R&D and Productivity of China Industrial Sectors: an Empirical Study by Using Firm Data

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Abstract: The main propose of this paper is to discuss the relationship between R&D expenses and productivity, understand different characters among 39 different industrial sectors by using about 200,000 firm data of 2006 from China National Bureau of Statistics. The result suggests that R&D input improves productivity in most sectors, but not all high-tech sectors have high elasticity in R&D expenses, though most of them have a higher input ratio in R&D. Some low-tech or labour intensive sectors have high elasticity in R&D expenses, though they have low R&D input ratio. Different capital hold ratios are considered in the model, overseas capital hold give a high positive explanation of productivity, but not in all sectors.

JEL Classification: D21 L60 O31

Key Words: R&D, Productivity, Capital Hold Ratio

1. Introduction

After about 30 years reform and opening, China is becoming the manufacturing factoy of the world. Her development is not only the issues of herself, but also the key point to joint the world market of capital, product and labour. The enterprise's growth, especially innovation behaviour, determines further sustainable development of the economy, and the long-term growth of the world economy. What interests us is comparing with plenty of empirical studies in the world, how about the R&D elasticity in improving productivity in different China industrial sectors. The large amount of firm data, include almost all the industrial firms in China, might give us a new cognition among sectors.

In the beginning of this new century, Chinese government promulgated *National Medium and Long-term Science and Technology Development Plan (2006-2020)* to plan the establishment of a knowledge-based economy in the following years. It is a practical policy to enhance the competitiveness of industrial firms, converse China from a product center to a real manufacturing center. Innovation in firm level is emphasized in this plan like the Lisbon Agenda in EU.

The empirical study of relative area developed in method and data. Cobb-Douglas production function is a basic model to analysis the relations between input and output in production when it was founded in 1928. Many discussions, ameliorations and empirical studies have been improved by Tinbergen (1942), Solow (1957), Griliches (1979), Jorgenson (1987) and so on, especially after innovation criteria has been added to measure technology change and innovation factors.

The empirical study by using firm data grows faster recently to understand the relations of innovation and productivity in micro level, sustained by the development

of micro data collection. Griliches and Mairesse (1983) estimated the elasticity of R&D at about 0.05 by using US firm data, and the elasticity of high-tech firms is about 0.19. Cuneo and Mairesse (1984) got R&D elasticity of 0.21 in scientific French firms, 0.11 in nonscientific French firms, and 0.20 in combine these 2 groups. Jaffe (1986) got the elasticity of 0.2 from US firm data. Hall and Mairesse (1995) found the result run from 0.05 to 0.25 by using different years of French firm data. Mohnen (1992) compares the result of Canada and other main industrial countries. In general, The elasticity of R&D runs from 0.05-0.60 in different empirical research, but mainly centred from 0.1 to 0.2 (US Congressional Budget Office，2005). The elasticity of high-tech firms is higher than low-tech, and results by using cross-session data are always higher than time series data.

A few relative researches by using Chinese firm data can be found in Chinese and American Journals. Yao (1998) discussed innovation efficiency in 12 large sectors by using firm data from industrial census in 1992. It has been improved by adding ownership and region factors later (Yao & Zhang, 2001). Jefferson et al (2006) estimated the process of innovation input, innovation output and performance by using industrial survey data like this paper. In fact, these 3 articles have the same data resources with this paper. The difference includes: 1, Yao's original data has the same range with this paper, but he did a random sampling to get a much smaller sample; 2, Jefferson's data includes only large and middle firms, it's about 15% of this paper's firm amount and totally been involved in.

As a developing country, China has a complicated classification in firms' ownership mainly by different kinds of capital hold ratios. Different kinds of capital or ownership can get different encouragement and treatment in central and local government, especially for foreign capital and capital from Hong Kong, Macao and Taiwan. The difference in policy creates different outer environment in firms' management and development.

This paper focuses on measuring R&D elasticity among sectors, describes the characters and gives a new impression of R&D impact in China industry by using large data sets and extended Cobb-Douglas production function. Different kinds of capital hold ratios are considered in the function. The paper organizes as follows, session 2 introduces the extended function, session 3 describes data selection and its characters, session 4 shows the result of elasticity and influence of different capital holds, and session 5 draws the conclusion.

2.Model

By using a cross-sectional data and the aim of observing the difference among sectors, we use a simple extended Cobb-Douglas production function. The basic function is:

$$Q_i = AC_i^{\alpha} L_i^{\beta} \mathrm{R}_i^{\gamma} \mathrm{e}^{\varepsilon_i} \qquad \textbf{(1)}$$

where Q is the real output of firm i, A always explained as total factor productivity, C is physical capital input, L is labor input, R is R&D input inner a firm.

Equation (1) can be rewritten as a natural logarithm format like equation (2) and we can get equation (3) after all variables divided by labor.

$$\ln(Q_i) = \ln(A) + \alpha \ln(C_i) + \beta \ln(L_i) + \gamma \ln(R_i) + \varepsilon_i \qquad \textbf{(2)}$$

$$\ln(Q_i / L_i) = \ln(A) + \alpha \ln(C_i / L_i) + \gamma \ln(R_i / L_i) + (\alpha + \beta + \gamma - 1) \ln(L_i) + \varepsilon_i \qquad \textbf{(3)}$$

This paper use a extended function shown as equation (4), where p is labor productivity, cdl is total capital per employee, $rdpl$ is R&D expenses per

employee, brd is a binary variable to specify whether a firm has R&D expenses or not. A group of variables were added to explain ratio of different kinds of capital holds. They are ratio of collective capital (RCL), ratio of corporate capital (RCP), ratio of individual capital (RIC), ratio of capital from Hong Kong, Macau and Taiwan (RHC), and ratio of foreign capital (RFC). The ratio of state capital is not included in the function to avoid collinearity. DR_{ij} is a group of region dummies to specify which province the firm located in and control the residual at the same time. Based on firm data, the equations are estimated separately by 39 different industrial sectors.

$$\begin{aligned}\ln(p_i) = a &+ \alpha \ln(cdl_i) + \gamma \ln(rdpl_i) + (\alpha + \beta + \gamma - 1)\ln(L_i) \\ &+ \lambda_1 RCL_i + \lambda_2 RCP_i + \lambda_3 RIC_i + \lambda_4 RHC_i + \lambda_5 RFC_i \\ &+ \eta brd_i + \sum_{j=1}^{30} \psi_j DR_{ij} + \upsilon_i\end{aligned} \quad \textbf{(4)}$$

3.Data

The data comes from the yearly industrial survey organized by China National Bureau of Statistics. In fact, it is a yearly census of all state-owned firms, and those non-state-owned firms with their size higher than designated size[1]. The criteria are all hard data and most of them from the accounting form of the enterprise.

For the original data, we delete those firms whose employees are less than 10, sales of products are less than RMB 500 million[2], or value added is less then 0. Then, the growth rate of sales, labor and total capital of each firm are calculated separately.

[1] The designated size means Sales of Products is higher than RMB 5 million (EUR 500 thousand). Firms larger than this size are included in the census scheme and report their data every year by filling a set of statistics forms and gather from local government step by step. Firms lower than this size are surveyed separately by using sampling method.

[2] The delete of small sales firms can help us to get the same standard of state-owned and non-state-owned firms, since non-state-owned firms with sales less then 5 million are not included in the census scheme.

Firms with all the 3 growth rates between each 2.5 and 97.5 percentiles are kept in the modeling. At last, we get 192687 firms data from all the 297124 firms in 2006.

Three groups of variables are selected from the data set to estimate the equations. The first group is innovation variables, with R&D expenses (in log) and binary of R&D expense. R&D expenses is a criterion list as one item of management expenses in the accounting data and not includes the salary of R&D employee. Binary variable equals to 1 if a firm has R&D expenses. The second group is basic variables in production function, include value added, number of employee, capital (shown as total assets in the accounting data, include net value of fixed assets, current assets and intangible assets). We can divide value added by number of employee to calculate productivity and we can also get capital per employee and R&D expenses per employee. The third group is extended variables like total capital hold and 6 different kinds of capital holds, which can help us to calculate 6 ratios of capital holds. Anther variable is code of region, which can help us to define 31 variables of region dummies. All variables are explained in appendix A.

There are 39 industrial sectors in China Statistical Classification of Economic Activities, 6 of them are mining and quarrying sectors, 30 of them are manufacturing sectors and the other 3 are electricity, gas and water supply sectors. We estimate all the 39 sectors to understand the difference of productivity and R&D efforts, though most of the non-manufacturing sectors are monopolized by the government. Table 1 gives the basic description of variables in each corresponding sectors.

Ratio of R&D firms is 0.113 in industrial level, which means only 11.3% of all industrial firms above designated size have R&D input[3]. In sector level, 4 of all the

[3] R&D input, here explains by R&D expense, does not include salary of R&D person and purchase of fixed assets. It is one reason of why the ratio much lower than the ratio of CIS3 data in Germany and France (Griffith, 2006). Other reasons to explain the gap include the gap of development and developing backgrounds; survey data might have a high estimation, and so on.

sectors are higher than 0.2, 12 of them are between 0.1 and 0.2, and 24 of them lower than 0.1. Ratio of R&D firms in all the high-tech sectors[4] defined by China National Bureau of Statistics are higher than 0.15. Labor-intensive sectors like textile and wearing apparel have a ratio about 0.05 to 0.06 of R&D firms.

[Table 1 here]

4.Results

Table 2 shows the result of elasticity estimated by sectors. Figure 1 describes the coefficients of R&D, capital and labour of all the sectors[5] in one graph. Table 3 gives the semi-elasticity of capital ratios and coefficient of binary R&D.

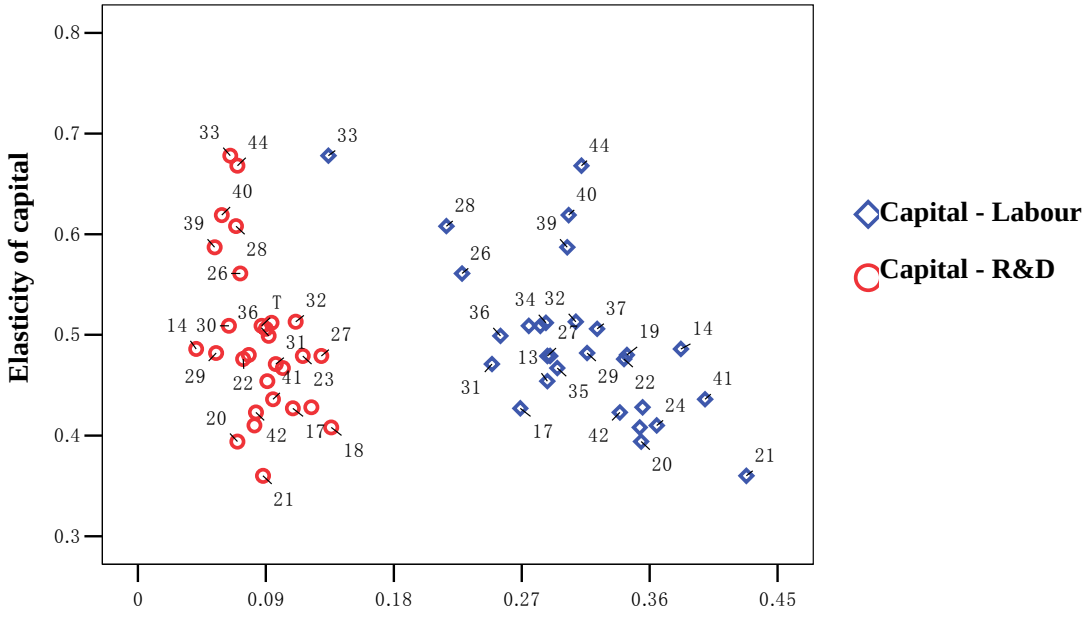

Figure 1: Scatter Plot of Elasticity by Sectors

[4] High-tech sectors (sub-sectors) include 2 whole sectors of Manufacturing of Medicines, Manufacturing of Communication Equipment, Computers and Other Electronic Equipment; and part of the following sectors (some sub-sectors): Chemical Products, Special Purpose Machinery, Measuring Instruments and software (in service sectors).

[5] All except those with unreasonable elasticity. Sectors are identified by code list in the column of "No." in table 1 and table 2.

The elasticity of R&D is 0.087 in industrial level, lower than the centred range of results in developed countries (0.1 to 0.2, US Congressional Budget Office，2005). The range of different sectors[6] is from 0.054 to 0.136. Seven of all significant R&D elasticity higher than 0.1, but not all of them are high-tech sectors. R&D elasticity of textile sector and wearing apparel sector are included in this group with the elasticity of 0.109 and 0.136. R&D elasticity of some high-tech sectors are not very high, e.g. elasticity of Electronic Equipment is 0.059, and Chemical Products is 0.072. All sectors of mining and quarrying are not significant in R&D elasticity.

For the elasticity of capital, it is 0.509 in industry level, centred from 0.37 to 0.71 in most sectors except some higher elasticity in 2 monopolistic sectors: Extraction of petroleum and manufacture of tobacco. Capital elasticity is in the low level in labour intensity sectors like textile, processing of food and agriculture products, manufacture of leather, wood, furniture and so on. It grows higher in capital intensity sectors like smelting and pressing of ferrous and non-ferrous metals, manufacture of transport equipment, processing of petroleum and relative chemical products and so on. In most high-tech sectors, it is also higher, e.g. manufacture of electrical machinery and equipment, communication equipment, computers and other electronic equipment. All the sectors of production and supply of electric power and heat power, gas and water, mostly monopolized by the government, have a high elasticity in capital input.

For the elasticity of labour, calculated from coefficients of capital, labour and R&D, it is 0.275 in industry level, centred from 0.2 to 0.4 in sector level. They are contrary to the elasticity of capital, i.e. lower in capital intensity sectors and higher in labour intensity sectors. In measuring the scales return by variable labour, most of the sectors are significantly reduced except some monopolistic sectors like supply of electric

[6] Only include the significant sectors, and the largest, with the value of 0.942 in sector of Production and Supply of Gas, is not included.

power and heat power. The result is similar in Yao's (1998) paper by using earlier data.

[Table 2 here]

Table 3 gives the semi-elasticity of capital hold ratio and binary of R&D. In all the 6 kinds of capital hold ratios, referenced by state capital, the other 5 have positive coefficients in 10 sectors, e.g. textile, manufacturing of chemical products, chemical fibers and plastics, all of which are highly competitive in market. State capital is the highest positive in manufacture of measuring instruments and machinery for cultural activity and office work. None of the 5 capital ratios is significant in processing of petroleum and other 3 sectors. Here we pay much attention to the foreign capital, private capital and state capital.

[Table 3 here]

Foreign capital hold is the largest positive coefficient in total industry level. It is significantly positive in 24 of all the 39 sectors, and it has the largest positive coefficient in 15 of these sectors, which means foreign capital ratio has a strong positive influence on productivity in most of the sectors, especially in high-tech sectors and high-profit sectors. For individual capital hold, it is strongly positive in textile, processing of timber, manufacturing of chemical products and chemical fibers, manufacturing of rubber and plastics, manufacture of metal products, manufacture of electrical machinery and equipment, most of which are light industry. State capital keeps its predominance in extraction of petroleum, processing of petroleum, mining and processing of metal ores, manufacturing of medicine, manufacturing of artwork, production and supply of electric power and heat power, most of which are monopolistic sectors and resource-based sectors.

The coefficients of binary of R&D shows that firms with input in R&D can reach a higher average level of productivity in most sectors, include some of those sectors

whose R&D elasticity are not significant.

5.Conclusion

After the presenting of empirical results comes from firm data and an extended Cobb-Douglas function, we might find at least 4 conclusions, and some of them might be problems for the knowledge-based, sustainable development of China manufacturing industries in the future.

The first is innovation input can improve productivity, especially in market-based, highly competitive sectors. Some traditional low-tech sectors, like textile and wearing appeal, grew fast in both quantity and quality after the opening and reform 30 years ago. Different capital can compete in both domestic market and worldmarket, with less pressure of techniques and foreign capital. R&D is an efficient way to improve firm's productivity and competitiveness in these sectors, though they are low-tech sectors with low proportion of R&D. The problem for further development in the future is that they should improve the level of profit and quantity by R&D input and other methods to increase the welfare of employee, face the strict standard of world market and improved request in domestic market.

The second is the low level of R&D elasticity comparing with the results of developed economies. The proposition of the selection and intensity of R&D in firm level are still very low, comparing with European countries. It is difficult to sustain the plan of sustainable and knowledge-based development in the following 20 years. The question is how to encourage firms to input more in innovation. We wish the new tax preferential policy[7] could give a positive result.

[7] After the publish of National Medium and Long-term Science and Technology Development Plan (2006-2020) in early 2006, the government are establishing new policies to reduce tax in innovation input firms. It is an important signal to encourage innovation, instead of encourage foreign capital only.

The third is not all high-tech sectors have high elasticity in R&D, some important high-tech sectors have very low elasticity in R&D. Manufacturing of communication equipment, computers and other electronic equipment, with a very low R&D elasticity of 0.059, is one of the only 2 sectors[8] with all sub-sectors included in the high-tech catalog. The fact is 49.9% of its capital hold is foreign capital, 65.8% of its products are export in 2006. Both R&D work and market of the sector are not in domestic China. China is only the low-grade machining factory with low profit but high preferential policy in relative area. It can partly explain the phenomenon of high-tech but low elasticity. The question is how to improve innovation (Research and development) in the key high-tech sectors in China mainland, with the common preferential policy to foreign capital at the same time.

The fourth is that different capital ratios influence the productivity significantly in most sectors. Based on the market economy, foreign capital and private capital are more efficient in improving productivity, especially in well compete and high-tech sectors. State capital only keeps advantage in monopolistic sectors and resource-based sectors.

This paper is only the beginning to give a glance of R&D and productivity in sector level by using micro firm data. It might be useful for understanding realities of industry development in China. From these results, we might well understand that China is far more to a manufacturing centre in the world. She should encourage more in innovation, balance the preferential policy to encourage not only foreign capital, but also various of other kinds of capital, especially in high-tech and high value-added sectors, and many other works to do for the knowledge-based economy.

[8] The other sector is manufacturing of medicine.

Reference

[1] Cobb,Charles W. and Douglas Paul H., 1928, A Theory of Production, ***The American Economic Review***, Vol. 18, No. 1, pp. 139-165.

[2] Congress of the United States, Congressional Budget Office, 2005, R&D and Productivity Growth, http://www.cbo.gov/ftpdocs/64xx/doc6482/06-17-R-D.pdf

[3] Cuneo, Philippe, and Jacques Mairesse, 1984, Productivity and R&D at the Firm Level in French Manufacturing, In R&D, Patents, and Productivity, Ed. by Zvi Griliches, Chicago: University of Chicago Press.

[4] Griffith, R., E. Huergo, J. Mairesse and B. Peters, 2006, Innovation and Productivity Across Four European Countries, ***Oxford Review of Economic Policy***, 22(4):483-498.

[5] Griliches, Z., 1979, Issues in Assessing the Contribution of Research and Development to Productivity Growth, ***Bell Journal of Economics***, 10(1):92-116.

[6] Griliches, Zvi, and Jacques Mairesse, 1983, Comparing Productivity Growth: An Exploration of French and U.S. Industrial and Firm Data, ***European Economic Review***, vol.21:89-119.

[7] Hall, Bronwyn and Jacques Mairesse, 1995, Exploring the Relationship Between R&D and Productivity in French Manufacturing Firms, ***Journal of Econometrics***, vol.65(1):263-293.

[8] Jaffe, Adam, 1986, Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value, ***The American Economic Review***, vol.76,no.5,pp.984-1001.

[9] Jefferson G.; B. Huamao; G. Xiaojing and Y. Xiaoyun, 2006, R and D Performance in Chinese Industry, ***Economics of Innovation and New Technology***, 15(4/5):345-366.

[10] Jorgenson, Dale W., 1988, Productivity and Postwar U.S. Economic Growth, ***The Journal of Economic Perspectives***, Vol. 2, No. 4, pp. 23-41.

[11] Jorgenson, Dale W.; Gollop, Frand M. and Fraumeni, Barbara M., 1987, Productivity and U.S. Economic Growth, Cambridge, Harvard University Press.

[12] LIU Xiaoxuan, 2000, The Impact of the Structure of China's Industrial Enterprise's Ownership on Its Efficiency, ***Economic Research Journal (Chinese)***, 2:17-25.

[13] Mohnen, Pierre, 1992, The Relationship Between R&D and Productivity Growth in Canada and Other Major Industrialized Countries, Ottawa: Economic Council of Canada.

[14] Solow, Robert M., 1957, Technical Change and the Aggregate Production Function, ***The Review of Economics and Statistics***, Vol. 39, No. 3, pp. 312-320.

[15] Solow, Robert M., 1988, Growth Theory and After, ***The American Economic Review***, Vol.78, No.3, pp. 307-317.

[16] State Council, 2006, National Medium and Long-term Science and Technology Development Plan (2006-2020) (Chinese), Xinhua.net, 2006.2.9.

[17] Tinbergen, J., 1942, Professor Douglas' Production Function, ***Review of the International Statistical Institute***, Vol. 10, No. 1/2, pp. 37-48.

[18] YAO Yang and ZHANG Qi, 2001, An Analysis of Technological Efficiency of Chinese industrial firm, ***Economic Research Journal (Chinese)***, 10:13-19.

[19] YAO Yang, 1998, Non-state Owned Capital and its Influence to Firm Innovation Efficiency in China Industries, ***Economic Research Journal (Chinese)***, 12:29-35.

Appendix 1: Variable Definitions

Variable Name		Explanation
Basic		
p	**Productivity**	Value Added per employee
cdl	**Capital per Employee**	Total assets per employee
L	**Labor**	Number of employees
Innovation		
rdpl	**R&D Expenses**	R&D Expenses
brd	**R&D or not**	Binary variable equals to 1 if R&D Expenses is larger than 0
Others		
-	**State Capital**	Ratio of State Capital in total capital hold (**reference**)
RCL	**Collective Capital**	Ratio of Collective Capital in total capital hold
RCP	**Corporate Capital**	Ratio of Corporate Capital in total capital hold
RIC	**Individual Capital**	Ratio of Individual Capital in total capital hold
RHC	**HMT Capital**	Ratio of Hong Kong, Macao and Taiwan Capital in total capital hold
RFC	**Foreign Capital**	Ratio of Foreign Capital in total capital hold
DRj	**Region Dummies**	30 dummy variables are defined to represent 30 provinces in China mainland. (Zhejiang for reference)

Table 1: Means of Variables of Firm Data by Sectors (Year=2006)

No.	Sector	Observation	Labor (people)	Capital (1000 RMB)	Value Added (1000 RMB)	R&D Expenses (1000 RMB)	Ratio of R&D firms
06	Mining and Washing of Coal	3718	1077	264088	81729	16055	0.041
07	Extraction of Petroleum and Natural Gas	123	6632	5463841	4376629	113013	0.260
08	Mining and Processing of Ferrous Metal Ores	1260	250	85371	32008	2852	0.023
09	Mining and Processing of Non-Ferrous Metal Ores	565	260	68875	36698	1179	0.069
10	Mining and Processing of Nonmetal Ores	1493	218	40043	17734	1340	0.054
11	Mining of Other Ores	6	80	24048	22627	0	0.000
13	Processing of Food from Agricultural Products	9711	173	52251	27067	928	0.081
14	Manufacture of Foods	3871	261	76826	31358	1269	0.156
15	Manufacture of Beverages	2424	303	133979	50357	3888	0.137
16	Manufacture of Tobacco	119	1006	2183330	1355977	22944	0.387
17	Manufacture of Textile	17213	290	56519	18901	2189	0.060
18	Manufacture of Textile Wearing Apparel, Footwear and Caps	8666	330	34120	16253	1291	0.047
19	Manufacture of Leather, Fur, Feather and Related Products	4603	424	39226	20213	875	0.058
20	Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm and Straw	3738	169	30516	13354	2161	0.044
21	Manufacture of Furniture	2210	287	45573	17170	1603	0.078
22	Manufacture of Paper and Paper Products	5622	192	77507	20728	2535	0.049
23	Printing, Reproduction of Recording Media	3342	165	47813	13892	1155	0.060
24	Manufacture of Articles For Culture, Education and Sport Activities	2586	358	36919	14402	1201	0.086
25	Processing of Petroleum, Coking, Processing of Nuclear Fuel	1275	429	397937	145991	4794	0.100
26	Manufacture of Raw Chemical Materials and Chemical Products	12797	196	106864	32816	3043	0.159

Table 1 (continues)

No.	Sector	Observation	Labor (people)	Capital (1000 RMB)	Value Added (1000 RMB)	R&D Expenses (1000 RMB)	Ratio R&D firms
27	Manufacture of Medicines	3681	293	138797	41927	2694	0.414
28	Manufacture of Chemical Fibers	995	358	224136	51677	7282	0.105
29	Manufacture of Rubber	2241	295	81004	25851	3269	0.112
30	Manufacture of Plastics	9163	170	43278	14200	1065	0.068
31	Manufacture of Non-metallic Mineral Products	14743	223	61003	19515	1383	0.075
32	Smelting and Pressing of Ferrous Metals	4453	550	445095	131826	24537	0.061
33	Smelting and Pressing of Non-ferrous Metals	3088	303	196686	73528	5550	0.099
34	Manufacture of Metal Products	10221	186	44222	16656	1697	0.074
35	Manufacture of General Purpose Machinery	15468	198	63903	20579	2968	0.140
36	Manufacture of Special Purpose Machinery	6989	223	73812	22905	2738	0.198
37	Manufacture of Transport Equipment	8304	338	181319	48764	8976	0.199
39	Manufacture of Electrical Machinery and Equipment	11592	281	94016	33601	5936	0.188
40	Manufacture of Communication Equipment, Computers and Other Electronic Equipment	6221	640	258795	92422	15838	0.267
41	Manufacture of Measuring Instruments and Machinery for Cultural Activity and Office Work	791	357	56725	21364	1597	0.154
42	Manufacture of Artwork and Other Manufacturing	3748	279	34475	14552	1273	0.081
43	Recycling and Disposal of Waste	255	127	39360	19511	547	0.063
44	Production and Supply of Electric Power and Heat Power	3896	546	758721	145224	10191	0.072
45	Production and Supply of Gas	321	310	265763	43328	471	0.047
46	Production and Supply of Water	1175	296	243728	22354	467	0.027
-	**Total Industry**	**192687**	**294**	**113935**	**37610**	**4919**	**0.113**

Table 2: Coefficients of Production Function (Elasticity)

No.	Sector	Capital	Labor	(α + β + γ -1)	R&D	F	Adj R-squared	Observation
-	**Total Industry**	0.509***	0.275	-0.128***	0.087***	1567.74	0.3981	192687
		(0.002)		(0.002)	(0.003)			
06	Mining and Washing of Coal	0.544***	0.145	-0.303***	0.009	118.18	0.5316	3718
		(0.015)		(0.012)	(0.028)			
07	Extraction of Petroleum and Natural Gas	0.993***	-0.097	0.016	0.121	15.88	0.7796	123
		(0.074)		(0.054)	(0.087)			
08	Mining and Processing of Ferrous Metal Ores	0.418***	0.410	-0.236***	-0.064	15.19	0.2886	1260
		(0.028)		(0.024)	(0.087)			
09	Mining and Processing of Non-Ferrous Metal Ores	0.592***	0.164	-0.234***	0.011	13.82	0.4360	565
		(0.038)		(0.037)	(0.070)			
10	Mining and Processing of Nonmetal Ores	0.401***	0.244	-0.284***	0.071	25.49	0.3903	1493
		(0.022)		(0.023)	(0.051)			
13	Processing of Food from Agricultural Products	0.454***	0.288	-0.167***	0.091***	83.74	0.2494	9711
		(0.011)		(0.010)	(0.018)			
14	Manufacture of Foods	0.486***	0.382	-0.092***	0.041**	38.18	0.2726	3871
		(0.016)		(0.014)	(0.018)			
15	Manufacture of Beverages	0.428***	0.355	-0.096***	0.122***	22.75	0.2593	2424
		(0.020)		(0.018)	(0.026)			
16	Manufacture of Tobacco	1.083***	0.134	0.187***	-0.030	23.05	0.8737	119
		(0.067)		(0.066)	(0.047)			

Table 2 (continues)

No.	Sector	Capital	Labor	(α + β + γ -1)	R&D	F	Adj R-squared	Observation
17	Manufacture of Textile	0.427***	0.269	-0.194***	0.109***	235.46	0.3411	17213
		(0.006)		(0.006)	(0.011)			
18	Manufacture of Textile Wearing Apparel, Footwear and Caps	0.408***	0.353	-0.103***	0.136***	99.60	0.2963	8666
		(0.009)		(0.009)	(0.019)			
19	Manufacture of Leather, Fur, Feather and Related Products	0.480***	0.344	-0.098***	0.078***	110.65	0.4617	4603
		(0.012)		(0.011)	(0.026)			
20	Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm and Straw Products	0.394***	0.354	-0.182***	0.070**	44.98	0.3090	3738
		(0.013)		(0.015)	(0.035)			
21	Manufacture of Furniture	0.360***	0.428	-0.124***	0.088**	22.36	0.2635	2210
		(0.021)		(0.017)	(0.035)			
22	Manufacture of Paper and Paper Products	0.476***	0.342	-0.108***	0.074***	59.21	0.2770	5622
		(0.013)		(0.011)	(0.023)			
23	Printing, Reproduction of Recording Media	0.479***	0.290	-0.115***	0.116***	38.13	0.3024	3342
		(0.016)		(0.015)	(0.028)			
24	Manufacture of Articles For Culture, Education and Sport Activities	0.410***	0.365	-0.144***	0.082***	46.23	0.3590	2586
		(0.016)		(0.015)	(0.026)			
25	Processing of Petroleum, Coking, Processing of Nuclear Fuel	0.668***	0.150	-0.123***	0.058	24.16	0.4021	1275
		(0.030)		(0.023)	(0.038)			
26	Manufacture of Raw Chemical Materials and Chemical Products	0.561***	0.228	-0.139***	0.072***	181.15	0.3485	12797
		(0.009)		(0.007)	(0.010)			

Table 2 (continues)

	Sector	Capital	Labor	(α + β + γ -1)	R&D	F	Adj R-squared	Observation
27	Manufacture of Medicines	0.479***	0.288	-0.104***	0.129***	31.16	0.2422	3681
		(0.019)		(0.016)	(0.014)			
28	Manufacture of Chemical Fibers	0.608***	0.217	-0.106***	0.069**	20.07	0.4085	995
		(0.027)		(0.023)	(0.035)			
29	Manufacture of Rubber	0.482***	0.316	-0.146***	0.055**	39.78	0.3840	2241
		(0.019)		(0.016)	(0.024)			
30	Manufacture of Plastics	0.509***	0.283	-0.143***	0.064***	148.82	0.3801	9163
		(0.009)		(0.009)	(0.017)			
31	Manufacture of Non-metallic Mineral Products	0.471***	0.249	-0.183***	0.097***	221.03	0.3679	14743
		(0.007)		(0.007)	(0.013)			
32	Smelting and Pressing of Ferrous Metals	0.513***	0.308	-0.069***	0.111***	54.20	0.3123	4453
		(0.015)		(0.012)	(0.025)			
33	Smelting and Pressing of Non-ferrous Metals	0.678***	0.134	-0.124***	0.065***	49.82	0.3754	3088
		(0.018)		(0.016)	(0.025)			
34	Manufacture of Metal Products	0.512***	0.287	-0.107***	0.094***	152.40	0.3602	10221
		(0.009)		(0.009)	(0.015)			
35	Manufacture of General Purpose Machinery	0.467***	0.295	-0.136***	0.102***	191.02	0.3183	15468
		(0.008)		(0.007)	(0.008)			
36	Manufacture of Special Purpose Machinery	0.499***	0.255	-0.153***	0.092***	87.87	0.3150	6989
		(0.012)		(0.011)	(0.011)			

Table 2 (continues)

No.	Sector	Capital	Labor	(α + β + γ -1)	R&D	F	Adj R-squared	Observation
37	Manufacture of Transport Equipment	0.506***	0.323	-0.082***	0.090***	112.76	0.3442	8304
		(0.010)		(0.009)	(0.010)			
39	Manufacture of Electrical Machinery and Equipment	0.587***	0.302	-0.057***	0.054***	219.74	0.4176	11592
		(0.008)		(0.007)	(0.009)			
40	Manufacture of Communication Equipment, Computers and Other Electronic Equipment	0.619***	0.303	-0.018**	0.059***	144.68	0.4608	6221
		(0.011)		(0.009)	(0.010)			
41	Manufacture of Measuring Instruments and Machinery for Cultural Activity and Office Work	0.436***	0.399	-0.071***	0.095***	21.22	0.4260	791
		(0.031)		(0.027)	(0.033)			
42	Manufacture of Artwork and Other Manufacturing	0.423***	0.339	-0.155***	0.083***	63.39	0.3937	3748
		(0.014)		(0.014)	(0.023)			
43	Recycling and Disposal of Waste	0.716***	0.158	-0.071	0.054	5.89	0.3810	255
		(0.072)		(0.061)	(0.090)			
44	Production and Supply of Electric Power and Heat Power	0.668***	0.312	0.050***	0.070***	125.87	0.5556	3896
		(0.012)		(0.013)	(0.025)			
45	Production and Supply of Gas	0.592***	-0.795	-0.261***	0.942***	8.38	0.4671	321
		(0.063)		(0.058))	(0.238)			
46	Production and Supply of Water	0.591***	0.266	-0.138***	0.005	41.44	0.5732	1175
		(0.022)		(0.024))	(0.073)			

Note: There are 2 coefficients in labor columns. The first is labor elasticity (β) for reference, which are calculated from the other 3 coefficients. The second is original output of (α + β + γ -1), which can be used to test hypothesis of constant returns to scale.

Table 3: Coefficients of Production Function (Semi-elasticity)

No.	Sector	RCL	RCP	RIC	RHC	RFC	brd
-	Total Industry	0.181***	0.250***	0.237***	0.101***	0.296***	0.100***
		(0.014)	(0.012)	(0.012)	(0.013)	(0.014)	(0.006)
06	Mining and Washing of Coal	0.131***	0.219***	0.244***	-0.472	1.388***	0.371***
		(0.050)	(0.049)	(0.046)	(0.488)	(0.536)	(0.080)
07	Extraction of Petroleum and Natural Gas	-0.677*	-0.338	-0.646**	0.255	-1.592**	-0.165
		(0.353)	(0.239)	(0.318)	(0.966)	(0.744)	(0.294)
08	Mining and Processing of Ferrous Metal Ores	-0.132	0.061	-0.080	-0.892*	-0.596	0.218
		(0.142)	(0.120)	(0.118)	(0.477)	(0.577)	(0.183)
09	Mining and Processing of Non-Ferrous Metal Ores	0.117	0.091	0.099	-0.089	0.557*	0.449***
		(0.178)	(0.145)	(0.143)	(0.324)	(0.333)	(0.145)
10	Mining and Processing of Nonmetal Ores	0.309***	0.338***	0.267***	-0.002	0.220	0.240**
		(0.101)	(0.091)	(0.090)	(0.161)	(0.181)	(0.096)
13	Processing of Food from Agricultural Products	0.187***	0.243***	0.218***	0.218***	0.131**	0.080**
		(0.069)	(0.047)	(0.046)	(0.069)	(0.061)	(0.036)
14	Manufacture of Foods	0.136	0.174**	0.146**	0.124	0.259***	0.063
		(0.099)	(0.072)	(0.071)	(0.087)	(0.081)	(0.043)
15	Manufacture of Beverages	0.097	0.214***	0.151*	0.398***	0.696***	0.206***
		(0.111)	(0.080)	(0.079)	(0.119)	(0.103)	(0.056)
16	Manufacture of Tobacco	0.447**	-0.175	1.422***	-3.789***	0.419	0.334**
		(0.220)	(0.140)	(0.339)	1.239)	1.328)	(0.146)

Table 3 (continues)

No.	Sector	RCL	RCP	RIC	RHC	RFC	brd
17	Manufacture of Textile	0.381***	0.484***	0.444***	0.389***	0.480***	0.247***
		(0.057)	(0.049)	(0.048)	(0.051)	(0.053)	(0.024)
18	Manufacture of Textile Wearing Apparel, Footwear and Caps	-0.111	0.034	0.074	-0.075	0.030	0.273***
		(0.086)	(0.075)	(0.074)	(0.075)	(0.076)	(0.038)
19	Manufacture of Leather, Fur, Feather and Related Products	0.045	0.073	0.116	-0.050	-0.072	0.090*
		(0.155)	(0.143)	(0.143)	(0.144)	(0.145)	(0.054)
20	Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm and Straw Products	0.276**	0.368***	0.206**	0.024	0.325***	0.137**
		(0.109)	(0.083)	(0.082)	(0.095)	(0.096)	(0.067)
21	Manufacture of Furniture	0.536**	0.495**	0.314	0.186	0.348**	0.101
		(0.222)	(0.196)	(0.195)	(0.199)	(0.200)	(0.062)
22	Manufacture of Paper and Paper Products	0.138*	0.212***	0.191***	0.054	0.230***	0.126**
		(0.081)	(0.074)	(0.073)	(0.081)	(0.086)	(0.052)
23	Printing, Reproduction of Recording Media	-0.077	0.063	0.011	0.027	0.257***	0.202***
		(0.069)	(0.050)	(0.048)	(0.068)	(0.082)	(0.055)
24	Manufacture of Articles For Culture, Education and Sport Activities	0.306*	0.361**	0.326**	0.171	0.218	0.161***
		(0.171)	(0.154)	(0.153)	(0.153)	(0.154)	(0.054)
25	Processing of Petroleum, Coking, Processing of Nuclear Fuel	-0.134	0.122	0.172	0.005	0.318	0.259***
		(0.154)	(0.122)	(0.122)	(0.238)	(0.194)	(0.092)
26	Manufacture of Raw Chemical Materials and Chemical Products	0.252***	0.344***	0.353***	0.320***	0.555***	0.016
		(0.049)	(0.041)	(0.041)	(0.051)	(0.050)	(0.022)

Table 3 (continues)

No.	Sector	RCL	RCP	RIC	RHC	RFC	brd
27	Manufacture of Medicines	0.036	-0.071	-0.022	0.077	0.326***	0.003
		(0.106)	(0.073)	(0.073)	(0.107)	(0.092)	(0.036)
28	Manufacture of Chemical Fibers	0.793***	0.649***	0.599***	0.392*	0.529**	0.066
		(0.232)	(0.203)	(0.206)	(0.219)	(0.227)	(0.086)
29	Manufacture of Rubber	0.405***	0.556***	0.446***	0.413***	0.501***	0.122**
		(0.129)	(0.117)	(0.116)	(0.125)	(0.124)	(0.053)
30	Manufacture of Plastics	0.199***	0.363***	0.361***	0.193***	0.346***	0.155***
		(0.076)	(0.069)	(0.068)	(0.071)	(0.072)	(0.032)
31	Manufacture of Non-metallic Mineral Products	0.153***	0.311***	0.311***	0.254***	0.427***	0.144***
		(0.040)	(0.035)	(0.034)	(0.048)	(0.048)	(0.026)
32	Smelting and Pressing of Ferrous Metals	-0.076	0.179**	0.183**	0.100	0.340***	0.069
		(0.093)	(0.079)	(0.078)	(0.117)	(0.109)	(0.057)
33	Smelting and Pressing of Non-ferrous Metals	0.225**	0.179*	0.166*	-0.130	0.017	-0.041
		(0.108)	(0.093)	(0.092)	(0.119)	(0.120)	(0.059)
34	Manufacture of Metal Products	0.074	0.223***	0.216***	-0.009	0.154**	0.074**
		(0.063)	(0.058)	(0.058)	(0.063)	(0.063)	(0.030)
35	Manufacture of General Purpose Machinery	0.316***	0.372***	0.350***	0.346***	0.566***	0.053***
		(0.042)	(0.037)	(0.036)	(0.046)	(0.043)	(0.019)
36	Manufacture of Special Purpose Machinery	0.374***	0.429***	0.434***	0.383***	0.582***	0.057**
		(0.063)	(0.050)	(0.049)	(0.060)	(0.057)	(0.027)

Table 3 (continues)

No.	Sector	RCL	RCP	RIC	RHC	RFC	brd
37	Manufacture of Transport Equipment	0.105**	0.173***	0.207***	0.042	0.326***	0.038
		(0.052)	(0.042)	(0.042)	(0.055)	(0.050)	(0.024)
39	Manufacture of Electrical Machinery and Equipment	0.255***	0.280***	0.289***	0.017	0.258***	0.030
		(0.059)	(0.051)	(0.051)	(0.056)	(0.056)	(0.020)
40	Manufacture of Communication Equipment, Computers and Other Electronic Equipment	0.224**	0.159**	0.266***	0.109	0.321***	0.015
		(0.092)	(0.066)	(0.066)	(0.067)	(0.067)	(0.027)
41	Manufacture of Measuring Instruments and Machinery for Cultural Activity and Office Work	-0.431*	-0.675***	-0.709***	-0.818***	-0.556***	0.091
		(0.248)	(0.203)	(0.198)	(0.197)	(0.202)	(0.077)
42	Manufacture of Artwork and Other Manufacturing	-0.027	0.122	0.019	-0.215**	-0.050	0.188***
		(0.122)	(0.103)	(0.102)	(0.105)	(0.106)	(0.049)
43	Recycling and Disposal of Waste	-0.600	-0.175	-0.229	-0.339	-0.909	-0.168
		(0.605)	(0.598)	(0.589)	(0.611)	(0.628)	(0.255)
44	Production and Supply of Electric Power and Heat Power	0.026	0.017	-0.147***	0.100	0.106	0.329***
		(0.073)	(0.035)	(0.050)	(0.116)	(0.110)	(0.055)
45	Production and Supply of Gas	0.577*	0.314*	0.357*	0.016	0.228	1.050***
		(0.338)	(0.160)	(0.209)	(0.244)	(0.295)	(0.302)
46	Production and Supply of Water	0.383***	0.156**	0.225**	0.570***	0.692***	0.221
		(0.075)	(0.067)	(0.099)	(0.218)	(0.243)	(0.144)