Innovation and Productivity in Chinese Firms: a Micro Study of Four Manufacturing Sectors

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ABSTRACT: This paper investigates relations of innovation input, innovation output and production performance in China for four major manufacturing sectors: Textile, Wearing Apparel, Transport Equipment and Electronic Equipment, by using a large sample of firm level micro data and a structural model in estimation. A wave from 2005 to 2006 is estimated and results of all the sectors proves positive effects from innovation input to output, then to firm performance. Market share, export, subsidy, firm size, capital category and other characters of firms are involved in the estimation, which explains significant difference in engaging in innovation and production. In all the sectors, market share improves R&D input, continuous R&D input and export improve new products output. Subsidy sustains R&D input, but not in innovation output. Comparing with private firms, overseas capital based firms tend to input less and output less in innovation, but they do have higher productivity.
KEYWORDS: R&D, New Product, Performance, Micro Data

1. Introduction

Innovation is a key concept in moving into the knowledge-based economy, not only for the further development of developed economies such as the United States and European countries, but also for the reform and development of China. During the past thirty years of reform, China has achieved rapid growth and becomes a "world factory". In the new century, China is seeking for a new development approach to improve productivity, save energy and resources, but maintaining the fast pace of development and aiming to be the world's manufacturing center at the same time. The most practicable strategy is to establish a knowledge-based economy and make innovation a main factor in research and development, production and management, especially in manufacturing sectors at the firm level.

Based on a large sample of firm level data, this paper will investigate why firms choose to carry out R&D, how R&D input supports new product output, how R&D activity affects productivity. The paper focuses precisely on four major but distinctive manufacturing industries: Textiles (code 17), Wearing Apparel (code 18), Transport Equipment (code 37) and Electronic Equipment (code 40). The first two industries are more labor intensive and low-tech, while the others are more capital intensive and high-tech. Our analysis thus relies on four firm samples separately for the 2 years: 2005-2006.

The paper is organized as follows. Section 2 summarizes the literature strands. Section 3 introduces the equations of the structural model. Section 4 describes data and variables selection. The empirical results are presented in section 5 and section 6 draws the conclusion and policy suggestions.

2. Literature Review

Griliches (1979) develops the knowledge production function and gives innovation criteria a new position in production function. Crépon Duguet and Mairesse (1998) propose a new system, combining the innovation selection function, the knowledge production function and the production function together to analyze the innovation procedure and production performance. That is what we call the CDM model.

The CDM model is a systematic attempt to understand the relationships and linkages among innovation input, innovation output and production performance, especially using firm level data. Most of the existing studies using a CDM model incorporate survey data, especially Community Innovation Surveys (CIS) data from European countries. Lööf and Heshmati (2002) study Swedish CIS II data to analyze knowledge capital and firm performance. The parameters are various but all are positive using French and Swedish data. Janz et al. (2004) compare innovation and productivity in Germany and Sweden by using CIS III firm data and get "a common story across countries". Ferreira et al. (2007) give both separate and simultaneous estimation of a CDM equations system and get different results by using Portuguese CIS II firm data. Mohnen et al. (2006) work on CIS I firm data to compare 7 European countries and develop the measure of innovativity. Benavente (2002) estimates the CDM model by using Chilean survey data designed under the reference of CIS, but the sample size is much smaller.

A CDM related model has been estimated in a few papers using hard data, including data from China. Jefferson et al. (2006) studies R&D and firm performance of Chinese large and medium-size manufacturing firms by using a rich set of census data from 1997 to 1999. Hu and Jefferson (2004) discuss the same question using sample survey data of state-owned enterprises located in Beijing. These results suggest substantial and significant returns to R&D, and a difference across industries.

This paper will focus on firm behavior, from the innovation process to firm performance. The contribution of this study is the subdivided sector level study which tests the effectiveness of the CDM model by not using survey, but firm level hard data.

3. Econometric Model

The CDM model brings together three main fields of investigation in the econometrics of innovation, i.e. why firms select innovation inputs, innovation output efficiency, and innovation's impact on productivity. It has three steps and four equations written as follows, with i index firms and t index year. Vector x series are explanatory variables, vector b series are parameters and vector u series are error terms.

Innovation input:
$$brd_{(t-1)i} = x_{0(t-1)i} b_0 + u_{0i} \quad (1)$$
$$lrdpl_{(t-1)i} = x_{1(t-1)i} b_1 + u_{1i} \quad (2)$$

Innovation output:
$$lnppl_{ti} = \alpha * \widehat{lrdpl}_{(t-1)i} + x_{2ti} b_2 + u_{2i} \quad (3)$$

Innovation performance:
$$lp_{ti} = \gamma * \widehat{lnppl}_{ti} + x_{3ti} b_3 + u_{3i} \quad (4)$$

Step one, known as the innovation function, explains innovation input with equations (1) and (2). The first equation is a probit model as a selection equation to understand firms' decisions about whether or not to input innovation. The second equation is a Tobit model to explain why they would like to spend more or less on innovation. Explained variables in innovation input are measured by a binary variable (brd) in the probit model to identify whether firms have made an innovation input or not, and R&D intensity measured by R&D expenses per labor unit ($lrdpl$, in log.) in the Tobit model to explain why they would choose to spend different amounts on innovation. The regressors are market share, capital intensity, binaries of subsidy, as well as control variables such as firm size dummies and ownership dummies.

Step two with equation (3) is a knowledge production function. Innovation output is measured by new product output per labor unit ($lnppl$, in log.) to identify the extent to which firms have innovation output. The predictor variables are predicted value of R&D expenses ($\widehat{lrdpl}$), capital intensity, binaries of subsidy, and dummy groups of firm size and ownership.

Step three with equation (4) is an extended Cobb-Douglas production function to explain innovation output and its influence on productivity, measured by labor productivity (lp, in log.). The predicted value of innovation output ($\widehat{lnppl}$) is a regressor, except for the traditional variables of capital intensity and number of employees. Dummy variables for ownership, as well as region and sub-sector are also added in this step.

In order to include all the firms in the model, we follow the estimation method in Griffith et al. (2006) by using predicted values from earlier steps in later steps. We also estimate the innovation input equation one year earlier than the innovation output and firm performance equations, assuming that innovation input has a time lag in influencing innovation output, but the effect of innovation output on performance is mainly in the same year. Similarly, we estimate the pooled four sectors to test the robustness of our findings.

4. Data and Description

This paper will use the industrial census data in 2005 and 2006. They are the most recent firm level data that it is possible to obtain from the China National Bureau of Statistics. It is a yearly census of all state-owned firms, and those non-state-owned middle and large firms above a designated size. The criteria are all hard data and most of them are from yearly accounting reports by enterprises. The dataset gives us a wide field of research, but also poses challenges in terms of variances and other metters which require sector by sector investigation.

From the original data we delete those firms with fewer than 10 employees, or whose sales of products are less than RMB 5 million, or whose value added is less then zero. Then we calculate the growth rates of sales, labor and capital for each firm. Firms with all the three growth rates between the 2.5 and 97.5 percentile are kept in the modeling. Thus we obtain two-year balanced data from 2005 to 2006.

The basic description of variables in each sector and each corresponding year shows the average labor productivity increases more than 15% in textiles and transport equipment in 2006, about 10% in wearing apparel, but only 3.5% in electronic equipment. The average numbers of employees are around 300, 340 and 350 in the first three sectors respectively, and they do not change much across the two years. The number is much higher in electronic equipment firms, and it grows about 10% in 2006 to nearly 700 people per enterprise.

For innovation variables, only about 5% to 6% of firms have R&D input in the first two low-tech sectors. This grows to about 20% in transport equipment, and nearly 30% in electronic equipment. In all these four sectors, for those firms with R&D input in 2005, more than half of them continue to input in innovation in the second year. The proportion of firms outputting new products firms is about 1% to 2% higher than the R&D input ratio in the two low-tech sectors, but is lower in the two high-tech sectors, especially about 7% to 8% lower in electronic equipment.

The ratio of firms receiving subsidy is higher in the high-tech sectors than in the low-tech sectors. Nearly 20% of high-tech firms have subsidy from the government, either for innovation or export. Only about 15% of textile firms and 12% of wearing apparel firms receive any subsidy from the government. The trend of this ratio goes slightly down in 2006 for all the sectors except transport equipment.

Ownership dummies show private firms are the largest ownership group in the first three sectors, comprising around 58% of textile firms, about 42% of wearing apparel firms and the same proportion in transport equipment firms. Overseas capital, including Hong Kong, Macao and Taiwan (HMT) and foreign capital, controls more than half of electronic equipment firms. Moreover, state-owned firms are a very small proportion in all these four sectors: 5% in transport equipment, and less than 2% in the other three sectors. Together with Limited Liability Corporations and Share-holding Corporations, firms controlled by state or public capital are less than 20% in all the sectors, except about 27% in transport equipment.

Table 1: Average Value of Main Variables

	Textile		Wearing Apparel		Transport Equipment		Electronic Equipment	
	2006	2005	2006	2005	2006	2005	2006	2005
Productivity (RMB 1000)	80.3	68.7	50.2	45.7	104.1	90.0	117.8	113.9
Labor (person)	307	303	342	333	362	355	684	622
Capital per Employee (RMB 1000)	67.7	64.3	23.4	22.5	74.2	70.7	80.8	80.2
R&D per Labor (RMB 1000)	2.5	1.5	1.7	1.9	10.1	8.5	18.3	16.9
New Product per Labor (RMB 1000)	75.5	62.3	102.1	86.2	514.2	421.7	790.6	707.0
R&D>0	0.062	0.057	0.048	0.047	0.215	0.192	0.281	0.251
New Product>0	0.083	0.072	0.061	0.067	0.180	0.164	0.196	0.181
Subsidy=1	0.140	0.154	0.115	0.120	0.187	0.182	0.192	0.193
Number of Firms	13245		6645		5926		4534	

5. Empirical Result

We start the interpretation by considering why and to what extent firms choose to innovate. The eight columns in Table 2 give estimates of the four selected sectors, and compare selection and intensity equations sector by sector. The innovation input equations show that firms' capital intensity and market share are significantly positive in improving R&D input for all the four sectors, in both selection and intensity equations, in 2005. They are extremely similar among sectors and between selection and intensity equations.

Table 2: Innovation Input: Selection and Intensity Equation

	Textile		Wearing Apparel		Transport Equipment		Electronic Equipment	
Dep. Var.= R&D	Selection	Intensity	Selection	Intensity	Selection	Intensity	Selection	Intensity
Market Share	0.109***	0.349***	0.130***	0.271**	0.039***	0.194***	0.156***	0.196***
	(0.017)	(0.071)	(0.021)	(0.119)	(0.014)	(0.036)	(0.014)	(0.042)
Capital per Employee	0.109***	0.510***	0.137***	0.251**	0.236***	0.574***	0.070***	0.227***
	(0.018)	(0.074)	(0.028)	(0.123)	(0.021)	(0.067)	(0.013)	(0.038)
Rho		0.825		0.66		0.37		0.322
		-0.04		-0.229		-0.086		-0.119
Wald		95.56		28.05		136.88		159.88
Log Likelihood		-4053.9		-1773.9		-4634.2		-9673.5

*** Size and ownership dummies, constant and observations are omitted due to the limitation of pages.**
**** Ownerships are not included in intensity equation.**

The knowledge production function in table 3 shows that predicted R&D expenses were positive in improving innovation output in 2006. The marginal effects are similar (about 0.15 to 0.20) in the first three sectors, and up to 0.84 in electronic equipment. And if firms continue to do R&D in the second year, they will produce more new products. Firms size dummies tell the same story of the importance of size in the first three sectors, supporting the opinion that large firms tend to have more new product output. On the other hand, large electronic equipment firms tend to have low new product intensity. Ownership in all the four sectors indicates that firms controlled by state or public capital have a high intensity of innovation output and firms controlled by overseas capital have less.

Table 3: Innovation Output: Knowledge Production Function

Dep. Var.= New Product	Textile	Wearing Apparel	Transport Equipment	Electronic Equipment
R&D_hat	0.152***	0.190**	0.156*	0.844***
	(0.049)	(0.081)	(0.082)	(0.097)
Continuous R&D	0.996***	1.110***	0.914***	0.528***
	(0.075)	(0.123)	(0.060)	(0.050)
Capital per Employee	0.059*	-0.04	0.036	-0.103***
	(0.035)	(0.037)	(0.055)	(0.032)
Pseudo R^2	0.2899	0.1838	0.3065	0.2333
Log Likelihood	-2638.3	-1240.5	-1935.1	-3343.5

*** Size dummies, ownership dummies, constant and observations are omitted due to the limitation of pages.**

Finally, we interpret the firm performance estimation of the production equation as shown in Table 4. The parameters of estimated new product output in all four sectors give a positive effect. The elasticity of each sector is from 0.246 in transport equipment, to 1.112 in electronic equipment. In contrast with the results of the R&D input equations and new product output equations, the results for firm performance are quite different for the ownership dummies. Compared with private domestic firms, firms controlled by overseas capital tend to have higher productivity, though they input less in R&D terms, and produce fewer new products. On the other hand, firms controlled by state and public capital tend to have lower productivity, though they are apt to carry out R&D and have more new products.

Table 4: Innovation Performance: Production Function

Dep. Var. = Productivity	Textile	Wearing Apparel	Transport Equipment	Electronic Equipment
Capital per Employee	0.209***	0.188***	0.233***	0.125***
	(0.007)	(0.010)	(0.012)	(0.009)
Labor	-0.300***	-0.214***	-0.188***	-0.294***
	(0.008)	(0.013)	(0.015)	(0.010)
New Product_hat	0.354***	0.467***	0.246***	1.119***
	(0.017)	(0.040)	(0.026)	(0.029)
F	96.86	46.7	40.71	103.32
R^2	0.2913	0.1803	0.2927	0.3979

*** Ownership dummies, constant and observations are omitted due to the limitation of pages.**

6. Conclusion And Policy Remarks

We conclude the paper by discussing key outcomes, which also indicate the directions for relative policy recommendation.

The main result is that the model proves the positive effect of innovation input on innovation output, and on innovation output on productivity. It sustains the national innovation strategy of improving innovation input in research and development, especially at the firm level.

The second outcome is the interesting opposite effect of different ownerships in innovation and productivity. Firms controlled by state and public capital innovate more, though they tend to have low levels of productivity. Firms controlled by overseas capital innovate less but produce more, due to their lack of local R&D input, but transfer technology from abroad. The policy of encouragement of firms based on ownership criteria should be weakened, and the government should pay more attention to the construction of a fair market and competition environment.

The last outcome is that innovation is effective not only in high-tech, but also low-tech sectors. Innovation policy should pay more attention to encouraging R&D in this kind of sector, which is important for the maintenance of its competitiveness and for sustaining its employment.

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