7 Growing into an Innovative Economy:

Evidence from Chinese Firm-Level Data Analysis

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Introduction

Since initiating market reforms in 1978, China has undergone a significant economic transformation (Lin 2011). A more recent development is that China now aims to become a knowledge-intensive economy. This goal may constitute a part of the force that drives the redistribution of knowledge in the international market (Sergey and Breidne 2007). The following question, proposed by Jones and Romer (2010: 231), may become increasingly relevant:

China's population is roughly equal to that of the United States, Europe, and Japan combined. Over the next several decades, the continued economic development of China might plausibly double the number of researchers throughout the world pushing forward the technological frontier. What effect will this have on incomes in countries that share ideas with China in the long run?

On 9 February 2006, the State Council published the '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 emphasises 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, 'Innovate independently, achieve development in selected areas by leaps and bounds, support development and guide the future' (Sun and Du 2010).

While there are intricate relationships between education, institutional quality, science and technology performance and economic growth, this chapter is focused on one question: how will institutional quality affect China's innovation performance?

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

This question is fundamentally important. There has long been debate about how China has grown fast, 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 (Acemoglu & Johnson 2005; Hall and Jones 1999), 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, some analysts regard China as a counter-example to the existing literature on law, institutions, and growth (Allen et al. 2005). The reason why China has been able to be an outlier in the past 30 years could be, however, that the development stage of this period is 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.

The spectacular growth of China up till now has been driven by the reallocation of labour and capital across manufacturing firms (Song, Storesletten and Zilibotti 2011) and mainly by export-oriented, labour-intensive manufacturing activities (Wu 2010). The success of such an economy could rely much less on institutional quality, compared with an economy that relies on R&D investment from firms as the major source of technological progress and productivity growth. This is because R&D investment is a long-term investment process, the returns of which take time to realise. And, compared with physical capital investment and technology imitation or technology imports, R&D investment is also intrinsically more risky and costly. If, for example, the protection of property rights, and especially the protection of intellectual property rights, is weak, firms may be too short-sighted to invest in R&D due to the high risk of losing the fruit of their costly R&D efforts. Therefore, if China is to continue to converge towards the world technology frontier, and become increasingly knowledge intensive, it may not in the long run be possible to be an outlier in terms of the importance of institutional quality for economic growth.

This chapter adds to the understanding of China's innovation prospects by examining how variations of institutional quality within China impact on the R&D efforts of firms located in provincial regions. While there exist studies that regard China as a whole and look at how its institutional quality is related to its economic growth in a cross-country context, this study explores the issue inside China. 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 where the institutional quality is higher? This is the main research question of this study. If the answer is positive, institutional quality will certainly be a key to the realisation of China's science and technology take off.

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.

R&D Investment: Provincial Variation

As shown in Figure 7.1, China's national R&D expenditure (current prices) has experienced a continuous and accelerating growth in the last two decades. While China's annual GDP growth rate during the period 1990–2010 was 10.4 per cent (Lin, 2011), the growth of national R&D expenditure has been faster and, therefore, the national R&D intensity of China has been increasing as well (Figure 7.2). The 'National Medium- and Long-Term Program for Scientific and Technological Development (2006–2020)' sets an R&D intensity goal of 2.5 per cent by 2020, a level similar to that of the higher-income countries such as the United States, Japan and South Korea (Fisher-Vanden and Ho 2007).

One interesting angle for examining the 'science and technology take-off' (Gao and Jefferson 2007) of China is to look more closely at performance at the provincial level. Through the analysis of variation in regional R&D performance, it is possible to better understand the forces behind changing R&D intensity, and thus help design policies that regions, with weaker R&D performance, could adopt to boost that performance.

Figure 7.1 National R&D expenditure

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

Figure 7.2 China's national R&D intensity (the ratio of R&D expenditure in GDP) from 1995–2010

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

Figure 7.3 and Figure 7.4 show the intramural R&D expenditure in 31 provincial regions in China 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, several provinces such as Jiangsu, Guangdong, Shandong and Zhejiang have caught up with Beijing. Jiangsu province has even overtaken Beijing in terms of R&D expenditure. While Figure 7.3 and Figure 7.4 inform us of the changing amount of R&D expenditure in various regions, Figure 7.5 presents the R&D intensity change in various regions from 1999 to 2010. During this period, China's national R&D intensity increased by about one per cent (Figure 7.2), but with significant variation across provinces (Figure 7.5). Tianjin, Zhejiang, Shanghai, Jiangsu, Shandong realised a rapid increase in R&D intensity of about 1.5 per cent. In contrast, the R&D intensity in Hainan decreased, and that in Shaanxi barely changed.

In China's 'National Medium- and Long-Term Program for Scientific and Technological Development (2006–2020)', not only is the growth of R&D intensity emphasised, it is also proposed that business enterprises should become an increasingly important entity in conducting R&D. How do various regions perform in this regard? To answer the question about business enterprises' R&D performance, statistics are given for large and medium-sized enterprises in China, which are reported in the *China Statistical Yearbook on Science and Technology*.

Figure 7.6 illustrates the share of large- and medium-sized enterprises' intramural R&D expenditure in total regional R&D expenditure in year 1999 and year 2010 respectively, and also the change of the share from 1999 to 2010.

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 per cent during 1999 and 2010. In contrast, in Hainan, this share decreased significantly from 50 per cent to as low as 26 per cent; in Ningxia, Qinghai, Guizhou, Fujian and Guangdong, the respective shares began from more than 70 per cent in 1999, and yet shrank from the original high level. Interestingly, large- and medium-sized enterprises' R&D share in Beijing is very low, at only 13 per cent in 2010, and higher only than the share in Tibet.

Figure 7.3 Intramural R&D expenditure of 31 provincial regions in 1999 (billion RMB)

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

Figure 7.4 Intramural R&D expenditure of 31 provincial regions in 2010 (billion RMB)

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

Figure 7.5 Change of intramural R&D intensity in 31 provincial regions from 1999 to 2010

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

Figure 7.6 Share of large and medium-sized enterprise R&D expenditure in regional R&D expenditure in 1999 to 2010 and changes of this share from 1999 to 2010

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

In order to simultaneously stimulate the growth of regional R&D intensity and promote the importance of enterprise R&D, it is fundamental that business enterprises allocate a larger share of resources towards R&D activities. Figure 7.7 represents the changes to the share of the R&D intensity of large- and medium-sized enterprises from 1999 to 2012. The focus of this chapter is on the determinants of R&D intensity of large- and medium-sized enterprises in China using a firm-level dataset. Researchers have already investigated various factors that may induce Chinese firms to carry out R&D activities. This literature has not, however, provided a rigorous study of the impact on R&D activities

of the institutional quality of the economic environment in which the firms are located. Hence, this chapter examines whether institutional quality plays a critical role in enhancing the R&D investment of Chinese firms.

Figure 7.7 Change of R&D intensity of large and medium-sized enterprise (the share of R&D expenditure in gross output) from 1999 to 2010

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

Institutional Quality and Firm Research and Development Activities

In the existing literature, several channels through which institutional quality could impact on a firm's innovation activities have been identified. Firstly, in terms of external financing, some studies show that sound legal systems and efficient financial infrastructures can facilitate the access of firms to external finance and, thus, their ability to fund investment projects (La Porta et al. 1997, Demircuc-Kunt and Maksimovic 1999, Beck et al. 2006). Secondly, in terms of 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.

Thirdly, the characteristics of innovation activities as a form of investment make them particularly sensitive to institutional quality. Jorde and Teece (1990) 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'. Other analysts also regard risks and uncertainties as defining characteristics of innovation, since technological development is full of unforeseeable contingencies; and they emphasise the

importance of formal laws and regulation introduced by the state to help reduce the risk and uncertainty that is faced by firms engaging in innovation (Kaasa, Kaldaru and Parts 2007).

In terms of the specific institutions that matter for innovation activities, Eicher and García-Peñalosa (2008) suggest that the key institution that determines sustained growth in R&D-based or innovation-driven growth models is the strength of intellectual property rights. In the Romer model (1990), 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 model applies to countries at the world technology frontier that rely on innovation for economic growth, there is also 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.

Other Determinants of Firm-Level R&D Intensity

It is recognised in the literature that government subsidies play a role in firms' innovation activities. For example, it is maintained by some that the use of public funding to foster private research and development (R&D) activities is common in many countries. Statistics from Eurostat (2009) have been used to illustrate that the public share in R&D activities from the mid 1990s to the mid 2000s was about 35 per cent in the EU27, 30 per cent in the United States and 18.5 per cent in Japan (Zúñiga-Vincente et al. 2012). And a sizable amount of these public R&D funds is used to subsidise R&D activities undertaken by private enterprises. Hence, the share of subsidy in industrial sales is a potential determinant of Chinese firms' innovation activities as well.

While this study examines whether Chinese firms' R&D investment is associated with government subsidies, assessing the economic impact of government subsidies for firms' R&D investment thoroughly, however, requires

the following two questions to be considered. First, will R&D activities that are supported via government subsidy be economically rational and efficient? Will a firm's R&D activities, if funded by government subsidy, bring about market value? Public policies should be aimed at supporting only those private R&D projects that are socially desirable and which would not otherwise be undertaken. The major justification for the public support of R&D is that market failures, such as the incomplete appropriability of R&D returns and the problems of information and incomplete markets, would otherwise hamper firms from reaching the socially optimal level of R&D. Nevertheless, identifying the target projects to which public effort should be devoted is not a simple task. Second, what is the relationship between a government subsidy for R&D and a firm's actual R&D expenditure? Will government subsidies act as a stimulant for R&D or, contrarily, exert a crowding-out effect on private R&D investment and be dissipated in higher R&D wages, instead of stimulating real private R&D spending (Lokshin and Mohnen 2012)? These two problems are critical for the role of government subsidy in promoting firm R&D activities and will need further research to be addressed fully.

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. Firms with high R&D expenditure tend to have few tangible assets that can serve as collateral for credit (Brown et al. 2009). R&D expenditures largely go to salaries and wages for scientists and researchers, which is human capital investment that cannot be collateralised. Furthermore, due to the need to protect their proprietary information over innovation, firms may be unable or unwilling to offer sufficient information about their intended R&D programs to potential funding providers (Maskus, Neumann and Seidel 2012).

Basic alternatives for innovation financing include internal finance (out of profit) and external finance (credit-based or equity-financed systems) (Unger and Zagler 2003). 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).

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 R&D activities.

Closely related to the financial constraints problem are the issues about the size, market structure and innovation activities of firms. Joseph Schumpeter argued that large firms operating in a concentrated market are the main engines of technological progress. The seven reasons behind Schumpeter's argument include the ability of large firms to cover the fixed costs of R&D projects, scale and scope economies in the production of innovations, the better position of larger firms 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 (Symeonidis 1996). As to firms with greater market powers, these firms are in a better position to finance R&D from their own profits. 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 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.

There is evidence in the literature that R&D-intensive firms have, on average, higher wages. Four possible explanations for how the positive relationship between R&D intensity and wages should be understood include the demand for workers in particular occupations or with particular skills in firms with higher R&D intensity; the need for more educated workers with innate ability, or other unobserved characteristics, in firms with higher R&D intensity; quasi-rents generated by R&D intensive firms to be shared with workers with certain characteristics; and, wage premiums are related to firm size (Mishra and Smyth 2012). The size of R&D-intensive firms is larger because investing in R&D is likely to involve more fixed costs. Therefore, the average wage of employees is included in the regression analysis.

The age of a firm can exert two distinct impacts on R&D. Although Loderer and Waelchli (2009) are not focused on the relationship between age and R&D, the effect of a firm's age is clearly explained by them. On the one hand, age allows firms to become more efficient as they 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 organisational decay. On balance, it is therefore unclear whether older firms experience increased prosperity, or whether they are burdened by their age, which could result in an insignificant estimate of the coefficient of the variable age in the regression analysis.

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 (Porter 1990). The causality could also be reverse. It could also be because firms that export to international markets are more likely to be exposed

to the stock of world knowledge, and enjoy larger knowledge spillovers, which in turn promotes R&D activities. 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 prospect. This question will be fully addressed in the next chapter where firm-level production data will be merged with transaction-level trade data. In that merged dataset, it is possible to observe the trade activities of different firms, such as the number of imported intermediate and capital goods, unit value of imported goods, geographical diversification of export markets and forms of trade. The various channels through which trade activities impact on a firm's innovation performance are illustrated in the next chapter.

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 over five million RMB. The NBS has requested all these firms to report information to the local statistical offices that 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 NBS, accounting for about 90 per cent of total output in most industries. The NBS has endeavored to maintain consistency in data collection across time, industries and regions (Yi, Wang and Kafourous 2013). Table 7.1 and Table 7.2 provide a description of the R&D activities of the firms in the dataset from 2005 to 2007.

To measure institutional quality of provincial regions in China, I adopt the National Economic Research Institute (NERI) Index of Marketization for China's Provinces (Fan, Wang and Zhu 2011). The NERI index is an assessment system for relative progress in marketisation for China's provinces (Wang, Fan and Zhu, 2004). It assesses marketisation 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 constitutes the overall marketisation index. The five fields covered are government and market relations, development of the non-state enterprise sector, development of the commodity market, development of factor markets, 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 marketisation index from the NERI index system. The other measure

is the basic index for the protection of intellectual property rights, 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 intellectual property rights is based on numbers of patent applications and patent grants per technical personnel in various regions.

On the one hand, intellectual property protection receives considerable attention in the discussion about incentives for a firm engaging in innovation and, on the other hand, overall institutional quality will affect the production process and a firm's ability to enjoy the fruits of R&D investment. Therefore, these two measures of institutional quality are both examined in the regression analyses below.

Table 7.1 Number of all firms and number of firms that engaged in R&D expenditure

Year	N	Number of observations with nonzero R&D	Percentage
2005	243994	26051	0.106769
2006	271002	29804	0.109977
2007	304936	34232	0.1122596

Source: Annual Census of Chinese Industrial Firms compiled by the National Bureau of Statistics of China.

Table 7.2 Descriptive statistics of the sample for regression

Descriptive statistics				
Variables	Mean	Standard deviation	Min	Max
R&D intensity	0.0018	0.0146	0	0.9906
size	4.66	1.08	2.2	12.1
age	9.2	9.12	1	180
k	87.97	231.3	-4.78	26,818.19
herfindahl	0.015	0.027	0.00099	0.92
marketshare	0.0017	0.0089	0	0.88
wage	2.72	0.57	-5.3	8.39
profitability	0.0102	8.88	-7710.8	628.8
exportintensity	0.17	0.34	0	1.4
debt ratio	0.57	0.44	-24.3	270.5
interestpayment	0.015	4.62	-28	4130
subsidy	0.0028	0.036	-0.24	17.24
intellectual property protection	13.22	10.59	0.02	41.47
overall institutional quality	8.47	1.58	0.29	10.92
percapitaGDP	26,329.84	12,033.13	5052	66,367

Source: Annual Census of Chinese Industrial Firms compiled by the National Bureau of Statistics of China.

Empirical Specification and Estimation

$$\begin{aligned}
 R\&Dintensity_{i,j,k,t} = \\
 &\beta_0 + \beta_1 * size_{i,j,k,t} + \beta_2 * age_{i,j,k,t} + \beta_3 * profitability_{i,j,k,t} + \beta_4 * \\
 &exportintensity_{i,j,k,t} + \beta_5 * wage_{i,j,k,t} + \beta_6 * marketshare_{i,j,k,t} + \beta_7 * \\
 &herfindahl_{j,t} + \beta_8 * debtratio_{i,j,k,t} + \beta_9 * k_{i,j,k,t} + \beta_{10} * subsidy_{i,j,k,t} + \beta_{11} * \\
 &interestpayment_{i,j,l,t} + \beta_{12} * institutionalquality_{k,t} + \beta_{13} * percapitaGDP_{k,t} + \\
 &\varepsilon_{i,j,k,t} \quad (1)
 \end{aligned}$$

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 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 innovative inputs or output. Measures of output include the number of patents, the number of significant innovations, and indices of the 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). There is no information about the number of patents and the personnel involved in R&D in our dataset, and therefore R&D intensity is adopted.

$size_{i,j,k,t}$ is the natural logarithm of a firm's number of employees.

$age_{i,j,k,t}$ is the number of years of a firm's existence.

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

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

$wage_{i,j,k,t}$ is the average wage of the firm's employees; i.e. the sum of wage compensation and welfare compensation divided by the number of employees.

$marketshare_{i,j,k,t}$ is the share of a firm's industrial sales 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 Herfindahl 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 a firm's fixed assets per employee.

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

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

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

$percapitaGDP_{k,t}$ is the per capita GDP of the province in which a firm is located.

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 one uses ordinary least squares (OLS) estimation on the non-zero part of the original variable $R\&Dintensity_{i,t}$, 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 fixed effects at the firm level, requires an estimation strategy that can tackle these two problems at the same time. Previous studies on the determinants of the R&D intensity of Chinese firms 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. Therefore, this study adopts an estimation strategy (Kyriazidou 1997). This estimation strategy solves the sample selection problem and the omitted variables problem due to unobserved firm heterogeneity at the same time.

Empirical Results

Table 7.2 presents the descriptive statistics of the sample for the regression. Table 7.3 and Table 7.4 report the regression results. Table 7.3 examines how intellectual property rights protection influences the R&D intensity of firms, and Table 7.4 illustrates the effect of overall institutional quality. It can be seen that the results based on these two different measures of institutional quality are qualitatively similar. All other things being equal, a firm with a larger size 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 where received subsidy is of a larger proportion in the industrial sales is more likely to do R&D; lastly, when the protection of intellectual property rights (or overall institutional quality) is stronger in the province where a firm is located, the firms is more likely to do R&D.

Table 7.3 Regression results

Regressors	Likelihood of conducting R&D activities		R&D intensity (share of R&D expenditure in total industrial sales)	
	Coefficients	Standard error	Coefficients	Standard error
size	0.48***	2.6E-02	-2.3E-03	1.6E-03
age	-0.0034	3.3E-03	-1.8E-05	3.9E-05
k	6.2E-05	7.2E-05	4.1E-06	6.4E-06
herfindahl	-0.27	0.71	0.057***	2.0E-02
marketshare	0.16	2.1	-0.073***	2.6E-02
wage	0.38***	2.1E-02	6.5E-04	1.3E-03
profitability	0.055**	2.6E-02	-0.010	5.6E-03
exportintensity	0.29***	6.4E-02	-3.0E-03	3.2E-03
debtratio	-0.15***	4.7E-02	-3.5E-03	2.2E-03
interestpayment	0.22	0.15	0.080***	3.0E-02
subsidy	0.56**	0.26	0.074	5.2E-02
intellectual property protection	0.029***	4.3E-03	-7.9E-05	2.0E-04
percapitaGDP	-7.70E-07	8.5E-06	4.6E-07	3.6E-07
year2006	0.075	2.5E-02	6.1E-04	8.7E-04
year2007	0.15	4.9E-02	-1.6E-03	1.7E-03

Note: ***, **, * indicate that the level of significance is 1%, 5% and 10%, respectively.

Source: Author's own estimations.

The influences of these variables on the R&D intensity of a firm that indeed conducts R&D activities are as follows. If the four-digit industry to which a firm belongs becomes less competitive, the more R&D intensive a firm becomes. The higher the market share of a firm in the four-digit industry, the less R&D intensive the firm becomes. The larger the share of interest payment in the industrial sales of a firm, the more R&D intensive the firm becomes.

Comparing how the variables impact on the likelihood of doing R&D and the R&D intensity of firms, one can see the following two points. First, the market share 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 exert influence on the R&D intensity of a firm that conducts R&D activities, but not on the decision whether to do R&D. Secondly, the size of a firm, wage rate, profitability, export intensity, debt burden of a firm, received subsidy and

intellectual property rights 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.

Table 7.4 Regression results

Regressors	Likelihood of conducting R&D activities		R&D intensity (share of R&D expenditure in total industrial sales)	
	Coefficients	Standard error	Coefficients	Standard error
size	0.48***	2.62E-02	-1.2E-03	1.3E-03
age	-0.0034	3.21E-03	-2.4E-05	4.6E-05
k	6.34E-05	7.23E-05	-1.1E-06	7.1E-06
herfindahl	-0.27	7.08E-01	0.068***	2.6E-02
marketshare	0.27	2.09E+00	-0.10***	3.5E-02
wage	0.38***	2.05E-02	1.3E-03	1.4E-03
profitability	0.055**	2.56E-02	-0.015*	8.3E-03
exportintensity	0.30***	6.37E-02	4.7E-04	2.7E-03
debt ratio	-0.15***	4.64E-02	-1.5E-03	2.5E-03
interestpayment	0.22	1.55E-01	0.094***	3.8E-02
subsidy	0.55**	2.55E-01	0.10	6.2E-02
Overall institutional quality	0.022***	5.17E-02	9.3E-04	1.8E-03
percapitaGDP	2.28E-05***	6.34E-06	4.0E-07	3.0E-07
year2006	-0.0751**	2.87E-02	9.4E-04	9.6E-04
year2007	-0.093*	4.81E-02	-1.1E-04	1.7E-03

Note: ***, **, * indicate that the level of significance is 1%, 5% and 10%, respectively.

Source: Author's own estimations.

On the one hand, the finding that a firm of larger size and a firm with higher profitability are more likely to do R&D, but may not be more R&D intensive, reflects 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 consistent with Schumpeter's argument, and it requires further research on the channels behind the results to provide a convincing explanation.

As to the relationship between financial constraints and innovation activities, the finding that a firm with a larger debt burden is less likely to do R&D supports the hypothesis that internal funds are a critical funding source for a firm's R&D activities, and a firm with more equity will conduct more R&D activities. When R&D intensity is considered, the significant role of the share of interest payment in the industrial sales of a firm suggests the importance of

the availability of external funding sources, such as bank loans to fund R&D activities. Interestingly, the share of subsidy in total industrial sales is found to increase the propensity of a firm to do 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 requires further research. Also, the fact that institutional quality matters for engaging firms in R&D activities, but not for R&D intensity once firms opt in to R&D activities, further points to the importance of other potential determinants of R&D intensity.

Stronger intellectual property protection 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 Scientific and Technological Development (2006–2020)', that firms should become the major agents of R&D activities, one helpful strategy that the government could adopt is to build up institutions that facilitate market operations and strengthen the protection of intellectual property rights that increase the expected return to R&D investment of firms. Interestingly, intellectual property protection 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 intellectual property rights 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.

The real per capita GDP of the province where a firm is located is included in the regression to act as a control for the influences from the stage of development. Provinces with higher real per capita GDP may enjoy better infrastructure, more human resources, or a generally more mature business environment. These factors could be conducive to a firm's R&D activities and could also be correlated with institutional quality. Therefore, real per capita GDP is controlled in the regression. We can see from the results that real per capita GDP is not significant in explaining the likelihood of a firm to perform R&D, and the R&D intensity of firms that have already decided to perform R&D. This finding further confirms the importance of institutional quality itself.

Lastly, a firm that has higher export intensity is found to be more likely to conduct R&D activities, although, for a firm that is doing R&D, export intensity is not significantly associated with R&D intensity.

Policy Implications

As China continues to draw level with countries on the world knowledge frontier, the need has intensified for the economy to become more knowledge-intensive and innovative in order to sustain the growth momentum. 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 chapter suggest the institutional quality is critical for China's innovative performance and hence for the economy's future growth.

This study employs a firm-level panel dataset which covers the period 2005–2007 and covers all state-owned enterprises and all enterprises with annual turnover of over five million RMB. Based on an estimation strategy (Kyriazidou 1997) which takes into account the sample selection problem and the firm-level fixed effects at the same time, the study shows that higher levels of overall institutional quality and higher levels of intellectual property rights protection that exists in 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. The two measures of institutional quality are not, however, 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 decision of firms to enter 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, improving 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 pool of knowledge and technology. Better understanding of other factors that influence the R&D intensity of firms after they begin to have R&D investment 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 not the R&D intensity of the firm, more trade-related measures will need to be considered in a complete study on the effects of firm-level trade or innovation.

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