An Analysis of the Impact of Public Capital on Cost Structure of Manufacturing Firms in China

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Since 1978, China government has spent a huge amount on public capital, including infrastructure, education, and R&D. It is important to know whether those expenditures on public capital have a positive impact on improving manufacturing firms' productivity and thus reducing their production cost. In this study, we applied a data set with 1,371,726 sample points from the manufacturing sector of China from 1998 to 2006 with a traditional cost function to estimate the impact of public capital on firms' production cost, with a firm-level fixed effect. Then we estimate the substitutability of public capital and private inputs. We found that both education and infrastructure have a significant impact on reducing production cost for manufacturing firms, while education expenditure has a larger effect. On the other hand, R&D expenditure has little effect on reducing production cost.

Keywords: public capital, cost structure, china
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1 Introduction

Since 1980, when China started the open door policy, China government has spent huge amounts of investment on public capital, including energy, transportation, education and science as the strategic tool for economic development to increase national competitiveness, economic growth, energy

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efficiency, and quality of life. For instance, total length of highway in China as a whole was only 300 kilometers in 1982, while it has increased to 53,600 kilometers in 2007. Now the total length of highway in China is the second longest of the world.

Public capital does not only increase economic growth, but it also has an external effect on firms' productivity. Furthermore, public capital will also affect on firms' production inputs because the public capital could be seen as a production inputs, too. Therefore, it is important to know how public capital affects on firms' productivity and cost structure, and to know what the substitutability of public capital and private production inputs is.

One of the seminal studies was Meade (1952), where Meade (1952) took public capital as an unpaid fixed input since it is free for firms to use it. Then Aschauer (1989) followed Meade (1952), applying a data set from the USA in 1949 to 1985 and a Cobb-Douglas production function, and found that the output elasticity of infrastructure is 0.36 while the return to scale is 1.21 for infrastructure.[1]

Moreover, Garcia-Mila and McGuire (1992) applied a panel data from 38 countries in 1969 to 1983 to estimate the impact of road and education on production function, and they found that both types of public capital have a significant impact on firms' output. Meanwhile, Eberts (1986) applied a translog production function to estimate the effect of public capital on firms' output on manufacturing sector, and he found that public capital did have a positive effect on output although the output elasticity is smaller (0.03). Furthermore, according to the law of decreasing marginal return, the marginal effect of public capital is different with the total size of public capital. Employing a data set from twelve countries, Demetriades and Mamuneas (2000) found that the marginal return for public capital will be larger for a country with a smaller size of public capital.

In the past thirty years, the public capital has been increasing at a very high speed in China, and it not only accelerates economic growth rate, but also should have a significant impact of firms' productivity and production cost. However, there is little literature studying on this issue. Applying a translog production function with a data set from the two-digit industries in manufacturing sector of China, Chen et al. (2010) analyzed the impact

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[1] There are numerous literature applying Cobb-Douglas production to estimate the impact of public capital on firms' production behavior, including Mera (1973), Holz-Eakin (1988), Munnell (1990a,b), Eisner (1991), Kamps (2006), and Cadot et al. (2006).

of infrastructure on cost structure. However, Chen et al. (2010) was using a data set with manufacturing industries, but not a firm-level data set.

The purpose of this study is to estimate the external effect of the public capital, including infrastructure, education, and R&D, by applying a translog production with a firm-lever data set from the manufacturing sector of China, on cost structure, and also to estimate the substitutability of public capital and production inputs. Since there are 1,371,726 firm-level data point applied by this study, the estimation results should be very robust and persuasive. There are a few specific questions that we like to ask in this study which include: Firstly, does the public capital bring a positive external effect on firms' productivity and thus reduces the production costs? Secondly, we like to estimate the elasticity of factor demand and then to check whether the production factors and different types of public capital are substitutes or compliments, both in terms of different industries and different types of ownership. Tertiary, we like to study whether the effect of public capital on production cost could be different for different industries in China.

The structure of this paper is as follow: the second Section will build a traditional translog production function, and then the data set and definitions of variables will be explained in detail in the Section 3. The empirical results will be discussed in the Section 4. Finally, we will conclude this study in the Section 5.

2 Constructing a cost function

In order to measure contribution of public capital on firms' production, we will build a cost function which including public capital as a part of factor inputs. And then we will apply the Shephard Lemma to derive the demand function for factor inputs and to estimate factor share for each share. Finally, we could estimate the cost elasticity of public capital and demand elasticity for factor inputs, and thus we could analyze if the relationship between public capital and factor inputs is substitute or complement.

Diewert (1986) is a seminal paper to study the impact of public capital on aggregate cost function, and then there are numerous literature applying cost function to estimate the contribution of public capital on production cost.[2] Furthermore, they applied duality theory to analyze the relation of

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[2] For example, Berndt and Hansson (1991), Nadiri and Mamuneas (1994), Shah (1992),

production function and cost function, so that the structure of cost function became more complete.

Suppose there is a short-run cost function with an input price as $\mathbf{p} = (\mathbf{p}_f, \mathbf{p}_v)$, where $\mathbf{p}_f$ is for fixed inputs and $\mathbf{p}_v$ is for variable inputs. Moreover, the aiming for a firm in question is to choose a variable input fixed input $(\mathbf{x}_v)$ to minimize its cost, given a fixed input $(\mathbf{x}_f)$ and an output level (y), i.e.

$$c\left(\mathbf{p}, y, \mathbf{x}_f\right) = \min_{x_v} \mathbf{p}_v'\mathbf{x}_v + \mathbf{p}_f'\mathbf{x}_f. \tag{1}$$

Here, we assume that private capital is a fixed input and public capital is a free fixed input. Moreover, following Nadiri and Mamuneas (1994), there are three types of public capital included in cost function, as infrastructure, education, and government R&D expenditure.

The average cost function we applied is this study is as follow:

$$\begin{aligned}\ln C_h - \ln y_h = {} & \beta_{0h} + \sum_i \beta_{ih} \ln p_{ih} + \beta_{th} t \\ & + \sum_{i \neq j} \sum_j \beta_{ijh} \ln p_{ih} \ln p_{jh} + \sum_i \beta_{ith} \ln p_{ih} \cdot t \\ & + \sum_s \phi_{sh} \ln g_s + \sum_s \sum_i \phi_{ish} \ln p_{ih} \ln g_s \\ & i, j = l, k, m;\ s = I, R, E;\ h = 1, \cdots, n. \end{aligned} \tag{2}$$

where C_h is the average cost for firm h; y_h is the total output for firm h; p_{lh}, p_{kh}, p_{mh} stand for labor price, fixed capital price, and intermediate good price, respectively; g_I, g_R, g_E stand for the stock for three types of public capital as infrastructure, g_I, R&D, g_R, and education, g_E; and t is the time trend for technology progress.

Following Varian (1993), the cost function should be monotonicity, homogeneous of degree one, and concave, so we rewrite the empirical function as:

$$\begin{aligned}\ln\left(C_h/P_{mh}\right) - \ln y_h &= \ln\left(C_h/P_{mh} y_h\right) \\ &= \beta_{0h} + \sum_i \beta_{ih} \ln\left(p_{ih}/p_{mh}\right) + \beta_{th} t\end{aligned}$$

Morrison and Schwartz (1996), and Paul and Biswal (2004).

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\begin{aligned}
&+\sum_{i\neq j}\sum_{j}\beta_{ijh}\ln\left(p_{ih}/p_{mh}\right)\ln\left(p_{jh}/p_{mh}\right)\\
&+\sum_{i}\beta_{ith}\ln\left(p_{ih}/p_{mh}\right)t+\sum_{s}\phi_{sh}\ln g_{s}\\
&+\sum_{s}\sum_{i}\phi_{ish}\ln\left(p_{ih}/p_{mh}\right)\ln g_{s},\\
&i,j=l,k;\ s=I,R,E;\ h=1,\cdots,n. \qquad (3)
\end{aligned}
$$

By Shephard's Lemma (Diewert, 1974), we could get a factor share function as follow:

$$
\begin{aligned}
s_{ih}&=\frac{p_{ih}x_{ih}}{C_h}=\frac{\partial\ln\left(C_h/p_{mh}\right)}{\partial\ln\left(p_{ih}/p_{mh}\right)}=\beta_{ih}+\sum_{i\neq j}\beta_{ijh}\ln w_{jh}+\beta_{ith}t\\
&\quad+\sum_{s}\phi_{ish}\ln g_s \quad i,j=l,k;\ s=I,R,E;\ h=1,\cdots,n \qquad (4)\\
s_{mh}&=1-\sum_{i}s_{ih}. \qquad (5)
\end{aligned}
$$

By the estimated coefficients in the above functions, we could check the external effect of public capital on cost function and factor demand function. In order to estimate the productivity effect of public capital on cost function, we could do partial derivatives of three types of public capital (g_s) on cost function. And then so we could get the cost elasticity of public capital as

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\begin{aligned}
\eta_{csh}&=\frac{\partial\ln C_h}{\partial\ln g_s}=\phi_{sh}+\sum_{i}\phi_{ish}\ln\left(p_{ih}p_{mh}\right)\\
&\quad i=l,k;\ s=I,R,E;\ h=1,\cdots,n. \qquad (6)
\end{aligned}
$$

If the estimated elasticity (η_{csh}) is negative, it implies that more public capital will reduce production cost. On the other hand, if the estimated elasticity is positive, it implies that public capital could increase production cost.

Finally, this study will also estimate the relationship of public capital (g_s) with production factors (x_{ih}) as:

$$
\begin{aligned}
\eta_{ish}&=\frac{\partial\ln x_{ih}}{\partial\ln g_s}=\eta_{csh}+\frac{\phi_{ish}}{s_{ih}},\quad i=l,k;\ s=I,R,E;\\
&\quad h=1,\cdots,n, \qquad (7)
\end{aligned}
$$

$$\eta_{msh} = \eta_{csh} - \frac{\sum_i \phi_{ish}}{1 - \sum_i s_{ih}}, \quad i = l, k;\ s = I, R, E;\ h = 1, \cdots, n. \quad (8)$$

If the estimate coefficient (η_{ish}) is positive, it implies that this type of public capital will be a complement for the factor input and more public capital will bring more factor input. On the other hand, if the estimated coefficient is negative, it implies that this type of public capital is a substitute for factor input and more public capital will cause less factor input.

3 Data and variables

A translog cost function is applied in this study to estimate the average cost for firms in the manufacturing industries in China. There are three types of prices of private factor inputs in the cost function, including labor price (p_l), capital price (p_k), and intermediate goods price (p_m). Meanwhile there are three types of public capital, too, including infrastructure (g_I), government R&D expenditure (g_R), and education (g_E).

The firm data employed in this study is called "The Industrial Firm Survey Data Bank" from the manufacturing sector in China. This survey is conducted by the National Bureau of Statistics in which only large and medium-size firms with sales above 5 millions RMB are surveyed.[3] And the industries are divided as four types, including light industry, heavy industry, chemical industry, and high-tech industry, and also are divided by four types of ownership, including SOE, private-owned, HK, Macau and Taiwan (HMT), and foreign-owned. The time period of data set is from 1998 to 2006, we treat those data as a cross-sectional data set.[4] After cleaning the data set, the sample size we applied in this study is 1,371,726 firms. Finally, all other macro data are from "China Statistical Data Book".

The definitions of variables are as follow:

1. Total output y: real total output for each firm and deflated by WPI each year. Since there may have many different products for each firm, here we use total sales (measured by RMB) as the output for each firm.

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[3] We thank for the referee's mentioned about the correct name of the data set.

[4] In "The Industrial Firm Survey Data Bank", the firms includes all SOEs and private firms with yearly sales more than 5 million RMB.

2. Price of labor p_l: real average wage, i.e. total wage expenditure divided by total employees, and deflated by wage index each year.
3. Price of private capital, p_k:

$$p_k = p_{kindex}(d + r)(1 + t), \tag{9}$$

   where p_{kindex} is the price index of fixed investment. d is the annual depreciation rate,[5] r is five-year long term rate, and t is an effective tax rate.[6]

4. Price of intermediate goods p_m: the price index of raw material, fuel, and energy.

   For public capital g_i, because it is difficult to investigate the actual amount of fixed capital and the actual amount of fixed capital might be quite different from the nominal amount, so we have to estimate the existing public capital stock. There are two ways to estimate existing capital stock, one is a direct estimation method, and the other one is an indirect estimation method, as shown in Figure 1.

5. Infrastructure g_I: real total amount of infrastructure including transportation, communication, and energy infrastructure, which is deflated by GDP deflator each year. Moreover, we applied a perpetual inventory method, by Goldsmith (1951), to estimate the capital stock for infrastructure as Figure 1.

   Rearranging Equation (10), one could get:

$$K_t = (1 - \delta)K_{t-1} + I_{t-1}, \tag{10}$$

   where K_t is the total stock of fixed asset in year t, I_{t-1} is the investment amount in year t-1, and δ is the appreciation rate for fixed asset.

   Rearranging Equation (10), one could get:

$$K_t = (1 - \delta)^t K_0 + \sum_{i=0}^{t-2}(1 - \delta)^i I_{t-1-i}. \tag{11}$$

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[5] The actual depreciation rate we applied here is equal to annual depreciation amount divided by total asset that year.

[6] Since the effective tax rate is difficult to get, we assume that the t is zero in this study, so the actual price of private capital is $p_k = p_{kindex}(d + r)$.

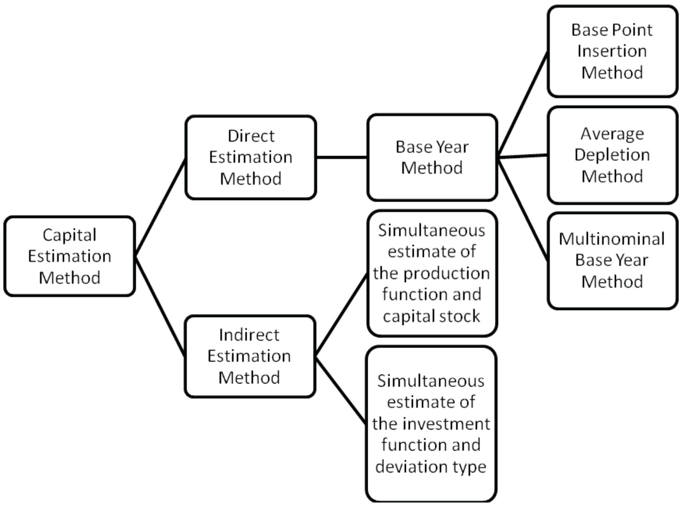

Figure 1: Estimation of capital stock

Sources: This study.

The base year in this study is 1986 and the capital stock for the base year 1986 is:

$$K_0 = I_0/(g + \delta), \tag{12}$$

where K_0 is capital stock at the base year of 1986, I_0 is the annual investment in fixed asset, g is the growth rate of infrastructure from 1986 to 2006. Moreover, we use 5% as the average depreciation rate per year as Perkins (1998), Hu (1998), Wang (2000), and Wang and Yao (2001).[7]

6. R&D capital g_R: real R&D investment, deflated by GDP deflator.

   Here we also applied the perpetual inventory method to total stock of R&D. Considering the lag effect of R&D, we fellow Griliches and Mairesse (1983) and Cuneo and Mairesse (1984) and define the cap-

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[7] There are some literature use different depreciation for fixed capital, such as Young (2000) and Hall and Jones (1999) took 6% as the depreciation rate, while Guang and Shieh (2004) applied 10% as the annual depreciation rate. However, According to Griliches (1978), the estimated results are usually not sensitive to the chosen depreciation rate.

ital stock of R&D as follow:

$$R_t = \sum_{\tau=0}^{\tau=4} (1 - \delta_R)^{\tau} E_{t-\tau}, \tag{13}$$

where t is year t, τ is the period of depreciation, R_t is the total stock of R&D in the year of t, while $E_{t-\tau}$ is the R&D investment in the year of $t - \tau$.

Following Park (1995), we assume that the time lag for the R&D capital is four years. Moreover, δ_R is the depreciation rate for R&D stock and we assume it is 10% per year and then it reduces at a geometric rate as Nadiri and Mamuneas (1994).

7. Education capital g_E:

   The way to estimate education capital stock is the same as R&D, we also applied the perpetual inventory method and we also assume that the annual depreciation rate is 6% per year as Luh (1995) suggested.[8]

8. Total cost, C:

   The total cost C is equal to the sum of total wage, total intermediate input, and total net fixed asset. And all the three figures are deflated by their price indices, respectively. Since the total output is measure by RMB, the total cost here is also measured by RMB.

Finally, the definitions of all variables and their sources are summarized in Table 1.

4 The Empirical Results of the Cost Function

4.1 Basic Statistics

The data set employed in this study is from "The Industrial Firm Survey Data Bank" of China, which contains 28 manufacturing industries with total number of 1,371,726 firms and the time period is from 1998 to 2006.

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[8] Since we could not get the provincial data for the three types of public capital for all provinces, in this study we applied a country-level data for these three types of public capital stock. Since China is a large country, the public capital for different provinces may be quite different, and therefore it should be more meaningful to use provincial data to estimate the public capital on the production efficiency for each firm. Hopefully, we could get the provincial data in our future study.

Table 1: Definitions of variables

	Definition	Explanation	Sources
C_h	Total cost	The aggregate of total labor input, intermediate goods input, and net fixed assets, measured by RMB.	Industrial Firms Data Bank
y_h	Total output	Total output (sales) by firms measured by RMB	Industrial firms Data Bank
p_{mh}	Intermediate goods price	Annual price index of raw materials, fuel, and power purchases.	China Statistical Yearbook
p_{lh}	Labor prices	Total salaries/total employees	Industrial firms Data Bank
p_{kh}	Capital prices	$p_k = p_{kindex}(d + r)$	Industrial firms Data Bank and China Statistical Yearbook
t	Technological progress	Time variable	—
g_E	Educational capital stock	Perpetual inventory method, with a depreciation rate of 6%.	Industrial firms Data Bank and China Statistical Yearbook
g_I	Infrastructure stock	Perpetual inventory method, with a depreciation rate of 5%.	China Statistical Yearbook
g_R	R&D capital stock	Perpetual inventory method, with a depreciation rate of 10%.	China Statistical Yearbook
s_{lh}	Labor factor share	Total salaries/total cost	Industrial firms Data Bank
s_{kh}	Capital factor share	Net fixed assets/total cost	Industrial firms Data Bank

Sources: This study.

Figure 2 shows that light industry and heavy industry have a large portion in the manufacturing sector with 36% and 35%, respectively, while high-tech industry has only 5%.

Since the total number of observations in this study is as large as 1,371,726,

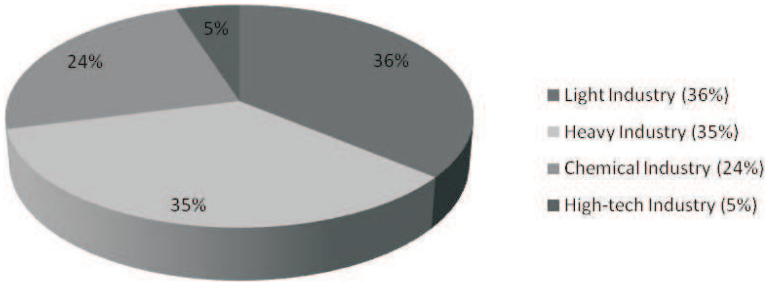

Figure 2: Proportion of Four Major Industries in Manufacturing Sector in China

Sources: This study.

we provided the data distribution by provinces and by industries in Table 2. In Table 2, we could see that Liaoning (215,282), Heilongjiang (182,916), and Beijing (158,461) have the largest number of observations in this data set. Meanwhile, there are only 22 sample points for Inner Mongolia.

In terms of industries, the light industry has the largest number of observations as 501,701, while the heavy industry has the second largest number of observations as 465,311; while the high-tech industry has the smallest number of observations as 80,272.

Moreover, Table 3 shows the data distribution in different years. In Table 3, one could see that the number of firms is increasing quickly from 1998 (102,101) to 2006 (232,064). Since the firms in this data set are large and medium-size firms with sales more than 5 millions RMB and as the economy in China had gone quickly in the past year, there are more and more firms which had crossed the threshold.

In Table 4, one may also see that the intermediate input has the largest portion (67.1%) of cost in all industries, while the share of labor cost is the smallest one (6.5%). The cost share shown here is quite different from Nadiri and Mamuneas (1994), where they shown that the cost share of labor is larger than that of capital share in the US. Moreover, applying a data set from Canada, Paul and Biswal (2004) found a similar result with Nadiri and Mamuneas (1994). The result is consistent with our intuition in that the labor cost in China is much lower than that in the US and Canada, and so is the labor cost share. See Table 5.

In order to know the details of the difference between industries, fol-

Table 2: The Number of Firms in Each Province of Manufacturing Sector in China, by Industries

	Light industry	Chemical industry	Heavy industry	High-tech industry	Total
Beijing	48,051	41,882	58,180	10,348	158,461
Tianjin	2,190	2,340	2,986	481	7,997
Heibei	4,785	3,064	4,255	1,390	13,494
Shanxi	5,601	2,634	3,247	873	12,355
Inner Mongolia	6	8	8	0	22
Liaoning	66,297	46,404	88,928	13,653	215,282
Jilin	28,758	13,952	21,108	2,614	66,432
Heilongjiang	70,467	44,919	58,705	8,825	182,916
Shanghai	62,085	23,531	54,766	6,537	146,919
Jiangsu	17,390	8,376	19,309	1,737	46,812
Zhejiang	6,672	4,746	3,999	1,126	16,543
Anhui	2,629	1,255	1,342	324	5,550
Fujian	9,112	4,642	4,585	1,101	19,440
Jiangxi	18,532	10,190	6,416	1,311	36,449
Shandong	3,607	4,073	7,306	831	15,817
Henan	6,867	7,712	6,974	1,204	22,757
Hubei	2,517	2,367	2,985	335	8,204
Hunan	10,443	6,897	8,776	2,021	28,137
Guangdong	4,212	3,099	3,048	501	10,860
Guangxi	9,252	9,152	8,526	1,175	28,105
Hainan	7,270	3,493	3,656	451	14,870
Chongqing	6,058	4,258	4,233	664	15,213
Sichuan	33,093	18,567	26,777	9,580	88,017
Guizhou	31,695	19,640	29,155	4,338	84,828
Yunnan	4,183	3,160	2,134	668	10,145
Tibet	2,680	2,073	2,812	601	8,166
Shaanxi	10,679	10,223	11,227	3,069	35,198
Gansu	2,425	2,109	1,872	526	6,932
Qinghai	1,953	1,019	780	107	3,859
Ningxia	2,503	2,291	1,964	317	7,075
Xinjiang	4,715	4,489	3,769	859	13,832
Taiwan	9,739	8,582	8,928	2,181	29,430
HongKong	5,234	3,271	2,571	522	11,598
Macao	1	4	4	2	11
Total	501,701	324,422	465,331	80,272	1,371,626

Sources: This study.

Table 3: The Frequency Distribution of Data, by Years

	Frequency	Percent %	cumulative %
1998	102,101	7.44	7.44
1999	109,032	7.95	15.39
2000	106,171	7.74	23.13
2001	121,787	8.88	32.01
2002	130,235	9.49	41.50
2003	149,303	10.88	52.38
2004	211,779	15.44	67.82
2005	209,254	15.25	83.07
2006	232,064	16.92	100.00
total	1,371,726	100.00	100.00

Sources: This study.

lowing Huang et al. (2003), we divide the manufacturing sector into four industries, including light, heavy, chemical, and high-tech industries. The basic statistics are shown in Table 4.

On labor price, one may see that the high-tech industry has the highest labor price (16.665), since it needs more high quality labor, while the light industry has the lowest labor price (10.934). In terms of capital price, Table 4 shows that the high-tech industry also has the highest capital price (14.333), while the light industry has the lowest capital price (12.773).

According to "The Investment Environment and Risk Report on China, 2008", the total length of highway in China was only 300 km, but it was sharply increased to 53.6 thousands km in 2007, which is the second longest of the world. At the same time, the total expenditure on telecommunication was 243.1 billion RMB in 1998, with 10% households having telephone in their home. Then the total expenditure on telecommunication was increased to 2,384.1 billion RMB, with 74.3% of households having their own phone at home in 2007.

About the development of education, there were 13 million college graduates and 500 thousand people with MA or higher degree. However, in 2008, there were 25.3 million college graduates and 1.6 million people with MA or higher degree.

On government R&D expenditure, there were 5778 units of R&D

Table 4: Basic Statistics of Production Cost and Main Variables in the Manufacturing Sector in China, by Industries

		All	Light industry	Chemical industry	Heavy industry	High-tech industry
Number of observations		1,371,726	501,701	324,422	465,331	80,272
Average cost(a)	mean	0.980	0.919	1.084	0.976	0.969
(RMB thousand dollars)	S.E.	0.037	0.020	0.143	0.040	0.034
Labor price	mean	12.197	10.934	11.401	13.342	16.665
(RMB thousand dollars)	S.E.	0.184	0.105	0.076	0.515	0.651
Capital price	mean	13.340	12.773	13.416	13.727	14.333
(RMB thousand dollars)	S.E.	0.009	0.015	0.019	0.016	0.041
Labor cost share	mean	0.065	0.067	0.058	0.066	0.072
(%)	S.E.	0.000	0.000	0.000	0.000	0.000
Capital cost share	mean	0.264	0.264	0.289	0.242	0.293
(%)	S.E.	0.000	0.000	0.000	0.000	0.001
Intermediate goods	mean	0.671	0.669	0.653	0.692	0.635
cost share (%)	S.E.	0.000	0.000	0.000	0.000	0.001
R&D	mean	666.810	660.114	661.656	692.843	637.889
(100 million dollars)	S.E.	0.285	0.493	0.612	0.512	1.222
Education	mean	3,801.630	3,748.647	3,757.677	3,917.813	3,636.903
(100 million dollars)	S.E.	1.466	2.429	3.014	2.505	6.046
Infrastructure	mean	22,922.150	22,641.990	22,695.390	23,528.890	22,072.380
(100 million dollars)	S.E.	7.897	13.101	16.238	13.470	32.578

Sources: This study.
Note: (a) Since the total production is taken as an output, the average cost here stands for the average input for per dollar output.

Table 5: Comparison of Shares of Average Cost

	Country	Share of labor cost	Share of capital cost
This research	China	0.034–0.097	0.173–0.423
Nadiri and Mamuneas (1994)	United States	0.078–0.478	0.050–0.218
Paul and Biswal (2004)	Canada	0.146–0.870	0.130–0.854

Sources: This study.

agencies. In 2008, there were 7 national engineer research institutes, 51 national labs, 575 national certified firm-owned technology centers, 4,886

Table 6: Annual Public Capital Stock in China

	Infrastructure capital stock (100 mill RMB)	R&D capital stock (100 mill RMB)	Educational capital stock (100 mill RMB)
1998	7,965.553	250.366	1,392.167
1999	10,584.276	280.069	1,630.425
2000	13,243.857	310.797	1,924.940
2001	15,942.608	360.946	2,283.540
2002	18,948.587	415.568	2,741.896
2003	22,032.744	554.523	3,441.368
2004	25,383.079	733.715	4,431.520
2005	30,559.054	988.595	5,409.123
2006	37,060.245	1,237.677	6,339.307
Avg. capital growth rate	0.2119	0.2211	0.2086

Sources: China Statistical Yearbook, The Industrial Firms Survey Data Bank, and this study.

provincial level technology centers, and 24,300 product inspection centers. In 2008, the total government expenditure on R&D was 457 billion RMB.

Using the basic data from “China Statistical Yearbook” and “The Industrial Firm Survey Data Bank”, we got the annual investment on public capital first and then, applying the perpetual inventory method, we estimated the total stocks of public capital for infrastructure, R&D, and education and the results are shown in Table 6 and Figure 3. One may see that during the past twenty years, most of the government investment was using in infrastructure and the amount is about 30 times as much as in R&D. On the other hand, in terms of investment growth rate, we found that investment on R&D has the highest growth rate (22.11%), while the investment on education has the lowest growth rate (20.86%). In conclusion, the public capital investment was increasing at a very high speed, so that the public capital should has a significant impact on firms’ production efficiency as we expected in this study.

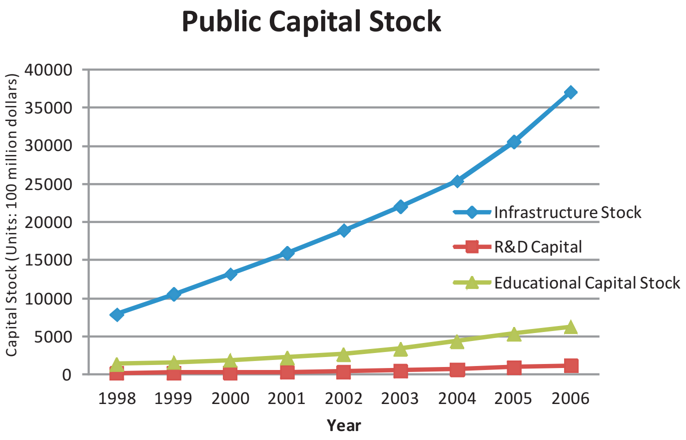

Figure 3: Types of Public Capital Stock

Source: see Table 6.

4.2 The Estimated Results of Cost Funciton, by Industries

Since our data set is a panel data set, it will be interesting to see the firm-specific fixed effect. Here, we apply a firm-specific fixed effect in order to catch the potential firm-specific characters on influencing the production efficiency for each firms.[9] The distribution of duration years of individual firm in our data set is shown in Table 7. In Table 7, one may see that there are 98,938 firms having one year observation; meanwhile, there are also 22,889 firms having nine years of observation.

Applying an OLS method and with a firm-specific fixed effect on a translog cost funtion as Equation (3), the estimated results are shown in Table 8. One may see that the Adj. R-squared is 0.1100 for all industries as a whole. For the coefficients of labor price and capital price are -0.772 and -0.723 and both are significantly differrence from zero. The results show that both labor price and capital price have an negaive and significan impact on average cost.[10] Moreover, the estimated marginal effect of public capital on cost function is -0.169, 0.619, and -1.979 for infrastructure, R&D,

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[9] The authers are thankful for a referee's suggestion on checking the potential fixed effect using this data set.

[10] One has to note the the net effect of labor price on cost funcion is not -0.772 since there are other variables as labor price*capital price and labor price *time which may also influence the average cost. So if one wants to calculate the actual impact of labor price on

Table 7: The Distribution of Duration Years of Individual Firm

Duration Years	Frequency	Percent %	Cumulative %
1	98,938	24.56	24.56
2	66,443	16.49	41.05
3	93,814	23.29	64.34
4	39,953	9.92	74.26
5	28,326	7.03	81.29
6	28,065	6.97	88.26
7	12,697	3.15	91.41
8	11,716	2.91	94.32
9	22,889	5.68	100.00
total	402,841	100.00	100.00

Sources: This study.

and education, respectively.

For the four different industries, the estimated results are also shown in Table 8. One may see that the estimated results are quite similar to total industry, for instance, the R-sequares are between 0.0809 to 0.1090, while most coeffieicnts have same signs and are significant, too.

To calculate the total impact of the three types of public capital on cost function, we applied Equation (6), i.e. the cost elasticity of public capital. Furthermore, we also applied Equation (8) to examine whether private inputs and public capital are substitue or compliment for each other. The estimated results are shown in Table 9. We also applied a Wald test to check if cost elasticity or the demand elasticity is significant or not.[11]

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cost function, he has to calculate all of the related coefficients.

[11] Following Nadiri and Mamuneas (1994), we calculate the Wald test as follow:

$$\text{var}\left(\sum_i \beta_i x_i\right) = \sum x_i^2 \text{var}\ (\beta_i) + 2\sum_{i\neq j} x_i x_j \text{cov}\ \left(\beta_i, \beta_j\right),$$

where β is the estimated coefficient and x is the mean of related variables.

Table 8: Estimations of the Cost Functions of Manufacturing Industry in China With a Fixed Effect on Firms, by Industries

	All manufacturers		Light industry		Chemical industry		Heavy industry		High-tech industry	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Labor prices	−0.772**	0.394	1.026	0.647	−3.920***	0.772	−1.640**	0.673	3.899**	1.737
Capital prices	−0.723	0.495	−2.654***	0.801	−0.465	0.947	0.905	0.843	0.579	2.274
Labor prices* Capital prices	0.029***	0.001	0.032***	0.001	0.035***	0.002	0.025***	0.001	0.035***	0.004
Time	0.247***	0.032	0.285***	0.053	−0.115*	0.063	0.289***	0.055	0.726***	0.136
Labor prices* Time	−0.031***	0.010	0.014	0.016	−0.106***	0.019	−0.055***	0.016	0.088**	0.042
Capital prices* Time	−0.020*	0.012	−0.071***	0.019	−0.013	0.023	0.017	0.020	0.008	0.054
Infrastructure	−0.169**	0.084	−0.189	0.135	0.497***	0.164	−0.299**	0.145	−1.169***	0.351
R&D capital	0.619***	0.031	0.667***	0.053	0.323***	0.061	0.773***	0.051	0.296**	0.131
Educational capital	−1.979***	0.105	−2.190***	0.179	−0.440**	0.206	−2.286***	0.174	−3.209***	0.455
Infrastructure* Labor prices	0.007	0.023	−0.107***	0.037	0.158***	0.046	0.067*	0.040	−0.244**	0.102
R&D capital* Labor prices	0.071**	0.035	−0.034	0.060	0.365***	0.069	0.110*	0.058	−0.206	0.155
Educational capital* Labor prices	0.056***	0.010	0.046***	0.018	0.010	0.020	0.069***	0.017	−0.037	0.045
Infrastructure* Capital prices	0.133***	0.032	0.290***	0.051	0.089	0.060	0.018	0.055	0.027	0.142
R&D capital* Capital prices	0.068***	0.010	0.155***	0.017	0.037**	0.020	0.066***	0.017	−0.070	0.051
Educational capital* Capital price	−0.113***	0.037	−0.096	0.061	−0.068	0.073	−0.196***	0.062	−0.054	0.181
Constant	7.890***	1.333	9.327***	2.185	−7.201***	2.605	10.436***	2.281	27.151***	5.649
Adj. R-squares	0.1100		0.1021		0.1063		0.1090		0.0809	
Number of observations	1,371,726		501,701		334,422		465,331		80,272	

Sources: This study.

Notes: 1. The coefficient with ***, **, or * implies that it is significantly different from zero at 1%, 5%, or 10% level of significance.

2. In order to save space, we did not put the all coefficients of fixed effect for individual firm here.

Table 9: Estimations of the Cost Elasticity of Manufacturing Industry in China With a Fixed Effect on Firms, by Industry

	All manufacturers		Light industry		Chemical industry		Heavy industry		High-tech industry	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Avg. cost elasticity										
infrastructure	−0.490***	0.000	−0.582***	0.000	−0.111***	0.000	−0.504***	0.000	−0.664***	0.001
R&D capital	0.321***	0.000	0.185***	0.000	0.453***	0.000	0.458***	0.000	0.537***	0.000
Educational capital	−2.416***	0.000	−1.879***	0.000	−1.223***	0.000	−2.113***	0.000	−2.613***	0.000
Labor demand elasticity										
infrastructure	−0.222***	0.002	0.040***	0.005	0.197***	0.005	−0.413***	0.000	−0.985***	0.006
R&D capital	−0.918***	0.007	−1.463***	0.013	−0.204***	0.010	−0.513***	0.009	−1.484***	0.039
Educational capital	1.675***	0.024	3.707***	0.043	1.333***	0.0408	1.188***	0.031	3.033***	0.1105
Capital demand elasticity										
infrastructure	4.040***	0.129	3.833***	0.098	3.909***	0.239	4.956***	0.227	0.017	0.163
R&D capital	2.903***	0.074	2.839***	0.059	1.880***	0.085	4.143***	0.144	1.518***	0.235
Educational capital	−4.243***	0.052	−2.662***	0.017	−1.520***	0.018	−6.162***	0.168	−0.695	0.459
Intermediate goods demand elasticity										
infrastructure	−2.067***	0.146	−2.200***	0.251	−1.170***	0.096	−2.600***	0.365	−0.972***	0.054
R&D capital	−0.325***	0.060	−0.442***	0.097	0.161***	0.026	−0.651***	0.193	0.754***	0.038
Educational capital	−2.541***	0.117	−2.568***	0.107	−1.430***	0.019	−1.350***	0.133	−4.746***	0.376

Sources: This study.

Notes: 1. The coefficient with ***, **, or * implies that it is significantly different from zero at 1%, 5%, or 10% level of significance.

2. The Wald test statistic is applied here.

3. The null hypothesis of average cost elasticity is H_o : $\eta_{csh} = 0$, s =I,R,E: and the null hypothesis of input factors demand elasticity is H_o : $\eta_{ish} = 0, i =$ l,k,m, s = I,R,E.

4.3 Cost Elasticities and Substitutability of Public Capital and Private Factors, by Industries

4.3.1 Cost Elasticities of Public Captial

Cost elasticities of infrastrucure

Table 9 shows that the cost elasticity of infrastrucutre for all manufacturing sector is −0.409 and it means that the average cost will be lower as China government increases its investment in infrastructure. This result is consistent with Aschauer (1989) and Munnell (1990b)'s findings, in that the public capital should have a positive impact on production and thus will reduce production cost. The

estimated cost elasticy we got here is higher that that of Chen et al. (2010) (−0.08 to −0.183). Moreover, the elasticity we got here is also higher than other estimations from other countries.[12] Furthermore, the variance of cost elasticity among industries is also larger than other studies.

Infrastrucutre has a negative cost elasticity and it means that government spending on infrastructure could reduce production cost singificantly. Moreover, high-tech industry has a highest cost elasticity both for infrastrucutre (−0.664), while the chemical industry has the lowest cost elasticity for infrastrucutre (−0.111). The result implies that the high-tech industry is more sensitive to infrastrucutre and to higher education labor as we expected. Our results here are consistent with Nadiri and Mamuneas (1994)'s results, that both infrastructure and R&D expenditure have a positive impact in cost function, while the cost elasticity of infrastructure is between −0.11 to −0.21 and the cost elasticity of R&D is between −0.009 to −0.056. The reason why in our estimation on the cost elasticity of infrastructure in China is larger than that in Nadiri and Mamuneas (1994) is because that the total amount of public capital for infrastructure in China is much less than that in the US.

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[12] Applying a data set from the manufacturing sector of the US, Nadiri and Mamuneas (1994) found that the cost elasticity is between −0.11 to −0.12. Paul and Biswal (2004) got the cost elasticity between −0.1 to −0.4 by using a data set from the manufacturing industry from Canada. Shah (1992) found the cost elasticity is −0.05 by using Mexico data. Finally, Sturm (1998) got the cost elasticity is −0.31 using a data set from New Zealand.

Cost elasticities of R&D

Table 9 shows that the cost elasticity of R&D has a positive elasticity (0.321), which is different from our expectation.[13] The result implies that the government R&D expenditure could not reduce firms' production cost. One possible reason is that so far most of the China government R&D output is still too low and could not spread out to private firms yet.

Cost elasticities of education

The estimated cost elasticity of education is less than zero (-2.416). The result shows that education expenditure in China could significantly increase labor quality and thus sharply reduce labor cost and total cost of firms. In fact, the cost elasticity of education is the largest among the three types of public capital. Moreover, the cost elasticity of education is also the largest for the four different industries. Our findings here is consistent with what Demetriades and Mamuneas (2000)'s result, where they applied a data set with twenty countries and found that the marginal contribution of public capital to the production efficiency will be higher for a country with less public capital.

4.3.2 Substitutes or Compliments

Now we like to apply Equation (8) to estimate the influenceof public capital on factor demand and to check whether public capital and factor inputs are substitues or compliments.

Demand elasticity of labor

Table 9 shows that the impact of infrastructure on demand elasticity of labor is negative (-0.222) and it implies that infrastructure and labor demand is substitute for each other. This result is consistent with our expectation in that better government infrastructure could increase production efficient so that the firms could reduce some labor transportation, and so on. Moreover, the high-tech industry has the highest elasticity of substitution between infrastructure and labor input.

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[13] Nadiri and Mamuneas (1994) found that the cost elasticity of R&D is between -0.009 and -0.234.

Table 9 also shows that the R&D and labor demand is also a substitute (−0.918) and it implies that R&D expenditure will reduce labor demand, too. Moreover, for individual industry, we found that light, chemical, and high-tech industries all show that R&D and labor demand are substitute, while the high-tech industry has the largest substitutability (−1.484).

On the impact of education on labor demand, Table 9 shows that education and labor demand are compliments (1.675) and it implies that more education expenditure could increase more labor demand. Moreover, education has a largest effect on positive labor demand in the light industry (3.707), while education has a smallest impact (1.188) on labor demand on the heavy industry.

Demand elasticity of private capital

For the impact of infrastructure on private capital input, one may see that the relationship of infrastructure and private capital input is positive (4.040) for the manufacturing sector as a whole, see Table 9. The result shows that if government could provide better infrastructure, such as electricity or telecommunication, then the firms will also put more capital in those related equipments. One may see that the heavy industry has the largest positive impact of infrastructure on private capital input (4.956).

Government R&D expenditure also has a positive impact on private capital input (2.903) in the manufacturing sector as a whole in China. The result shows that more government R&D could also increase private sector to invest more on capital. The effect is specifically important for the heavy industry (4.143).

Education has a negative effect with private capital input (−4.243) and it means that education and private capital input are substitutes. One reason is that with better education and better productivity of labor, the firms may prefer to hire more labor instead of capital. Among others, the heavy industry has the largest negative impact of education on private capital input (−6.612).

Demand elasticity of intermediate goods

Table 9 shows that infrastructure has a negative impact on demand for intermediate goods (−2.067), while the light industry has the largest impact. The result shows that more spending on infrastructure could reduce inter-

Table 10: The Relationship of Public Capital With Average Cost and Factor Demand, by Industries

	Ave. cost	Labor	Capital	Intermediate goods
Infrastructure	negative correlation	Sub/compl (2/2)*	compliment	substitute
R&D capital	positive correlation	substitute	compliment	sub/compl (2/2)
Educational capital	negative correlation	compliment	substitute	substitute

Sources: This study.
Note: * (2/2) means that two industries are substitutes and two are compliments.

mediate input. Government R&D expenditure also has a negative impact on intermediate input (−0.325) and it means that R&D and intermediate input are substitutes, too. Finally, education has a negative impact on intermediate goods input (−2.541), while the impact is the strongest on the high-tech industry (−4.746).

In summary, we found that both infrastructure and education could significantly reduce firms' production cost, but R&D could not. See Table 10. Moreover, comparing to infrastructure, education has a larger impact on reducing production cost. Furthermore, cost elasticity of public capital is larger than that of foreign countries. One of the reasons is that China is a developing country and its level of public capital is still much lower than that of developed countries, so that marginal contribution of public capital on firms' production cost is more significant.

For most industries in the manufacturing sector, more government spending on infrastructure and on R&D will reduce fimrs' labor input and increase capital input. On the other hand, more education expendiure will increase firms' labor demand, but reduce capital input. Nadiri and Mamuneas (1994) found that infrastructure has a substitute effect on private firms' demand for capital and labor, which is consistent with our findings using the data set from China. Moreover, Nadiri and Mamuneas (1994) found that the public capital has a compliment effect on private firms' demand for intermediate inputs, while in our paper by using a data set from China we found that public capital is a compliment with respect to intermediate goods only for R&D, but not for labor input. At the meantime, Berndt and Hansson (1991) applying a short term cost function and he found that infrastructure has a substitute impact with private firms' labor demand, while it has a compliment impact with private firms capital input and intermediate input.

4.4 The Estimated Results of Cost Function, Cost Elasticities, and Substitutability, by Ownership

Now, we want to estimate the cost function by different types of ownership, including state-owned (SOE), private-owned, HK, Macau, and Taiwan (HMT), and foreign-owned. One of the reasons that we want to see the potential difference of cost function and of the substitutability between public inputs and private production inputs for different types of ownership is that the input ratio (such as capital labor ratio) might be different for different types of ownership. We especially like to see the difference among domestic firms (both SOE and private-owned) and foreign firms (both HMT and foreign-owned) in China.[14] Table 11 shows the frequency of sample points of different types of firm in different provinces. While Liaoning (215,282), Heilongjiang (182,916), and Beijing (158,461) have more firms than other provinces, they also have more foreign firms as 36,963, 24,532, and 17,957, respectively. However, Sichuan (34,454), Guizhou (27,693), and Liaoning (26,758) have more firms from HK, Macau, and Taiwan.[15]

The estimated results of cost function for different types of ownership with a fixed effect on firms are shown in Table 12. The estimated adjusted R-squares are among 0.0675 to 0.1020 for four types of ownership and they are similar to that of total firms (0.1100). Moreover, in general, most estimated coefficients for different types of ownership are similar to that of total firms. The results have two important implications. The first is that the production behavior among different types of ownership is similar to each other. Moreover, since most coefficients have similar coefficients, it shows that our estimated results are quite robust.

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[14] We thank that one referee provided this idea, so that we could do a thorough analysis on this point.

[15] The data shows here is a little different from what we expected because, according to the investment data from Taiwan, Guangdong and Jiangsu have more Taiwanese firms than other provinces.

Table 11: The Number of Firms in Each Province of Manufacturing Sector in China, by Ownership

	State-owned (SOE)	Private-owned	Hong Kong, Macau and Taiwan-owned (HMT)	Foreign-owned	Total
Beijing	84,128	48,072	8,304	17,957	158,461
Tianjin	4,892	2,474	213	418	7,997
Heibei	7,290	4,684	405	1,115	13,494
Shanxi	8,011	3,317	371	656	12,355
Inner Mongolia	16	6	0	0	22
Liaoning	79,198	72,363	26,758	36,963	215,282
Jilin	24,479	32,383	3,847	5,723	66,432
Heilongjiang	80,961	67,861	9,562	24,532	182,916
Shanghai	43,675	75,887	14,195	13,162	146,919
Jiangsu	19,289	23,881	1,446	2,196	46,812
Zhejiang	9,763	5,528	659	593	16,543
Anhui	3,032	1,723	550	245	5,550
Fujian	5,744	6,712	4,357	2,627	19,440
Jiangxi	8,077	10,670	12,687	5,015	36,449
Shandong	7,933	6,640	482	762	15,817
Henan	12,096	9,258	775	628	22,757
Hubei	3,950	3,834	279	141	8,204
Hunan	15,686	9,808	1,371	1,272	28,137
Guangdong	6,780	3,456	381	243	10,860
Guangxi	18,104	8,431	807	763	28,105
Hainan	9,821	4,515	307	227	14,870
Chongqing	10,193	4,319	373	328	15,213
Sichuan	22,277	20,371	34,454	10,915	88,017
Guizhou	23,477	25,661	27,693	7,997	84,828
Yunnan	6,396	2,673	583	493	10,145
Tibet	5,076	2,286	436	368	8,166
Shaanxi	20,372	11,712	1,416	1,698	35,198
Gansu	3,222	3,383	97	230	6,932
Qinghai	1,988	1,794	46	31	3,859
Ningxia	3,438	3,382	107	148	7,075
Xinjiang	9,103	3,658	574	497	13,832
Taiwan	21,213	6,772	564	881	29,430
HongKong	8,923	2,216	181	278	11,598
Macao	8	1	1	1	11
Total	588,611	489,731	154,281	139,103	1,371,726

Sources: This study.

Table 12: Estimations of the Cost Functions Manufacturing Industries in China With Fixed Effect on Firms, by Ownership

	All manufacturers		State-owned (SOE)		Private-owned		Hong Kong, Macau and Taiwan (HMT)		Foreign-owned	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Labor prices	−0.772**	0.394	−2.231***	0.676	−3.545***	0.764	−2.971***	1.138	0.741	1.197
Capital prices	−0.723	0.495	−0.904	0.793	−0.743	0.938	1.863	1.393	−2.963*	1.777
Labor prices* Capital prices	0.029***	0.001	0.036***	0.001	0.025***	0.001	0.022***	0.002	0.010***	0.002
Time	0.247***	0.032	0.127**	0.055	0.003	0.063	0.435***	0.088	0.410***	0.100
Labor prices* Time	−0.031***	0.010	−0.063***	0.016	−0.085***	0.018	−0.077***	0.028	−0.006	0.029
Capital prices* Time	−0.020*	0.012	−0.031*	0.019	−0.021	0.022	0.058*	0.033	−0.045	0.042
infrastructure	−0.169**	0.084	0.236*	0.133	0.627***	0.186	−0.697***	0.225	−0.532**	0.271
R&D capital	0.619***	0.031	0.668***	0.063	0.546***	0.048	−0.066	0.085	0.317***	0.084
Educational capital	−1.979***	0.105	−1.797***	0.208	−1.284***	0.168	−1.701***	0.294	−2.227***	0.300
Infrastructure* Labor prices	0.007	0.023	0.091**	0.036	0.254***	0.051	0.044	0.067	−0.118	0.074
R&D capital* Labor prices	0.071**	0.035	0.203***	0.070	0.127	0.053	0.489***	0.101	0.043	0.094
Educational capital* Labor prices	0.056***	0.010	0.015	0.021	0.082***	0.015	−0.149***	0.030	0.022	0.027
Infrastructure* Capital prices	0.133***	0.032	0.192***	0.047	0.109*	0.066	−0.045	0.088	0.314***	0.116
R&D capital* Capital prices	0.068***	0.010	0.150***	0.020	0.044***	0.014	−0.103***	0.030	−0.116***	0.034
Educational capital* Capital price	−0.113***	0.037	−0.216***	0.070	−0.059	0.057	−0.137	0.109	0.097	0.126
Constant	7.890***	1.333	2.854	2.282	−3.871	2.684	14.110***	3.641	14.420***	4.177
Adj. R-squares	0.1100		0.1020		0.0675		0.0805		0.0803	
Number of observations	1,371,726		588,611		489,731		154,281		139,103	

Sources: This study.

Notes: 1. The coefficient with ***, **, or * implies that it is significantly different from zero at 1%, 5%, or 10% level of significance.

2. In order to save space, we did not put the all coefficients of fixed effect for individual firm here.

Next, we applied the estimated coefficients to calculate the cost elasticities for four types of ownership and the results are shown in Table 12. Comparing to estimated elasticities for total firms, the estimated elasticties are consistent for four types of ownership in Table 13. Again, the results show that our estimations are very robust here. Most of the coefficients are with expected signs and there are only a few estimated coefficients across the ownership having different signs.

There are only two minor points worthy for discussion in Table 13. The first one is that almost all elasticities, both for the cost elasticity and for factor demand with respect to public inputs, have similar signs across the ownership. This results show that the public capital inputs have similar impact on productivity in private sector across the structure of ownership, though the size of impact might have a little different. For instance, public capital on infrastructure has the largest impact on cost reduction in foreign-owned (−0,951), while it has a smaller impact on private-owned firms (−0.264). One reason for the difference might be because that foreign-owned firms are using more infrastructure than that of private-owned, so that the former may reduce more cost when the government provides more infrastructure. Moreover, public expenditure on education will have a larger impact on cost reduction for HMT (−2.528) and foreign-owned (−2.520), while the impact is smaller for SOE (−1.840) and private-owned (−1.468).

Moreover, the signs of elasticity of factor demand with respective to public capital are very consistent across the ownership structure, though the magnitude might have a little different. For example, the elasticity of labor demand on infrastructure for HMT has the largest figure (−1.357), while SOE has the smallest number (−0.054). The result implies that SOE may employ less labor, comparing to other types of ownership, when infrastructure is better, namely, they are substitute each other. The elasticity of labor demand with respect to education for SOE is the largest (3.201), while HMT has the smallest number (0.955). One of the reasons why SOE has a larger elasticity on education is because that SOEs are employing more educated workers.

Finally, the relationship of public capital with average cost and private factor demand for four types of ownership is summarized in Table 14. Comparing Table 10, one may find that the estimated results for different types of industry and ownership are consistent for each other.

Table 13: Estimations of the Cost Elasticity Manufacturing Industries in China With Fixed Effect on Firms, by Ownership

	All manufacturers		State-owned (SOE)		Private-owned		Hong Kong, Macau and Taiwan (HMT)		Foreign-owned	
	Estimated Coef.	S.D.	Estimated Coef.	S.D.	Estimated Coef.	S.D.	Estimated Coef.	S.D.	Estimated Coef.	S.D.
Avg. cost elasticity										
infrastructure	−0.490***	0.000	−0.463***	0.000	−0.264***	0.000	−0.704***	0.000	−0.951***	0.001
R&D capital	0.321***	0.000	0.273***	0.000	0.237***	0.000	0.490***	0.000	0.515***	0.000
Educational capital	−2.416***	0.000	−1.840***	0.000	−1.468***	0.000	−2.528***	0.001	−2.520***	0.000
Labor demand elasticity										
infrastructure	−0.222***	0.002	−0.054***	0.003	−0.492***	0.001	−1.357***	0.016	−0.975***	0.001
R&D capital	−0.918***	0.007	−1.371***	0.013	−1.335***	0.007	−0.678***	0.028	−1.405***	0.069
Educational capital	1.675***	0.024	3.201***	0.041	2.419***	0.016	0.955***	0.083	3.002***	0.120
Capital demand elasticity										
infrastructure	4.040***	0.129	2.835***	0.122	4.474***	0.246	−0.145***	0.053	1.791***	0.138
R&D capital	2.903***	0.074	1.175***	0.034	3.772***	0.184	0.843***	0.033	1.275***	0.038
Educational capital	−4.243***	0.052	−1.987***	0.005	−2.717***	0.065	−3.060***	0.050	−1.908***	0.031
Intermediate goods demand elasticity										
infrastructure	−2.067***	0.146	−2.465***	0.243	−0.913***	0.115	−0.752***	0.010	−1.836***	0.280
R&D capital	−0.325***	0.060	0.222***	0.006	−0.122***	0.064	0.551***	0.013	0.515***	0.000
Educational capital	−2.541***	.0117	−3.182***	0.163	−1.640***	0.031	−2.826**	0.064	−3.427***	0.287

Sources: This study.

Notes: 1. The coefficient with ***, **, or * implies that it is significantly different from zero at 1%, 5%, or 10% level of significance.

2. The Wald test statistic is applied here.

3. The null hypothesis of average cost elasticity is $H_o : \eta_{csh} = 0$, $s =$ I,R,E: and the null hypothesis of input factors demand elasticity is $H_o : \eta_{ish} = 0$, $i =$ l,k,m, $s =$ I,R,E.

Table 14: The Relationship of Public Capital With Average Cost and Factor Demand, by Ownership

	Ave. cost	Labor	Capital	Intermediate goods
Infrastructure	negative correlation	substitute	sub/compl (1/3)*	substitute
R&D capital	positive correlation	substitute	compliment	Sub/compl (1/3)
Educational capital	negative correlation	compliment	substitute	substitute

Sources: This study.
Note: * (1/3) means that there is one industry is substitute and three are compliments.

5 Conclusion

This study is different from other articles in studying the externality of public capital in several aspects: First, we applied a data set with a large sample of individual firms to examine the external impact of public capital. Secondly, we employed a translog cost function in this study and so we could also estimate the specific impact of public capital on factor demand for private firms. Tertiary, we include three types of public capital were included in this study, including infrastructure, R&D, and education, and so that we could find the external impact for a specific public capital on private cost.

Applying a panel data set from China with 1,371,726 data points from 1998 to 2006, we found that China government spending on infrastructure and education could significantly reduce firms' production cost, but government spending on R&D could not reduce firms' cost. Moreover, more spending on infrastructure could induce more private capital input, but will reduce demand for labor and for intermediate goods. More government R&D will induce more demand on capital and intermediate goods, but will reduce demand for labor. Finally, more government spending on education will induce more demand for labor, but less demand for capital and intermediate goods.

Our findings on the impact of infrastructure and education on firms' production cost is similar to some traditional literature, such as Garcia-Mila and McGuire (1992), Paul and Biswal (2004), Shah (1992), Sturm (1998) and Moreno et al. (2003), in that both types of public capital could reduce production cost sharply. However, the marginal contribution of public capital in China is larger than that of the traditional literature and the variance in different industries is also larger in this study, too. One of the reasons why the marginal contribution we found in this study is larger is because that China is a developing country so that the cost elasticity of public capital is larger, too.

However, our findings on the impact of government R&D on private production cost are different from that of the traditional literature, such as Cuneo and Mairesse (1984) and Nadiri and Mamuneas (1994). The reason may be because that so far government R&D in China is still far less than enough and so the private sector still could not enjoy government's R&D results.

There are two issues which are worthy for further study. The first one is that, after estimating the cost function, we may also estimate the contribution of public capital on firms' production efficiency and it will be an interesting issue to deal with. Furthermore, it will also be an interesting issue to check the difference of impact for difference years since the total amount of public capital is quite different among years.

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中國政府公共支出對於製造業成本結構影響之分析

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1978年改革開放以來, 中國政府在公共資本支出方面投入大量的金額, 包括基礎建設、教育及研發。這些公共資本對於製造業的生產力會有何影響? 對於他們的生產成本會有何影響? 這些都是很重要的研究課題。在本研究中, 我們引用中國製造業由1998到2006年的1,371,616個廠商的樣本資料, 再利用傳統的成本函數及考慮企業的固定效果下, 來估計公共資本對於製造業生產成本的影響; 然後, 再進一步推估公共資本對於企業要素投入之間的關係是替代或是互補。研究結果發現, 教育支出與基礎建設對於企業的生產成本有顯著減少的效果, 而且前者的效果更明顯; 但是, 政府研發支出對於企業成本的影響則不顯著。

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