1.0E-01
Overall institutional quality	0.34***	4.2E-02	-1.6E-03	2.5E-03
dummy_advertise	1.2***	2.9E-02		
year2006	-0.04**	2.9E-02	4.1E-03**	1.7E-03
year2007	-0.77*	4.7E-02	-1.9E-04	3.2E-03

Note: regression results on constants and industry dummies are not reported due to space limit.

***, ** and * indicate significance level of 1%, 5% and 10% respectively.

Table 6: Descriptive Statistics of the sample for regression on the cross-sectional data of 2007

	Descriptive Statistics				
Variables	**Mean**	**Medium**	**Standard Deviation**	**Min**	**Max**
RnDintensity	0.0020	0	0.015	0	0.99
size	4.6	4.5	1.1	0	12.1
age	9.0	7	8.5	1	180
k	108.2	49.1	498.3	0.0011	209520.5
herfindal	0.014	0.0069	0.026	0.0010	0.94
market_share	0.0016	0.00029	0.0087	1.5E-09	0.97
wage	2.9	2.8	0.57	-4.0	8.6
profitability	0.021	0.029	3.0	-1248	148.8
Exportintensity	0.16	0	0.33	0	1
Debtratio	0.56	0.57	0.30	-1.6	15.5
Interestpayment	0.0087	0.0012	0.099	-17.6	43.3
Subsidy	0.0024	0	0.027	-0.35	5.0
intellectual property protection	16.7	15.5	12.4	0.22	41.5
Overall institutional quality	8.9	8.6	1.6	1.6	10.9
Dummy_advertise	0.99	1	0.07	0	1
Average_mortality_rate_during_famine	14.4	13.2	5.8	7.2	38.9

Table 7: Regression Results of IV Probit (cross-sectional data of 2007, intellectual property rights protection)

	Likelihood of conducting R&D activities	
Regressors	Coefficients	Standard Error
size	0.063***	1.4E-02
age	1.7E-03	1.5E-03
k	-2.2E-06	1.1E-05
herfindal	0.92**	3.7E-01
market_share	-0.72	0.92
wage	0.31***	2.5E-02
profitability	0.056***	1.9E-02
exportintensity	-0.11***	5.5E-02
debtratio	-0.23***	5.5E-02
interestpayment	0.49***	1.5E-01
subsidy	0.58***	1.4E-01
intellectual property protection	4.3E-03*	2.3E-03
dummy_advertise	0.33	0.40
Wald test of exogeneity	Chi2(1)=0.03	Prob>chi2=0.87

Note: regression results on constants and industry dummies are not reported due to space limit.

***, ** and * indicate significance level of 1%, 5% and 10% respectively.

Dummies indicating two-digit industries and dummies indicating types are included.

Table 7 continued: Regression Results of IV Probit (cross-sectional data of 2007, intellectual property rights protection)

	Likelihood of conducting R&D activities	
Regressors	Coefficients	Standard Error
Firm_type120	-0.43***	0.14
Firm_type130	-0.32**	0.15
Firm_type141	-0.07	0.51
Firm_type142	-0.12	0.51
Firm_type143	-0.20	0.44
Firm_type149	-0.41	0.65
Firm_type151	-0,.096	0.15
Firm_type159	-0.05	0.08
Firm_type160	3.5E-04	0.10
Firm_type171	-0.50***	0.11
Firm_type172	-0.44**	0.18
Firm_type173	-0.16*	0.086
Firm_type174	-0.21	0.14
Firm_type190	-0.38	0.37
Firm_type210	-0.20*	0.11
Firm_type220	-0.43*	0.26
Firm_type230	-0.46*	0.11
Firm_type240	-0.21	0.34
Firm_type310	-0.19*	0.10
Firm_type320	-0.49*	0.26
Firm_type330	-0.44***	0.10
Firm_type340	0.033	0.22

The dummy indicating state-owned enterprises is omitted.

Therefore, the coefficients of the dummies above show the difference between enterprises of various types and state-owned enterprises.

Table 8: Regression Results of IV Probit (cross-sectional data of 2007, overall institutional quality)

	Likelihood of conducting R&D activities	
Regressors	Coefficients	Standard Error
size	0.066***	1.4E-02
age	1.7E-03	1.5E-03
k	1.7E-07	1.2E-05
herfindal	0.96***	3.7E-01
market_share	-0.76	0.92
wage	0.30***	2.6E-02
profitability	0.057***	1.8E-02
exportintensity	-0.13**	5.7E-02
debtratio	-0.24***	5.5E-02
interestpayment	0.50	1.5E-01
subsidy	0.62***	1.4E-01
Overall institutional quality	0.047**	2.4E-02
dummy_advertise	0.33	3.9E-01
Wald test of exogeneity	Chi2(1)=2.6	Prob>chi2=0.11

Note: regression results on constants and industry dummies are not reported due to space limit.

***, ** and * indicate significance level of 1%, 5% and 10% respectively.

Dummies indicating two-digit industries and dummies indicating types are included.

Table 8 continued: Regression Results of IV Probit (cross-sectional data of 2007, overall institutional quality)

	Likelihood of conducting R&D activities	
Regressors	Coefficients	Standard Error
Firm_type120	-0.45***	0.14
Firm_type130	-0.35**	0.15
Firm_type141	-0.091	0.51
Firm_type142	-0.14	0.51
Firm_type143	-0.20	0.44
Firm_type149	-0.43	0.65
Firm_type151	-0,.094	0.15
Firm_type159	-0.069	0.086
Firm_type160	-0.013	0.10
Firm_type171	-0.53***	0.11
Firm_type172	-0.47***	0.18
Firm_type173	-0.19**	0.09
Firm_type174	-0.24*	0.14
Firm_type190	-0.41	0.37
Firm_type210	-0.24**	0.11
Firm_type220	-0.46*	0.26
Firm_type230	-0.49***	0.11
Firm_type240	-0.24	0.34
Firm_type310	-0.21**	0.10
Firm_type320	-0.51*	0.26
Firm_type330	-0.47***	0.10
Firm_type340	0.014	0.22

The dummy indicating state-owned enterprises is omitted. Therefore, the coefficients of the dummies above show the difference between enterprises of various types and state-owned enterprises of various types and state-owned enterprises.

Table 9: Regression Results of IV Tobit (cross-sectional data of 2007, intellectual property rights protection)

	R&D intensity (share of R&D expenditure in total industrial sales)	
Regressors	Coefficients	Standard Error
size	1.1E-02***	1.8E-03
age	2.7E-04***	2.0E-05
k	-3.5E-08	2.6E-07
herfindal	6.9E-02***	5.9E-03
market_share	-6.0E-03	1.4E-02
wage	2.1E-02***	3.3E-04
profitability	7.8E-03***	4.7E-04
exportintensity	-3.7E-03***	6.1E-04
debtratio	-1.1E-02***	6.4E-04
interestpayment	0.075***	3.0E-03
subsidy	6.4E-02***	4.3E-03
Intellectual property rights protection	2.0E-05	2.8E-05
Number of left-censored observations	266379	
Number of uncensored observations	32424	
Log likelihood	-1088721.2	
Wald test of exogeneity	Chi2(1)=73.9	Prob>chi2=0.000

Note: regression results on constants and industry dummies are not reported due to space limit.

***, ** and * indicate significance level of 1%, 5% and 10% respectively.

Table 9 continued: Regression Results of IV Tobit (cross-sectional data of 2007, intellectual property rights protection)

	Likelihood of conducting R&D activities	
Regressors	Coefficients	Standard Error
Firm_type120	-0.026***	1.6E-03
Firm_type130	-0.015***	1.8E-03
Firm_type141	5.6E-03	7.1E-03
Firm_type142	-1.5E-02**	7.2E-03
Firm_type143	-1.2E-02**	6.2E-03
Firm_type149	-1.8E-02***	6.8E-03
Firm_type151	0.012***	2.4E-03
Firm_type159	-1.2E-04	1.2E-03
Firm_type160	5.2E-03***	1.4E-03
Firm_type171	-0.019***	1.3E-03
Firm_type172	-2.3E-02***	1.9E-03
Firm_type173	-5.6E-03***	1.2E-03
Firm_type174	-8.1E-03***	1.7E-03
Firm_type190	-2.2E-02***	3.8E-03
Firm_type210	-8.1E-03***	1.7E-03
Firm_type220	-2.0E-02***	2.7E-03
Firm_type230	-2.6E-03***	1.4E-03
Firm_type240	-5.8E-03	4.5E-03
Firm_type310	-5.0E-03***	1.3E-03
Firm_type320	-1.7E-02***	2.7E-03
Firm_type330	-2.4E-02***	1.4E-03
Firm_type340	-1.4E-04	3.7E-03

The dummy indicating state-owned enterprises is omitted.

Therefore, the coefficients of the dummies above show the difference between enterprises of various types and state-owned enterprises

Table 10: Regression Results of IV Tobit (cross-sectional data of 2007, overall institutional quality)

	R&D intensity (share of R&D expenditure in total industrial sales)	
Regressors	Coefficients	Standard Error
size	1.1E-02***	1.8E-04
age	2.7E-04***	2.0E-05
k	-1.5E-08	2.6E-07
herfindal	6.9E-02***	5.9E-03
market_share	-5.7E-03	1.4E-02
wage	2.2E-02***	3.5E-04
profitability	8.5E-03***	6.4E-04
exportintensity	-3.0E-03***	6.4E-04
debtratio	-1.1E-02***	6.5E-04
interestpayment	0.075***	3.0E-03
subsidy	6.4E-02***	4.3E-03
Overall institutional quality	2.0E-04	2.8E-04
Number of left-censored observations	266379	
Number of uncensored observations	32424	
Log likelihood	-503148.96	
Wald test of exogeneity	Chi2(1)=11.8	Prob>chi2=0.0006

Note: regression results on constants and industry dummies are not reported due to space limit.

***, ** and * indicate significance level of 1%, 5% and 10% respectively.

Table 10 continued: Regression Results of IV Tobit (cross-sectional data of 2007, overall institutional quality)

	R&D intensity (share of R&D expenditure in total industrial sales)	
Regressors	Coefficients	Standard Error
Firm_type120	-0.027***	1.6E-03
Firm_type130	-0.017***	1.7E-03
Firm_type141	3.2E-03	7.1E-03
Firm_type142	-1.6E-02**	7.1E-03
Firm_type143	-1.2E-02**	6.0E-03
Firm_type149	-1.9E-02***	6.8E-03
Firm_type151	0.012***	2.3E-03
Firm_type159	-1.2E-03	1.2E-03
Firm_type160	4.3E-03***	1.4E-03
Firm_type171	-0.021***	1.3E-03
Firm_type172	-2.3E-02***	1.9E-03
Firm_type173	-7.0E-03***	1.2E-03
Firm_type174	-9.0E-03***	1.7E-03
Firm_type190	-2.3E-02***	3.8E-03
Firm_type210	-8.2E-03***	1.4E-03
Firm_type220	-2.2E-02***	2.7E-03
Firm_type230	-2.8E-03***	1.4E-03
Firm_type240	-7.5E-03*	4.5E-03
Firm_type310	-6.3E-03***	1.3E-03
Firm_type320	-1.9E-02***	2.7E-03
Firm_type330	-2.5E-02***	1.3E-03
Firm_type340	-1.4E-03	3.7E-03

The dummy indicating state-owned enterprises is omitted.

Therefore, the coefficients of the dummies above show the difference between enterprises of various types and state-owned enterprises

Table 11: Regression Results of Heckman two-step estimation (cross-sectional data of 2007, intellectual property rights protection)

	Likelihood of conducting R&D activities		**R&D intensity (share of R&D expenditure in total industrial sales)**	
Regressors	Coefficients	Standard Error	Coefficients	Standard Error
size	0.29***	3.4E-03	-3.4E-03***	9.7E-04
age	0.0074***	3.9E-04	-1.2E-05	2.9E-05
k	5.1E-08	5.1E-06	1.6E-06**	7.5E-07
herfindal	1.1***	1.2E-01	0.041***	8.1E-03
market_share	2.5***	0.34	-0.021*	1.3E-02
wage	0.40***	6.1E-03	8.2E-03***	1.4E-03
profitability	0.14***	1.1E-02	5.5E-03***	1.0E-03
exportintensity	-0.058***	1.2E-02	-4.1E-03***	8.2E-04
debtratio	-0.22***	1.2E-02	-7.6E-03***	1.1E-03
interestpayment	1.5***	8.1E-02	0.055***	6.2E-03
subsidy	0.47***	9.3E-02	0.13***	6.1E-03
Intellectual property rights protection	0.0036***	3.0E-04	1.7E-04***	2.2E-05
dummy_advertise	0.47***	7.5E-02		

Note: regression results on constants and industry dummies are not reported due to space limit.

***, ** and * indicate significance level of 1%, 5% and 10% respectively.

Table 11 continued: Regression Results of Heckman two-step estimation (cross-sectional data of 2007, intellectual property rights protection)

	Likelihood of conducting R&D activities		**R&D intensity (share of R&D expenditure in total industrial sales)**	
Regressors	Coefficients	Standard Error	Coefficients	Standard Error
Firm_type120	-0.53***	3.1E-02	-9.4E-03***	2.8E-03
Firm_type130	-0.30***	3.4E-02	-9.0E-03***	2.4E-03
Firm_type141	0.18	0.14	-8.2E-03	7.4E-03
Firm_type142	-0.38***	0.14	3.8E-03	1.1E-02
Firm_type143	-0.31***	0.12	6.9E-04	7.8E-03
Firm_type149	-0.31**	0.13	-0.020**	8.7E-03
Firm_type151	0.52***	5.4E-02	6.3E-04	2.4E-03
Firm_type159	-1.3E-03***	2.4E-02	-3.0E-03**	1.3E-03
Firm_type160	0.17***	2.9E-02	-2.6E-03*	1.6E-03
Firm_type171	-0.34	2.6E-02	-0.014***	2.0E-03
Firm_type172	-0.42***	3.7E-02	-0.010***	3.1E-03
Firm_type173	-0.10***	2.4E-02	-6.0E-03***	1.3E-03
Firm_type174	-0.12***	3.3E-02	-8.8E-03***	2.1E-03
Firm_type190	-0.43***	7.4E-02	-7.7E-03	5.5E-03
Firm_type210	-0.12***	2.8E-02	-8.2E-03***	1.6E-03
Firm_type220	-0.43***	5.2E-02	-0.011***	3.8E-03
Firm_type230	-0.53***	2.8E-02	-0.010***	2.4E-03
Firm_type240	-0.049	0.090	-0.0097**	4.7E-03
Firm_type310	-0.080***	2.7E-02	-7.5-03***	1.5E-03
Firm_type320	-0.34***	5.2E-02	-1.3E-02***	3.5E-03
Firm_type330	-0.47***	2.7E-02	-1.1E-02***	2.2E-03
Firm_type340	-0.16**	7.7E-02	1.4E-02***	4.2E-03

The dummy indicating state-owned enterprises is omitted.

Therefore, the coefficients of the dummies above show the difference between enterprises of various types and state-owned enterprises.

Table 12: Regression Results of Heckman two-step estimation (cross-sectional data of 2007, overall institutional quality)

	Likelihood of conducting R&D activities		**R&D intensity (share of R&D expenditure in total industrial sales)**	
Regressors	Coefficients	Standard Error	Coefficients	Standard Error
size	0.28***	3.4E-03	-3.4E-03***	9.7E-04
age	0.0074***	3.9E-04	-1.2E-05	2.9E-05
k	1.6E-08	5.2E-06	1.6E-06**	7.5E-07
herfindal	1.1***	1.2E-01	0.041***	8.1E-03
market_share	2.5***	0.34	-0.021	1.3E-02
wage	0.40***	6.1E-03	8.2E-03***	1.4E-03
profitability	0.14***	1.1E-02	5.5E-03***	1.0E-03
exportintensity	-0.058***	1.2E-02	-4.1E-03***	8.2E-04
debtratio	-0.22***	1.2E-02	-7.6E-03***	1.1E-03
interestpayment	1.5***	8.1E-02	0.055***	6.2E-03
subsidy	0.47***	9.3E-02	0.13***	6.1E-03
Overall institutional quality	0.022***	2.3E-03	2.4E-04	1.6E-04
dummy_advertise	0.47***	9.3E-02		

Note: regression results on constants and industry dummies are not reported due to space limit.

***, ** and * indicate significance level of 1%, 5% and 10% respectively.

Table 12 continued: Regression Results of Heckman two-step estimation (cross-sectional data of 2007, overall institutional quality)

	Likelihood of conducting R&D activities		R&D intensity (share of R&D expenditure in total industrial sales)	
Regressors	Coefficients	Standard Error	Coefficients	Standard Error
Firm_type120	-0.53***	3.1E-02	-1.0E-02***	2.8E-03
Firm_type130	-0.30***	3.4E-02	-1.0E-03	2.4E-03
Firm_type141	0.18	0.14	-9.0E-03	7.4E-03
Firm_type142	-0.38***	0.14	2.2E-03	1.1E-02
Firm_type143	-0.31***	0.12	-1.6E-03	7.8E-03
Firm_type149	-0.31**	0.13	-0.021**	8.7E-03
Firm_type151	0.52***	5.4E-02	7.5E-04	2.4E-03
Firm_type159	-1.3E-03***	2.4E-02	-3.5E-03***	1.3E-03
Firm_type160	0.17***	2.9E-02	-2.8E-03*	1.6E-03
Firm_type171	-0.34	2.6E-02	-0.014***	2.0E-03
Firm_type172	-0.42***	3.7E-02	-0.011***	3.1E-03
Firm_type173	-0.10***	2.4E-02	-6.9E-03***	1.3E-03
Firm_type174	-0.12***	3.3E-02	-9.0E-03***	2.0E-03
Firm_type190	-0.43***	7.4E-02	-8.3E-03	5.5E-03
Firm_type210	-0.12***	2.8E-02	-9.4E-03***	1.6E-03
Firm_type220	-0.43***	5.2E-02	-0.012***	3.8E-03
Firm_type230	-0.53***	2.8E-02	-0.012***	2.4E-03
Firm_type240	-0.049	0.090	-0.011**	4.7E-03
Firm_type310	-0.080***	2.7E-02	-8.5E-03***	1.5E-03
Firm_type320	-0.34***	5.2E-02	-1.5E-02***	3.5E-03
Firm_type330	-0.47***	2.7E-02	-1.1E-02***	2.2E-03
Firm_type340	-0.16**	7.7E-02	1.3E-02***	4.2E-03

The dummy indicating state-owned enterprises is omitted.

Therefore, the coefficients of the dummies above show the difference between enterprises of various types and state-owned enterprises.

Appendix A:

Code of registered types

Code	Registered Type	Code	Registered Type
100	**Domestic-owned enterprise**	172	Private-owned joint venture
110	State-owned enterprise	173	Private-owned limited liability company
120	Collective-owned enterprise	174	Private-owned joint stock limited liability company
130	Cooperative shares corporation	190	Other domestic-owned enterprise
140	Joint venture	200	**Hongkong-Macao-Taiwan invested enterprise**
141	State-owned joint venture	210	Equity joint venture with Hongkong-Macao-Taiwan investors
142	Collective-owned joint venture	220	Contractual joint venture with Hongkong-Macao-Taiwan investors
143	State- and collective- owned joint venture	230	Hongkong-Macao-Taiwan invested sole proprietership
149	Other joint venture	240	Hongkong-Macao-Taiwan invested joint stock limited liability company
150	Limited liability company	300	**Foreign invested enterprise**
151	State-owned limited liability company	310	Equity joint venture with foreign investors
159	Other limited liability company	320	Contractual joint venture with foreign investors
160	Joint stock limited liability company	330	Foreign-owned enterprise
170	Private-owned enterprise	340	Foreign invested joint stock limited liability company
171	Private-owned sole proprietorship		

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