RD Efficiency in High-Tech Firms in China

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R&D Efficiency in High-Tech Firms in China*

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Abstract

Using firm-level data from Changzhou, one of the representative prefectural cities in the Yangzi River Delta in China, we investigate the performances of both internal and external R&D in high-tech firms. We find that, on average, high-tech firms with more internal R&D expenditure apply for more patents in terms of both the total number of patents and the number of invention patents. Internal R&D is the most efficient in foreign firms, followed by private firms and then followed by SOEs (state-owned enterprises). These findings highlight the importance of privatizing high-tech firms in China if the Chinese government intends to accelerate industrial upgrading and convert the pattern of "Made in China" into "Created in China."

I. Introduction

China is well-known for its fast economic growth during the last four decades. What is often omitted is that China also quite actively involved in research and development (R&D) activities. As shown in Table 1, according to the China Statistical Yearbook 2015, R&D expenditure at the national level as well as its ratio to GDP have been increasing fast. More than 70% of the R&D expenditure pertains to industrial firms above scale. As a result, an increasing number of patent requests are submitted by industrial firms above scale. In 2014, R&D expenditure by industrial enterprises with total sale revenues of more than 20 million yuan was 925.43 billion yuan, which accounts for an 11.1% increase from 2013.

<Table 1> R&D activities in China

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These facts are in line with the ambiguous vision of the Chinese government – to replace the label "Made in China" with "Created in China." In order to achieve this goal, the Chinese government has selected some high-tech firms, believed to be the main force of the future for "Created in China." As reported in Table 2, both the R&D expenditure and the number of patents applied for by high-tech firms increased rapidly between 2009 and 2014. In comparison with Table 1, among the industrial firms above scales, the larger share of R&D activities was conducted by above-scale high-tech firms, that is, in 2014, more than 20% of R&D expenditures by industrial firms above scale occurred in high-tech firms.

<Table 2> R&D activities in high-tech firms in China

By 2014, China had 27,939 high-tech firms, which spent 192.22 billion yuan on R&D in 2014. High-tech firms receive preferential treatment such as reductions in business-income taxes, sales-tax exemptions for technology-transfer contracts, extra tax reductions for R&D expenditures as well as special government grants. Studying high-tech firms in China represents a good opportunity to further understand R&D efficiency in developing countries. According to Tables 1 and 2, for each billion yuan of R&D expenditures, industrial firms above scale apply for 425 patents, while high-tech firms apply for 625 patents. It induces that if we measure R&D performance by the number of patent applications, R&D activities by high-tech firms seem to be more important.

A large number of existing studies focuses on R&D efficiency in both developed countries (Gao and Chou, 2015; Tsai and Wang, 2005) and developing countries (Hu, 2001; Seo *et al.*, 2012; Hosseini and Narayanan, 2014). Empirical studies on the R&D efficiency in Chinese firms usually rely on data from industrial firms at the firm level or industrial level (Zhang et al., 2003; Zhang and Shi, 2011) or data from listed companies (Boeing *et al.*, 2016). To our knowledge, Hu's (2001) research on the R&D efficiency of high-tech firms in the Haidian District of Beijing, China, is the study most closely related to ours. Hu (2001) examines the link between its own (internal) R&D and productivity at the firm level as well as the heterogeneous effects of private and government R&D, respectively. The context of our empirical work is also high-tech firms in China, but we have a different research focus.

In this paper, we measure the effectiveness of high-tech firms through their patent applications. Patent counts or patent to R&D are some of the measures of innovative performance employed in existing studies (e.g., Acs and Audretsch, 1990, 1991; Cohen and Klepper, 1996a, 1996b; Pavitt *et al.*, 1987). Since Chinese government regards these measures as important measures of domestic firms' competitiveness, high-tech firms are encouraged to apply for patents. As a result, high-tech firms apply for patents not only because they are concerned about protecting their property rights, but also in order to fulfill the government's requirements if they want to receive government funding aimed at stimulating R&D activities in high-tech firms. Hence, patent applications might just reflect high-tech firms' efforts to obtain government funding rather than the effectiveness of their R&D. Further, we investigate the effectiveness of high-tech firms' R&D through revenues from new products as well as the R&D effectiveness of firms with different ownership types. Another departure from Hu (2001) is that we distinguish two different kinds of R&D expenditure: internal and external. External R&D expenditure refers to payments to other firms; this can be firms to which a high-tech firm entrusts its R&D activity or a firm with which a high-tech firm cooperates.

We find that high-tech firms' internal R&D significantly correlates with the number of patents or the number of invention patents applied for. This, however, does not apply to external R&D. We interpret this finding as firms relying less on external R&D workers for patent application, since business secrets are at stake. As for high-tech firms' with different ownership types, we find that return on internal R&D for private firms is lower than for foreign firms, but higher than for SOEs. Examining the revenue from new products further reveals that foreign high-tech firms are the most efficient with respect to internal R&D expenditures, while private firms are most efficient in seeking external R&D to generate more revenue from a new product.

The remainder of the paper is organized as follows. Section 2 presents the data and our empirical strategy. In Section 3, we present and discuss the results. Section 4 concludes.

II. Data and empirical strategy

Chinese government announced *National Guideline of Medium and Long-term Science and Technology Development* (2006-2020) in 2006. In March next year, National People's Congress approved the *Enterprise Income Tax Law of the People's Republic of China*, where preferential treatment is provided to high-tech and new-tech firms under the key support of the state. In order to make the law more practicable, *Administrative Measures for the Determination of High and New Tech Enterprises* were approved by State council. The Torch High Industry Development Center under the Ministry of Science and Technology is the main official institute that is responsible for the determination of high and new tech firms. In practice, R&D intensity is the most important condition for determination of high and new tech enterprises and receiving preferential treatment, i.e., enterprise income tax reduction.

The data in this study were obtained from surveys that cover all firms located in the National High-Tech and New-Tech Development Zones in China, or firms recognized as high-tech firms in Changzhou, Jiangsu province, China. The survey is compiled yearly by the Torch High Industry Development Center under the Ministry of Science and Technology, and its goal is to reinforce the overall technological innovation environment and promote high-tech industrialization in China. Department of Investigation and Statistics in the Torch Center is responsible for collecting data from high-tech firms in China. Our sample includes all high-tech firms in Changzhou, two county-level cities (Liyang and Jitang), and five districts (Gaoxing, Wujing, Tianling, Zhonglou, and Qiqu). We have 232, 233, and 235 firms in the sample for 2008, 2009, and 2010, respectively, and 230 of these form a balanced three-year panel.

Changzhou is a major industrial city in the Jiangsu province in the affluent Yangtze Delta Economic Region in China. It borders on the provincial capital of Nanjing to the west and it is not far from Shanghai, the main metropolis in the Yangtze Delta Region. In 2013, the R&D expenditures by industrial firms in the Jiangsu province with revenues above 20 million yuan were 1.24 billion yuan, which is the highest figure among all provinces in mainland China, accounting for 14.9% of the national total. Changzhou is representative of other large coastal cities in Eastern China, which account for a significant portion of the country's R&D activities. According to the China City Competitiveness Annual (KPMG, 2010), it is one of the most competitive cities for private investment in China. Changzhou thus represents a good location for us to gain a deeper understanding of R&D activities in high-tech firms in China.

Given the increasingly important role of high-tech firms in China as well as the active role of the Chinese government in industrial upgrading, the R&D effectiveness of high-tech firms with different ownership types might provide us with insights into the future of industrial upgrading in China and the importance of privatization of state-owned high-tech firms in China.

Existing studies often use patents to refer to innovative performance (e. g., Acs and Audretsch, 1990, 1991; Cohen and Klepper, 1996a, 1996b Pavitt *et al*., 1987). We use the number of firms' patents applications in the given year as one measure of firms' R&D outcome. We use both the total number of patents applied for (*patent*) and the number of invention patents applied for (*invent_patent*). The number of invention patents is more difficult to obtain. Since firms holding more patents are more likely to maintain their identity as high-tech firms or be recognized as such, they may apply for patents only to formally meet the requirements of the government and get preferential treatment. In this sense, patent application may not necessarily be an effective measure for firms' competitiveness. Hence, we further investigate the effectiveness of high-tech firms' R&D through revenues from new products. New products are defined as products using new techniques, new design, or substantial improvement over former products in structure, material or techniques, and, as a result, the performance or function of the products is significantly upgraded. We use the revenue from new products (*new_product*), rather than the market value of new products, to highlight that new products should generate market demand and be purchased by consumers or other firms.

Firm-level R&D data are not available for many years, and hence, following Toivanen *et al.* (2002) and Nagaoka (2006), we use the flow value of R&D rather than its stock value. One of our main explanatory variables is R&D expenditure in the reporting year. In the dataset, we divide the firms' total R&D expenditure into internal R&D and external R&D. External R&D expenditure refers to the amount that the firm paid to other firms for R&D activities that were outsourced or a result of cooperation. Our other main explanatory variable is the ownership type of the firm. We distinguish four different ownership types: SOEs, private firms, firms with investment from Hong Kong, Macau, and Taiwan (HMT), and firms with foreign investment. We expect that, on average, firms with more internal R&D expenditures will have more patent applications, including invention patents. For foreign firms, we expect the marginal effect of R&D expenditure on the number of patents to be relatively higher. Because of the lower efficiency of SOEs, however, we also expect that this effect on the number of SOEs' patents is relatively low. Since SOEs are less competitive and may be encouraged to apply for patents just to maintain their identity as high-tech firms, lower efficiency should also apply to the other dependent variable in our study – the revenue from new products,

The effect of external R&D activities on patent application might be different from that of internal R&D activities. This is because, concerned about property-rights protection, firms might want to keep the whole R&D process a business secret before they apply for a patent. As a result, the marginal effect of external R&D on patent application may not be as significant as that of internal R&D. This argument, however, may not hold for the effect of external R&D on the revenue from new products.

We employ two different regression models. Since the number of patent applications is left-censored to zero, we use a Tobit regression first. The fixed-effects Tobit model could be biased, thus, we use the random-effects model for our panel data. Furthermore, to consider time-invariant unobservable factors, we use the fixed-effects model with our panel data. However, some firms do not have any revenue from new products. In such cases, we use the random-effects Tobit model, followed by the fixed-effects model for panel data. As a robustness check, we lagged all the control variables for one or two years, capturing the fact that R&D investment to generating revenue from new products is a long process.

The main explanatory variables include internal R&D expenditure (*RDinput*), external R&D expenditure or outsourced R&D expenditure (*ORDinput*), and dummies for ownership type, where *SOE* stands for state-owned enterprises, *Private* for private firms, *HMT* for firms with investment from Hong Kong, Macau, and Taiwan, and *Foreign* for firms with foreign investment. The heterogeneous effect of R&D expenditures on patent application for firms with different ownership types could be captured by the coefficient of the interaction terms between ownership type and R&D expenditure. As suggested by Brambor *et al*. (2006), we also calculate the marginal effect of R&D expenditure on the number of patent applications for different ownership types.

Our control variables include firm-level characteristics and industry dummies at the 2-digit level. The number of R&D workers (*RDworkers*) is a proxy for the scale of R&D activities in the economy. Other controls include a dummy for whether the firm exports or not (*export*), whether the firm is located in a high-tech zone or not (*zone*). We use year dummies to control for factors that, year by year, affect the average R&D performance for high-tech firms with different ownership types. We report the descriptive statistics in Table 3.

<Table 3> Descriptive statistics

As for firms with different ownership types, we have 57 observations for SOEs (8.98% of all observations), 506 observations for private firms (79.69%), 33 observations for firms with investment from Hong Kong, Macau, and Taiwan (5.20%) and 39 observations for firms with foreign investment (6.14%). We treat private firms as the reference group since they represent the largest number of observations.

III. Results

First, we use a random-effects Tobit regression to investigate the effectiveness of R&D in the high-tech firms in the sample. We report the results in Table 4, where the dependent variable is the number of patent applications.

<Table 4> Patent application –random-effects Tobit regression

The results in Table 4 indicate that, on average, high-tech firms with more internal R&D expenditure apply for more patents. This does not hold for external R&D expenditure, however. Without considering the heterogeneous effect of firms' different ownership types, Column (1) in Table 4 shows that, on average, SOEs apply for fewer patents compared with the reference group (private firms). Further evidence from Column (2) indicates that SOEs apply for fewer patents because their internal R&D is less efficient compared with private firms. Further, the interaction terms indicate that the internal R&D of foreign firms and the internal R&D of firms with investment from Hong Kong, Macau, and Taiwan are more efficient than that of private firms. Including year dummies uncovers the general trend of technological upgrading: on average, the number of patent applications by high-tech firms has been increasing. There is no significant correlation between patent applications and external R&D expenditure. After we add the interaction terms between external R&D expenditure and ownership types, the basic results remain unaltered, as shown in Column (3).

Next, since the Tobit model does not control for firm-level fixed effects and the results might hence be affected by the missing-variable bias, we use a fixed-effects model for our panel data. As expected, Column (1) of Table 5 shows that, on average, only internal R&D expenditure, rather than external R&D expenditure, significantly correlates with patent applications. In Columns (2) and (3) of Table 5, the significant and positive coefficient of *RDinput* indicates that private high-tech firms with more internal R&D expenditure apply for more patents. Further, the coefficients of the interaction terms show that the internal R&D of foreign high-tech firms is more efficient than that of private firms. The interaction term of *SOE* and *RDinput* is, however, only marginally significant.

<Table 5> Patent applications – fixed-effects model

Following Brambor et al. (2006), we take Column (3) in Tables 4 and 5 and calculate the marginal effects of R&D expenditures for different ownership types. We report the results in Table 6. External R&D has no significant impact on firms' patent applications; however, for private and foreign high-tech firms more internal R&D results in more patent applications. For SOEs, the marginal effect of internal R&D on patent application is not significant in the Tobit model nor in the fixed-effects model. The marginal effect of firms with investment from Hong Kong, Macau, and Taiwan is not robustly significant.

<Table 6> Marginal effects of R&D expenditure on patent applications

Since an invention patent is more difficult to obtain, next, we study the determinants of invention-patent applications in more detail in Table 7. The results are comparable to the results reported in Tables 4 and 5.

<Table 7> Invention-patent applications

Following Columns (2) and (4) in Table 7, we calculate and report the marginal effects in Table 8. The basic results are the same as in Table 6. The marginal effects of external R&D are not always significant for firms with all ownership types. The marginal effects of internal R&D for both private and foreign firms are significantly positive; the magnitude of these effects is larger for foreign firms than for private firms. The marginal effect for firms with investment from Hong Kong, Macau, and Taiwan is, again, not robustly significant.

<Table 8> Marginal effects of R&D expenditure on invention-patent applications

High-tech firms may, rather than to protect property rights, apply for patents only to meet the requirements imposed by the government to qualify as high-tech firms. Hence, we investigate whether more R&D expenditure results in more revenue from new products. The definition of a new product implies that high-tech firms are more likely to have more revenue from new products that resulted from competitive pressures.

As shown in Column (1) of Table 9, on average, high-tech firms with more internal R&D or more external R&D have more revenue from new products. This is different from the previous regression results, where only the coefficient on internal R&D was significant. The explanation we offer is that firms might rely on external R&D for more new products, since it does not necessary relate to business secrets. Foreign firms are, again, more efficient in internal R&D compared with private firms. The coefficients of interaction terms between ownership and external R&D are difficult to explain (as we show below, the coefficients are not robust). Interestingly, the year dummies in Table 9 are no longer significant. This departure from previous results implies that although high-tech firms in China tend to apply for more patents each year, they do not show the same increasing ability in generating more revenue from new products.

There also exists an alternative explanation of foreign firms outperforming in R&D efficiency since they may receive technical support from mother companies. We dropped some foreign firms whose mother companies are big brand, which are more able to provide technical support. The result is robust. Although we cannot fully deny this possibility, we would argue that it is more reasonable for the mother companies to hold patent by themselves and charge permission fees from FDI firms in China other than providing technical support to FDI firms in China and allowing FDI firms in China to apply their own patent.

<Table 9> Revenue from new products

Next, we check the robustness of the results reported in Table 9. Since revenue from new products may be generated only some time after the R&D investment was made, we lag all independent variables by one year in regressions reported in Columns (1) and (3) of Table 10. In Columns (2) and (4), all independent variables are lagged by two years; in these regressions, we only have cross-sectional data since the original data are a three-year panel. Hence, in Columns (2) and (4), we employ a Tobit model and an OLS model for cross-sectional data. For the sake of comparability, we use the same models in Columns (1) and (3) of Table 10 and include year dummies..

<Table 10> Revenue from new products – robustness check

The basic result in Table 10 is the same when we use lagged dependent variables. Private high-tech firms with more internal and external R&D have more revenue from new products; the coefficients on linear terms of internal and external R&D are both significant and positive. Compared with private high-tech firms, SOEs are less efficient in converting R&D investment into revenue from new products and foreign high-tech firms are more efficient. The marginal effects are listed in Table 11, analogously to Tables 9 and 10.

<Table 11> Marginal effects of R&D expenditure on revenue from new products

The marginal effects from Table 11 indicate that, in terms of the revenue from new products, the internal R&D investment by foreign high-tech firms is the most efficient. For both private firms and SOEs, the marginal effects of their internal R&D investment on the revenue of new products are significant and positive. However, only for private high-tech firms is the marginal effect of external R&D investment on the revenue from new products significant, positive, and robust.

We finally do robustness test by dropping some outliers, with the amount of patent applied or value of new products far beyond most of the observation. For example, we dropped observations with number of patent applied above 100, number of invention patent applied above 30 and revenue of new product above 50 million RMB. The results are shown in table A1 and table A2 in appendix. Table A1 only reports marginal effect of internal R&D on both patent and invention patent applied. The basic results still hold compared with that in table 6 and table 8. The marginal effect of SOEs is always not significant. Although the marginal effect of private firms loses some significance, the coefficient is still positive (and nearly significant). Table A2 also provides the same results especially that the marginal effect of external R&D for private firms is always significantly positive.

IV. Conclusions

Based on firm-level data in Changzhou, a city representative of prefecture-level cities in the Yangzi River Delta in China, we examined the effectiveness of both internal and external R&D of high-tech firms. We found that, on average, high-tech firms with more internal R&D expenditure apply for more patents, both in terms of total patents and invention patents. Studying the marginal effects for firms with different ownership types showed that internal R&D makes foreign firms more efficient in patent application, followed by private firms and then followed by SOE. However, SOEs with more internal R&D expenditure do not apply for more patents. We found no significant correlation between external R&D and patent application.

The intuition behind this result is that firms might be reluctant to share innovation secrets pertaining to the R&D process with other firms.

Further study on the revenue from new products indicates that both private firms and SOEs are less efficient than foreign firms with respect to internal R&D, while private firms are the most efficient in seeking external R&D and generate higher revenues from new products.

If the Chinese government indeed intends to accelerate industrial upgrading and convert the pattern of "Made in China" into "Created in China," these findings highlight the importance of privatizing high-tech firms in China. Given that FDI has a positive spillover effect on domestic firms in developing countries, this also implies that industrial upgrading of Chinese firms should be accompanied by economic openness.

Our study has several limitations. Our sample is only representative of the developed regions in China, rather than of all regions nationwide. The time horizon is also limited, hence, we were not able to study the lagged effect of R&D on patent application in more detail. The role of HMT high-tech firms also requires further study, as we were unable to disentangle all influences.

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Table 1 R&D activities in China

	2009	2010	2011	2012	2013	2014
Total R&D expenditure (billion yuan)	580.21	706.26	868.70	1029.84	1184.66	1301.56
R&D expenditure / GDP (%)	1.68	1.73	1.79	1.93	2.01	2.05
R&D expenditure by industrial firms above scale (billion yuan)	377.57	-	599.38	720.06	831.84	925.43
Number of patent applied by industrial firms above scale (item)	166762	198890	265612	327116	359791	393480

Source: China Statistical Yearbook 2015, National Bureau of Statistics of China.

Table 2 R&D activities of high-tech firms in China

	2009	2010	2011	2012	2013	2014
R&D expenditure (billion yuan)	77.41	96.78	123.78	149.15	173.44	192.22
Number of patent applied (item)	51513	59683	77725	97200	102532	120077

Table 3 descriptive statistics

Variable	Obs	unit	Mean	Std. Dev.	Min	Max
patent	702	piece	7.54	17.56	0	278
invent_patent	702	Piece	2.25	7.36	0	138
new_product	702	100 million RMB	1.55	5.84	0	109.77
RDinput	702	1 million RMB	15.47	44.12	0.25	868.52
ORDinput	702	1 million RMB	0.70	2.59	0	37
RDworkers	702	Person	70.50	103.42	0	1099
export	702	-	0.60	0.50	0	1
zone	702	-	0.43	0.50	0	1

Table 4 patent application (random effect tobit regression)

	(1)	(2)	(3)
RDinput	0.236***	0.192***	0.186***
	(0.0283)	(0.0432)	(0.0439)
ORDinput	-0.236	-0.252	-0.182
	(0.253)	(0.241)	(0.247)
Ownership type			
SOE	-5.729**	2.574	3.371
	(2.644)	(2.991)	(3.120)
HMT	7.818**	-4.861	-8.233*
	(3.257)	(4.160)	(4.364)
Foreign	2.870	0.351	1.027
	(2.991)	(2.899)	(2.992)
*SOE*RDinput*		-0.281***	-0.274***
		(0.0743)	(0.0740)
*HTM*RDinput*		1.041***	1.063***
		(0.242)	(0.239)
*Foreign*RDinput*		0.129**	0.148**
		(0.0588)	(0.0622)
*SOE*ORDinput*			-0.718
			(0.922)
*HTM*ORDinput*			43.41**
			(18.91)
*Foreign*ORDinput*			-0.940
			(1.151)
RDworkers	0.00934	0.0192**	0.0215**
	(0.00811)	(0.00812)	(0.00900)
export	0.253	1.025	0.924
	(1.527)	(1.421)	(1.409)
zone	-3.109**	-1.834	-1.629
	(1.526)	(1.393)	(1.384)
year_2009	2.984**	2.850**	2.838**
	(1.397)	(1.401)	(1.409)
year_2010	5.071***	4.664***	4.608***
	(1.415)	(1.421)	(1.427)
industry fixed effect	Yes	Yes	Yes
Constant	-5.428	-6.925	-7.158
	(7.564)	(6.812)	(6.737)
Observations	635	635	635

Standard errors in brackets, *** p<0.01, ** p<0.05, * p<0.1

Table 5 patent application (fixed effect model)

	(1)	(2)	(3)
RDinput	0.344***	0.250***	0.252***
	(0.0439)	(0.0817)	(0.0819)
ORDinput	-0.347	-0.408	-0.437
	(0.387)	(0.385)	(0.392)
Ownership type			
SOE	-2.155	3.221	2.413
	(8.881)	(9.473)	(10.70)
HMT	3.660	6.157	2.259
	(8.551)	(8.921)	(9.648)
Foreign	5.554	0.861	-1.830
	(7.294)	(7.443)	(8.245)
*SOE*RDinput*		-0.157	-0.161
		(0.170)	(0.171)
*HTM*RDinput*		-0.418	-0.382
		(0.409)	(0.415)
*Foreign*RDinput*		0.168*	0.163*
		(0.0978)	(0.0983)
*SOE*ORDinput*			0.378
			(1.481)
*HTM*ORDinput*			21.52
			(23.66)
*Foreign*ORDinput*			1.382
			(1.806)
RDworkers	0.0248	0.0306	0.0284
	(0.0183)	(0.0187)	(0.0191)
export	1.282	0.944	0.895
	(3.247)	(3.235)	(3.243)
zone	1.029	0.406	0.356
	(10.48)	(10.42)	(10.45)
year_2009	2.873*	2.679*	2.766*
	(1.535)	(1.532)	(1.550)
year_2010	5.007***	4.934***	5.036***
	(1.550)	(1.545)	(1.565)
Constant	-83.87**	-117.9***	-3.845
	(32.51)	(35.88)	(29.67)
R-squared	0.221	0.238	0.240
Observations	635	635	635

Standard errors in brackets, *** p<0.01, ** p<0.05, * p<0.1

Table 6 marginal effects of R&D expenditure on patent application

Ownership type	internal R&D		external R&D	
	Tobit model	Fixed effect model	Tobit model	Fixed effect model
SOE	-0.088	0.092	-0.900	-0.059
	(0.066)	(0.151)	(0.906)	(1.466)
Private	0.186***	0.252**	-0.182	-0.437
	(0.044)	(0.082)	(0.247)	(0.392)
HMT	1.249***	-0.129	43.226**	21.082
	(0.236)	(0.407)	(18.908)	(23.658)
Foreign	0.335***	0.415***	-1.121	0.945
	(0.042)	(0.054)	(1.132)	(1.818)

Table 7 invention patent application

	Tobit model		Fixed effect model	
	(1)	(2)	(3)	(4)
RDinput	0.110***	0.109***	0.125***	0.126***
	(0.0167)	(0.0171)	(0.0351)	(0.0350)
ORDinput	-0.119	-0.111	-0.244	-0.260
	(0.0941)	(0.0973)	(0.165)	(0.168)
Ownership type				
SOE	1.304	1.465	0.914	1.424
	(1.134)	(1.191)	(4.067)	(4.572)
HMT	-1.393	-2.202	1.650	-0.231
	(1.575)	(1.666)	(3.830)	(4.124)
Foreign	-1.234	-1.209	0.522	-2.539
	(1.110)	(1.151)	(3.196)	(3.524)
*SOE*RDinput*	-0.129***	-0.127***	-0.0780	-0.0871
	(0.0284)	(0.0285)	(0.0728)	(0.0731)
*HTM*RDinput*	0.0693	0.0705	-0.176	-0.179
	(0.0903)	(0.0902)	(0.175)	(0.177)
*Foreign*RDinput*	0.0579**	0.0594**	0.109***	0.107**
	(0.0234)	(0.0249)	(0.0420)	(0.0420)
*SOE*ORDinput*		-0.139		0.108
		(0.365)		(0.633)
*HTM*ORDinput*		11.30		7.360
		(7.647)		(10.11)
*Foreign*ORDinput*		-0.0383		1.554**
		(0.468)		(0.772)
RDworkers	0.00286	0.00328	0.0109	0.0101
	(0.00313)	(0.00353)	(0.00801)	(0.00818)
export	0.0536	0.0202	-0.765	-0.775
	(0.547)	(0.546)	(1.389)	(1.386)
zone	-0.498	-0.444	-4.155	-4.185
	(0.523)	(0.525)	(4.475)	(4.465)
year_2009	1.052*	1.056*	0.900	0.913
	(0.585)	(0.589)	(0.658)	(0.663)
year_2010	2.029***	2.031***	2.012***	2.045***
	(0.593)	(0.596)	(0.663)	(0.669)
Constant	-0.975	-1.018	- 60.27***	-4.560
	(2.545)	(2.542)	(15.41)	(12.68)
R-square			0.327	0.335
Observations	635	635	635	635

Standard errors in brackets, *** p<0.01, ** p<0.05, * p<0.1

Table 8 marginal effects of R&D expenditure on invention patent application

Ownership type	internal R&D		external R&D	
	Tobit model	Fixed effect model	Tobit model	Fixed effect model
SOE	-0.018	0.039	-0.250	-0.152
	(0.026)	(0.064)	(0.359)	(0.627)
Private	0.109***	0.126***	-0.111	-0.260
	(0.017)	(0.035)	(0.097)	(0.168)
HMT	0.179**	-0.053	11.192	7.100
	(0.090)	(0.174)	(7.647)	(10.112)
Foreign	0.168***	0.233***	-0.150	1.294
	(0.017)	(0.023)	(0.459)	(0.777)

Table 9 revenue of new product

	Tobit model (1)	Fixed effect model (2)
RDinput	0.0671***	0.0240***
	(0.00696)	(0.00693)
ORDinput	0.118***	0.0955***
	(0.0302)	(0.0331)
Ownership type		
SOE	0.385	-0.836
	(0.514)	(0.905)
HMT	0.370	0.178
	(0.603)	(0.816)
Foreign	0.00167	-0.204
	(0.461)	(0.697)
*SOE*RDinput*	-0.00383	-0.00646
	(0.0110)	(0.0145)
*HTM*RDinput*	-0.0785**	-0.0298
	(0.0307)	(0.0351)
*Foreign*RDinput*	0.0552***	0.0934***
	(0.00833)	(0.00832)
*SOE*ORDinput*	-0.435***	-0.410***
	(0.112)	(0.125)
*HTM*ORDinput*	0.295	1.177
	(2.019)	(2.001)
*Foreign*ORDinput*	-0.315**	-0.262*
		(0.153)
RDworkers	0.00610***	-0.000490
	(0.00124)	(0.00162)
export	0.338*	0.132
	(0.204)	(0.274)
zone	-0.725***	0.315
	(0.249)	(0.883)
year_2009	0.0218	0.00755
	(0.135)	(0.131)
year_2010	0.171	0.177
	(0.137)	(0.132)
Constant	-1.505	2.694
	(1.300)	(2.509)
R-squared		0.874
Observations	635	635

Table 10 revenue of new product (robustness check)

	Tobit model		OLS	
	(1)	(2)	(3)	(4)
RDinput	0.0743***	0.0548***	0.0744**	0.0551**
	(0.00765)	(0.00957)	(0.0299)	(0.0228)
ORDinput	0.252***	0.628***	0.240**	0.611***
	(0.0524)	(0.122)	(0.105)	(0.196)
Ownership type				
SOE	-0.0182	0.00752	-0.0141	0.00954
	(0.0131)	(0.0189)	(0.0318)	(0.0296)
HMT	-0.0983*	-0.162*	-0.0878**	-0.135**
	(0.0542)	(0.0826)	(0.0357)	(0.0614)
Foreign	0.168***	0.205***	0.160***	0.214***
	(0.0144)	(0.0271)	(0.0355)	(0.0584)
*SOE*RDinput*	-0.129***	-0.127***	-0.0780	-0.0871
	(0.0284)	(0.0285)	(0.0728)	(0.0731)
*HTM*RDinput*	0.0693	0.0705	-0.176	-0.179
	(0.0903)	(0.0902)	(0.175)	(0.177)
*Foreign*RDinput*	0.0579**	0.0594**	0.109***	0.107**
	(0.0234)	(0.0249)	(0.0420)	(0.0420)
*SOE*ORDinput*	-0.209	-0.728***	-0.105	-0.626**
	(0.159)	(0.215)	(0.221)	(0.282)
*HTM*ORDinput*	-5.185	-6.605	-4.683*	-5.427**
	(3.959)	(4.373)	(2.448)	(2.334)
*Foreign*ORDinput*	0.179	4.746***	0.175	4.151***
	(0.219)	(0.648)	(0.341)	(1.356)
RDworkers	0.00923***	0.0129***	0.00818***	0.0106***
	(0.00162)	(0.00227)	(0.00311)	(0.00310)
export	0.608**	-0.0336	0.367	-0.0820
	(0.258)	(0.366)	(0.260)	(0.299)
zone	-0.837***	-1.047***	-0.565***	-0.813***
	(0.252)	(0.351)	(0.201)	(0.299)
year_2009	0.195		0.156	
	(0.233)		(0.187)	
Constant	-2.225*	-0.357	-1.952**	-0.185
	(1.163)	(1.579)	(0.989)	(0.854)
R-square / Pseudo R^2	0.3502	0.3919	0.911	0.935
Observations	427	206	427	206

Standard errors in brackets, *** p<0.01, ** p<0.05, * p<0.1

Table 11 marginal effects of R&D expenditure on revenue of new products

Ownership type	internal R&D					
	(1)	(2)	(3)	(4)	(5)	(6)
SOE	0.063***	0.056***	0.062***	0.018	0.060***	0.065***
	(0.010)	(0.012)	(0.017)	(0.013)	(0.020)	(0.018)
Private	0.067***	0.074***	0.055***	0.024***	0.074**	0.055**
	(0.007)	(0.008)	(0.010)	(0.007)	(0.030)	(0.023)
HMT	-0.011	-0.024	-0.107	-0.006	-0.013	-0.080
	(0.030)	(0.054)	(0.083)	(0.034)	(0.035)	(0.056)
Foreign	0.122***	0.243***	0.260***	0.117***	0.234***	0.269***
	(0.004)	(0.012)	(0.026)	(0.005)	(0.020)	(0.053)
Ownership type	external R&D					
	(1)	(2)	(3)	(4)	(5)	(6)
SOE	-0.317***	0.043	-0.100	-0.314**	0.135	-0.015
	(0.110)	(0.153)	(0.181)	(0.124)	(0.201)	(0.191)
Private	0.118***	0.252***	0.628***	0.096***	0.240**	0.611***
	(0.030)	(0.052)	(0.122)	(0.033)	(0.105)	(0.196)
HMT	0.413	-4.933	-5.977	1.273	-4.443*	-4.817**
	(2.019)	(3.958)	(4.371)	(2.001)	(2.438)	(2.320)
Foreign	-0.196	0.431**	5.374***	-0.166	0.415	4.762***
	(0.130)	(0.213)	(0.635)	(0.154)	(0.327)	(1.340)

Note: Column (1) is calculated according to column (1) in table 9. Column (2) is calculated according to column (1) in table 10. Column (3) is calculated according to column (2) in table 10. Column (4) is calculated according to column (2) in table 9. Column (5) is calculated according to column (3) in table 10. Column (6) is calculated according to column (4) in table 10.

Appendix

Table A1 marginal effects of internal R&D expenditure on patent application

Ownership type	patent application		invention patent application	
	Tobit model	Fixed effect model	Tobit model	Fixed effect model
SOE	-0.058	0.021	-0.01	0.004
	(0.043)	(0.09)	(0.011)	(0.026)
Private	0.022	0.044	0.021***	0.019
	(0.028)	(0.047)	(0.008)	(0.014)
HMT	0.773***	0.006	0.033	0.004
	(0.151)	(0.232)	(0.04)	(0.066)
Foreign	0.131***	0.023	0.028**	0.034
	(0.048)	(0.22)	(0.013)	(0.063)

Table A2 marginal effects of R&D expenditure on revenue of new products

Ownership type	internal R&D					
	(1)	(2)	(3)	(4)	(5)	(6)
SOE	0.063***	0.055***	0.065***	0.025*	0.059***	0.066***
	(0.010)	(0.011)	(0.015)	(0.013)	(0.020)	(0.018)
Private	0.067***	0.074***	0.055***	0.024***	0.071**	0.054**
	(0.007)	(0.008)	(0.009)	(0.007)	(0.029)	(0.021)
HMT	-0.012	-0.038	-0.131*	-0.008	-0.030	-0.122**
	(0.030)	(0.053)	(0.075)	(0.034)	(0.035)	(0.055)
Foreign	0.117***	0.113***	0.053	0.176***	0.089***	0.031
	(0.010)	(0.030)	(0.041)	(0.033)	(0.034)	(0.030)
Ownership type	external R&D					
	(1)	(2)	(3)	(4)	(5)	(6)
SOE	-0.314***	0.022	-0.087	-0.321***	0.052	-0.044
	(0.111)	(0.149)	(0.165)	(0.124)	(0.190)	(0.196)
Private	0.119***	0.249***	0.640***	0.097***	0.236**	0.613***
	(0.030)	(0.051)	(0.111)	(0.033)	(0.104)	(0.190)
HMT	0.425	-5.248	-5.949	1.012	-4.829*	-5.285**
	(2.025)	(3.836)	(3.977)	(2.000)	(2.605)	(2.389)
Foreign	-0.158	0.186	0.440***	-0.159	0.149*	-0.347
	(0.146)	(0.212)	(0.955)	(0.153)	(0.085)	(0.520)