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THE PRODUCTIVITY DYNAMICS OF CHINESE MANUFACTURING FIRMS

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Contents

The Productivity Dynamics of Chinese Manufacturing Firms

by

Wang Zhifeng

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Abstract

The Chinese economy has been growing at a very high speed rate since 1978. Productivity growth is considered as the engine of the long-run sustainable economy growth. Unlike the previous researches that use aggregate level data to investigate the contribution of productivity growth, this thesis uses a firm-level data set of Chinese manufacturing sector. The advantage of using the micro-level data is that we can study questions with macro-level implications by estimating firm-level production function instead of imposing a growth accounting framework.

Chapter 1 provides the motivation of this thesis. Chapter 2 aims to quantify the contribution of productivity growth in the Chinese manufacturing sector. Using a growth accounting framework, Zhu (2012) argues that China's total factor productivity (TFP) growth is mainly driven by resource reallocation due to market liberalization and institutional reforms. How much has the growth of Chinese manufacturing sector been driven by TFP growth? What's the contribution of resource reallocation? What is the distribution of productivity across different ownership types and regions? This chapter answers these three questions using Chinese manufacturing firms spanning 1998-2007. In particular, we empirically employ three production function estimation methods, i.e., ordinary least squares (OLS hereafter) , Ackerberg, Caves and Frazer (2006, 2015) (ACF hereafter) and Blundell and Bond (2000) (BB hereafter).

Chapter 3 focuses on the productivity of public infrastructure investment. The role of public infrastructure in promoting economic growth is still under investigation. This issue has become more important after the burst of global financial crisis since 2008. Existing studies mainly use macro-level data, and thus to tackle the inherited reverse causality problem becomes a challenging task. In this chapter, we employ a model of endogenous productivity to calculate the return rate of public infrastructure investment. It matches the firm-level data with the

province-level public infrastructure investment data to address those identification challenges. With the constant elasticity of substitution demand system, the short-run Keynesian demand effect can be separated from the long-run productivity effect. The estimated return rates of infrastructure are 9.2% and 2.5% for revenue-based and quantity-based total factor productivity. If spillover effects are considered, the return rates almost triple.

Chapter 4 investigates the dynamic learning by exporting effect in Chinese manufacturing firms. International trade plays a key role in promoting China's economic growth during 1998-2007. The productivity of exporters in China, however, is found to be unexceptional in literature. Previous researches usually focus on the comparison of the productivity of exporters with that of non-exporters. This research examines the dynamic learning by exporting effect. We find that the dynamic learning by exporting effect is significantly heterogeneous across industries. Only several industries significantly gain productivity growth advantage through exporting. Processing-trade firms have lower productivity growth in most of industries. The learning by exporting effect is positively related with firm's capital intensity. The protection policy in the international trade also contributes to the lower productivity growth rate of exporters. Chapter 5 summarizes our results and contributions.

Chapter 1

Introduction

Chapter 1 provides the motivation of this thesis. Since Solow (1956), TFP growth has been considered to be the main driving force for the long-run sustainable growth. The productivity growth is exogenous in the Solow model. Later researches try to find the source of endogenous productivity growth, such as Romer (1986), Romer (1990), and Aghion and Howitt (1992). Romer (1986) studies the increasing marginal productivity of knowledge, which makes the increasing growth rate possible. Romer (1990) also discusses the importance of the number of intermediate inputs to the economic growth. The increase of the number of intermediate inputs is treated as a type of innovation. Aghion and Howitt (1992) examine the role of quality innovation, which serves as the engine of creative destruction. Acemoglu (2001) and Acemoglu and Robinson (2012) emphasize the importance of social institution, for example, the property rights protection law. Young (1998) empirically calculates the relative contribution of TFP in the Four Asian Tigers. For Singapore, the contribution of TFP is found to be around 0. This finding is challenged by Hsieh (2002) using the dual approach.

After the Four Asian Tigers' growth miracle, China has been the leading role in the economic growth. In the past thirty years, the average per-capita gross domestic product (GDP) growth of China is around 10%. There are also some researches that intend to quantify the contribution of TFP to Chinese economy. Young (2003) argues that the average TFP growth is only 1.4% over 1978-1998. However, Zhu (2012) shows that TFP growth is the most important source of China's growth. 78% of the per capita GDP growth is explained by the TFP growth.

With the firm-level data, we can estimate the production function instead of imposing a growth accounting framework. After the productivity of each firm is estimated, we aggregate them to determine sector-level growth.

Chapter 2 estimates the productivity level using three leading methods of production function estimations. They are OLS, the methods developed by Ackerberg, Caves and Frazer (2006) and Blundell and Bond (2000). OLS is inconsistent due to the correlation between factor inputs and productivity level, while ACF and BB can solve this problem. Ackerberg, Caves and Frazer (2006) have a more flexible productivity process while Blundell and Bond (2002) can further distinguish the productivity from the firm's fixed effect. With OLS, ACF and BB estimates, we calculate the productivity growth of each industry and the whole manufacturing sector. The productivity growth calculated using firm-level data can be compared with the productivity growth produced by Zhu (2012).

Then, we intend to quantify the contribution of resource reallocation to the productivity growth, which is emphasized by Zhu (2012). He argues that the market competition forces the less productive firm to exit. This reallocation process improves the productivity of the manufacturing sector. As in Olley and Pakes (1996) and Pavcnik (2002), resource reallocation's contribution to the productivity growth is calculated. Hatingwanger decomposition is also used to quantify the contribution of the entry and exit of firms, as both Brandt, Van Biesebroeck and Zhang (2012) and Ding, Guariglia, and Harris (2016) find that firm's entry and exit promote the productivity growth.

Chapter 3 investigates the role of public infrastructure investment in promoting the productivity growth of the manufacturing firms. Since Aschauer (1989), the return rate to the infrastructure investment has been studied extensively. The public infrastructure capital is treated as a factor of aggregate production function. There is a reverse causality problem with this setting. With a higher GDP, there will be increased public infrastructure investment. At the same time, investment in infrastructure will foster economic growth. Fernald (1999) solves the reverse causality problem by exploring the cross-industry variation in the productivity effect of infrastructure. Röller and Waverman (2001) employ the structure estimation that specifies the demand and supply of telecommunication investment to address the reverse causality problem. But they have the detailed information about telecommunications prices, which usually is unavailable. There are also other econometric problems in the literature, such as the non-stationarity problem in the macro variables and endogeneity between factor inputs and unobserved productivity.

In China, there is a saying: to get rich, build roads first. The development of infrastructure is directly related to the performance of firms. With better infrastructure, the logistics cost will be lower. The inventory level can also go down, as confirmed by Li and Li (2013). If the network of road becomes larger, there should be more market destinations for the products of each firm. The quality and variety of intermediate inputs of each firm may also improve. Based on those potential channels, the productivity of firms is influenced by the infrastructure and its investment.

To address the endogeneity between factor inputs and unobserved productivity, Ackerberg, Caves and Frazer (2006) method will be employed. However, there is another issue in this setting: is the productivity gain a long-run productivity effect or just a short-run Keynesian demand effect? To distinguish those two effects, a constant elasticity of substitution (CES) demand framework will be imposed, as in De Loecker (2011). In this setting, the short-run demand effect of public infrastructure investment is first controlled. Then the quantity productivity can be backed out with this demand system. The quantity productivity gain represents the long-run effect.

Chapter 4 examines the dynamic learning by exporting effect. International trade is generally thought to be productivity-enhancing. Ordinary exporters supply their products not only to the domestic market but also foreign markets. While they face competition from both domestic and foreign peers, they should also have more opportunities to learn from their distributors and customers. Hence, Bernard, Eaton, Jensen and Kortum (2003) conclude that the exporters are generally larger in scale and more productive. Zhu (2012) also argues that trade liberalization leads to higher productivity growth, as the barriers to entry and exit will be reduced and market competition will be fiercer. However, there is no uniform conclusion about Chinese exporters. Lu (2010) argues that the less productive firms will automatically choose to be the exporters to avoid the competition pressure from the domestic firms. Dai, Maitra and Yu (2016) find that the processing-trade firms are less productive than the non-exporters and should be responsible for the unexceptional exporter performance in China. This chapter focuses on the dynamic learning by exporting effect rather than the comparison of the productivity between exporters and non-exporters. The first question is that whether there is a positive learning by exporting effect among Chinese exporters. There are two forces here: the knowledge learned from the foreign market will promote the productivity growth, while the productivity growth may be lower if competition in the foreign market is less fierce, especially for the labor-intensive industries. As in Dai, Maitra and Yu (2016), exporting intensity's influence on the productivity growth will be studied. We want to know whether the learning by exporting effect is positively or negatively related with the exporting intensity. The higher is exporting intensity, the less competitive pressure that exporters face in the Chinese market. Heavily exporting intensive firms tend to be the processing-trade firms, which usually only focus on the production stage of the total value chain. They may have a lower productivity growth than the non-exporters. The roles of capital intensity, ownership and government protection policies will also be examined. Chapter 5 summarizes the results and contributions.

Chapter 2

The evolution and distribution of productivity of Chinese manufacturing firms

2.1 Introduction

The Chinese economy has experienced a rapid growth since 1978. The average growth rate of real GDP over years 1978—2013 is 9.92%. What is the contribution of TFP to the economic assent of China? Young (2003) uses data on the non-agricultural sector of China, providing empirical evidence regarding this question. After some adjustments to the statistics for human capital and the official deflator, the estimated TFP growth rate of the Chinese non-agricultural economy is found to be a mere 1.4% over the 1978-1998 period, while TFP growth rate, computed using the original official data, is 3%. For the 1995-2005 period, Zheng, Bigsten and Hu (2008) find that TFP growth is even lower (0.8%) when the capital share is assumed to be 60%. Brandt and Zhu (2010) find that TFP growth of the non-agricultural sector in the Chinese economy over the 1978-2007 period is 3.22%. There are huge variations in the numbers. Similar results are obtained in studies of Singapore. Hsieh (2002), using the dual approach, finds that Singapore's productivity growth during 1970-1990 is positive, while Young (1998) obtains a small negative number. Del Gatto et al. (2011) argue that, when data availability and computing power improve, more attention should be paid to TFP at the firm level rather than the aggregate and industry levels. Hence, findings based on aggregate level data may conflict with each other, while evidence based on firm-level data is necessary to provide a better understanding of this question.

Academics have also attempted to look into the productivity of Chinese manufacturing. Brandt, Van Biesebroeck and Zhang (2012) construct a reasonable panel data using the firm-level data of separate years provided by the National Bureau of Statistics of China. They mainly rely on the index method to estimate the productivity with value added as the dependent variable, though they also use other methods to check the growth of productivity. When they study the influences of the exiting firms and ownerships, they still use productivity estimated by the index method. Jefferson, Rawski and Zhang (2008) also study TFP, while they use the OLS and fixed effect estimation model to measure the labor coefficient with a constant return to scale assumption. The endogeneity problem between factor inputs and productivity is overlooked in their study, resulting in an inconsistent estimation. Furthermore, they only use the data of the years 1998 and 2005, whereas we believe their conclusion improves with data from the 1998-2007 period. Yu (2015) explores how reductions in tariffs on imported inputs and final goods affect the productivity of large Chinese trading firms, using the proxy and the dynamic panel approaches. Ding, Guariglia, and Harris (2016) also use these two approaches, but they do not compare the findings under the dynamic panel method and the proxy method.

Another disadvantage of studying economic growth with macro-level data is the difficulty of addressing heterogeneity across industries and firms. We can aggregate firm-level data at the industry-level to check for variation across industries. Productivity can be linked to firm characteristics. Firm-level data also enables us to study the reallocation of resources across sectors. The role of resource reallocation in promoting China's economic growth is highlighted in literature, for example, Zhu (2012).

Technical efficiency is also discussed in literature. Charoenrat and Harvie (2014) find that the small and medium sized enterprises in Thailand are relatively technical inefficient. Castiglione and Infante (2014) confirm that information and communication technology have a positive effect on the productivity and technical efficiency. Hailu and Tanaka (2015) study the technical efficiency of the manufacturing firms in Ethiopa. Stochastic frontier analysis is used in the previous two researches.

There are some researches which investigate the role of technological progress and scale efficiency in promoting productivity growth. Margono et al. (2010) find that technological progress and economies of scale bring more cost reduction in the Indonesian banks after Asian economic crisis. Alani (2012) finds that the technological progress brings in economic growth in Uganda. Wanke and Barros (2015) indicate public-private partnerships strongly affect the port scale efficiency in Brazil.

This chapter aims to answer the following three questions, using Chinese manufacturing firm-level data spanning 1998 through 2007. To what extent has Chinese manufacturing growth been driven by TFP growth? What is the contribution of resource reallocation? Which factors explain differences in TFP across firms?

To answer these three questions, the first task is to obtain a measure of productivity, for which the Solow residual is usually used in the literature. The Solow residual can be found after a consistent estimation of the production function. Two streams of literature can be used to obtain a consistent estimation of the production function: the proxy approach and the dynamic panel approach. The proxy approach mainly involves three methods: Olley and Pakes (1996) (OP hereafter); Levinsohn and Petrin (2003) (LP hereafter); and Ackerberg, Caves and Frazer (2006). To control for endogeneity between factor inputs and unobserved productivity, Olley and Pakes (1996) use investment as a proxy for productivity. As firms do not invest every year, Levinsohn and Petrin (2003) prefer to use intermediate inputs as a proxy, while Ackerberg, Caves and Frazer (2006, 2015) also utilize intermediate inputs as a proxy. Ackerberg, Caves and Frazer (2006) detect a collinearity problem in identifying the labor coefficient in OP and LP. All three of these proxy methods rely on an assumption of monotonicity between the proxy variable and unobserved productivity. The advantage of these methods is that the productivity process is more flexible than under the dynamic panel approach. The ACF method is now broadly used in empirical studies that have been published in top journals, such as, De Loecker (2011) and De Loecker (2013). However, the firm heterogeneity problem is not controlled under the proxy method. The dynamic panel production function estimation approach proposed by Blundell and Bond (BB, 2000) can control for heterogeneity. However, this method requires an exactly AR(1) productivity shock. According to Ackerberg, Caves and Frazer (2006), the

BB method is more data-demanding. Ackerberg, Caves and Frazer (2006) hope that economic predictions are insensitive to the estimation methods used. OLS will also be used. We will empirically compare these three methods, which is another motivation for this chapter.

After the production function estimation using these three methods, we calculate TFP growth by industry, and then aggregate the results at the manufacturing sector level. Next, we quantify the contribution of resource reallocation to TFP growth. Finally, we investigate factors that potentially contribute to differences in productivity across firms. The issues considered are fourfold. First, we link productivity performance with firm's entry and exit. Second, we will investigate the productivity of exporters. In 2001, China became a member of the World Trade Organization (WTO). Since then, Chinese firms have encountered lower entry barriers to the international market. Another dimension of the Chinese economy is regional disparity. The coastal provinces are relatively developed compared with other provinces. The economy in the coastal provinces is more market-oriented. Thus, we would expect that firms in the eastern provinces will have higher productivity. Fourth, we will compare the productivity level of state-owned enterprises with that achieved under other ownership types.

Our empirical results can be summarized as follows. The average productivity growth rate is between 3.75% and 5.99%, higher than the 2.85% found by Brandt, Van Biesebroeck and Zhang (2012). The growth rate peaks in 2005. Resource reallocation plays a key role in productivity growth only in the 1998-2002 period. The empirical results show that, the productivity of exiting firms is always lower. New entering firms are more productive. The order of productivity of regions is consistent with expectations. Firms in the coastal provinces have the highest productivity, while firms in the western provinces are least productive. We also find that the state-owned enterprises are the least productive during that period, while foreign internationally owned enterprises are the most efficient.

The results of comparing these three estimation methods are as follows. First, all three methods report the same time trend in the productivity growth rate at the manufacturing sector level, while the BB method yields the highest growth rate. Second, the roles of firm's entry and exit, age, ownership and regional location in explaining the distribution of productivity are generally robust. However, the impact of exporting on productivity is significantly positive under the OLS and BB approach and significantly negative under the ACF approach. We also perform the analysis with three two-digit industries, including the textile industry, the raw chemical material and chemical product industry, and the electronics and telecommunications equipment industry. Exporters are found to be more productive in the textile industry and less productive in the electronics and telecommunications equipment industry. The role of exporting in the raw chemical materials industry is not robust to the production function estimation approaches.

This chapter is organized as follows. Section 2 outlines the estimation methods in detail. Section 3 describes the data and the construction of the variables. Section 4 reports the empirical findings, including productivity growth and the determinants of productivity. Conclusions are presented in Section 5.

2.2 Empirical models

The Olley and Pakes (1996) method is widely used to estimate the productivity of Chinese firms, to name a few, Brandt, Van Biesebroeck and Zhang (2012), Liao, Li and Deng (2013), and Yu (2015). However, the implicit assumption of the OP model is that investment is an increasing function of productivity, which may not apply to Chinese firms during the 1998-2007 period because, during that period, many state-owned enterprises (SOEs) underwent reform. They sold machines and factory buildings to optimize their capital structures or adjust their strategies, while their productivity levels may have increased as a result of the reform process. Even private firms did not adjust their investment in proportion to the increase in productivity, especially in situations that involve adjustment costs, which indicates that investment is at most a non-decreasing function of productivity. The OP method is not the optimal choice to estimate Chinese firms' productivity. Van Biesebroeck (2007, 2008) provides a comparison of estimation approaches, finding that measures of productivity are highly correlated. Based on theoretical criticisms of the OP and LP methods in Ackerberg, Caves and Frazer (2006), we prefer the ACF model.

2.2.1 ACF approach

The ACF method, which uses intermediate inputs as a proxy for productivity, will be the first method employed to obtain a consistent estimation of the production function. Our dependent variable is sales revenue, while the independent variables are labor, intermediate inputs, and capital. We will employ the log-linear model. The model is:

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \omega_{it} + \varepsilon_{it} \tag{2.1}$$

where y, l, k and m represents the log of sales revenue, labor, capital, and intermediate inputs respectively. ω denotes an unobservable productivity, and ε is a random shock to the firm.

Following Ackerberg, Caves and Frazer (2006), capital is a "quasi-fixed" input chosen in period $t-1$. Labor is determined before material and after capital has been chosen. We assume that labor is chosen at $t-0.5$. The intermediate inputs are assumed to be chosen after ω_{it} is realized. In the optimization by the firm, m_{it} is a function of capital, labor and productivity.

$$m_{it} = f(l_{it}, k_{it}, \omega_{it}) \tag{2.2}$$

Ackerberg, Caves and Frazer (2006) assume that this function is invertible, which means that:

$$\omega_{it} = g(l_{it}, k_{it}, m_{it}) \tag{2.3}$$

Thus, unobservable productivity is a function of labor, capital, and materials. Additionally, revenue is also a function of labor, capital, and materials:

$$y_{it} = \phi(l_{it}, k_{it}, m_{it}) + \varepsilon_{it} \tag{2.4}$$

In the first stage, the OLS model, with expansions to the fourth order of labor, capital and intermediate inputs, will be employed to obtain the predicted ϕ.

We obtain the predicted value of ϕ using OLS at the first stage. We can calculate productivity as:

$$\omega_{it}(\beta) = \overset{\wedge}{\phi}_{it} - (\beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it}) \tag{2.5}$$

To obtain a consistent estimation of the coefficients, we rely on the law of motion of productivity, which is assumed to follow a first-order Markov process:

$$\omega_{it} = \rho_1 \omega_{it-1} + \rho_2 \omega_{it-1}^2 + \rho_3 \omega_{it-1}^3 + \rho_4 \omega_{it-1}^4 + \zeta_{it} \tag{2.6}$$

Then, an OLS regression is employed to obtain the innovation to productivity ζ_{it} in equation 2.6. We can subsequently construct the necessary moment conditions, which are given by:

$$E\left(\zeta_{it}\left(\beta_l, \beta_k, \beta_m\right) \ * \begin{bmatrix} l_{it-1} \\ k_t \\ m_{it-1} \end{bmatrix} \right) = 0 \tag{2.7}$$

2.2.2 BB approach

Following Blundell and Bond (2000), we rewrite the production function as follows:

$$y_{it} = \alpha_l l_{it} + \alpha_k k_{it} + \alpha_m m_{it} + \gamma_t + \eta_i + \upsilon_{it} + \xi_{it} \tag{2.8}$$

Compared with the ACF model, the BB model controls for both time fixed effects and firm fixed effects. Now υ_{it} is an autoregressive productivity shock that strictly follows an AR(1) process:

$$\upsilon_{it} = \theta \upsilon_{it-1} + e_{it} \tag{2.9}$$

This implies a dynamic panel model of the production function:

$$\begin{aligned} y_{it} &= \alpha_l l_{it} - \theta \alpha_l l_{it-1} + \alpha_k k_{it} - \theta \alpha_k k_{it-1} + \alpha_m m_{it} - \theta \alpha_m m_{it-1} \\ &\quad + \theta y_{it-1} + \gamma_t - \theta \gamma_{t-1} + \eta_i \left(1 - \theta\right) + e_{it} + \xi_{it} - \theta \xi_{it-1} \end{aligned}$$

After re-parameterization, we obtain:

$$\begin{aligned} y_{it} &= \pi_1 l_{it} + \pi_2 l_{it-1} + \pi_3 k_{it} + \pi_4 k_{it-1} + \pi_5 m_{it} + \pi_6 m_{it-1} \\ &\quad + \pi_7 y_{it-1} + \gamma_t^* + \eta_i^* + e_{it} + w_{it} \end{aligned} \tag{2.10}$$

There are three linear constraints with the following parameters:

$$\begin{aligned} \pi_2 &= -\pi_7 \pi_1 \\ \pi_4 &= -\pi_7 \pi_3 \\ \pi_6 &= -\pi_7 \pi_5 \end{aligned} \tag{2.11}$$

We use the minimum distance method to obtain α_l, α_k, α_m and θ with consistent estimates of $(\pi_1, \pi_2, \pi_3, \pi_4, \pi_5, \pi_6, \pi_7)$.

Ding, Guariglia, and Harris (2016) also employ the BB method. But they directly add observable firm characteristics into the production function, which is unusual in the literature. When they do the estimation, they combine some industries together.

Except for the two estimations, we also use OLS for comparison. Moreover, we segregate the estimation by industry and define productivity to be the Solow residual.

2.3 Data and Variables

In this chapter, we conduct the estimation using firm-level data. The data set, which covers 1998-2007, comes from the Annual Survey of Industrial Firms, conducted by China's National Bureau of Statistics. Firms are either state-owned or non-state-owned, with sales above 5 million RMB. In 1995 and 2004, China's National Bureau of Statistics conducted a national industry census. Brandt, Van Biesebroeck and Zhang (2012) produce comparisons between census data and the data in this data set. For 2004, 80% of all industrial firms excluded from this data set account for only a small fraction of economic activity. Employment in these small firms accounts for a mere 28.8% of the industrial workforce, while these firms produce 9.3% of the output and 2.5% of exports. The data for 1995 has characteristics similar to the data for 2004. Output produced by firms in this data set accounts for more than 90% of Chinese industrial output. Thus, conclusions based on this data set can be used to formulate some policy recommendations.

As the data is collected on a yearly basis, we must transform the database into a panel data set by allocating the data to each individual firm, using the firm's ID, names of legal representatives, phone number with city code, year of founding, geographic code, industry code, name of town and name of main product, following the methodology of Brandt, Van Biesebroeck and Zhang (2012). We also use the method of Brandt, Van Biesebroeck and Zhang (2012) to calculate the real capital stock, using information about the book value of fixed assets and the birth year. The depreciation rate is set at 9%. The number of employees is used to represent labor. Intermediate inputs are defined as inputs minus financial costs. As we conduct the analysis at the 2-digit industry level, we require the 2-digit level output and input deflators. Based on the 4-digit industry output and input benchmark deflators provided by Brandt, Van Biesebroeck and Zhang (2012), we take a simple average of them to obtain the corresponding 2-digit industry deflator.

Both *entry* and *exit* are denoted as dummy variables. If a firm is observed in the data set for the first time, the value of the *entry* dummy is 1. Otherwise, it is 0. We use the code of Yasar, Raciborski and Poi (2008) to define *exit*, a dummy variable indicating whether a firm will exit the market in year t+1[1].

Following Jefferson, Rawski and Zhang (2008), we divide China into four regions: coastal, central, western, and northeastern. The coastal region includes Beijing, Fujian, Guangdong, Hainan, Hebei, Jiangsu, Shanghai, Shandong, Tianjin, and Zhejiang; the northeast region includes Heilongjiang, Jilin, and Liaoning; the central provinces are Anhui, Guangxi, Henan, Hubei, Hunan, Inner Mongolia, Jiangxi, and Shanxi; the western provinces consist of Chongqing, Gansu, Guizhou, Ningxia, Qinghai, Shaanxi, Sichuan, Xinjiang, Tibet, and Yunnan.

Exporting is also a dummy variable. We define ownership by registration type, including SOE, collective-owned enterprise (COE), domestic private-owned enterprise (DPE), Hong Kong, Macau or Taiwan owned enterprise (HMT), foreign international owned enterprise (FIE), and other types (Others). Table 2-1 provides descriptions of the variables.

[1] The exit and entry are to indicate whether this firm is in this sample or not. We do not have the detailed information about whether the exiting firm really stops its business. But the entry dummy shows when the firm becomes above-scale according to the China NBS criterion.

2.4 Empirical Findings

2.4.1 Production function coefficients

Table 2-2 reports the estimated coefficients by industry. The coefficients for labor and capital are relatively small, below 0.1 in most of cases. The BB estimates for labor and capital are generally larger than the OLS and ACF estimates. The coefficients for intermediate inputs are relatively large, usually above 0.8 in the OLS and ACF estimates. This reflects the low ratio of value-added in Chinese manufacturing industries. Yu (2015) also reports the estimation results of the production function coefficients, using the same data set and mainly following the method of Olley and Pakes (1996). The overall pattern is very similar: the labor and capital coefficients in Yu (2015) are also very small, while the materials coefficient is quite large. A few coefficients in the BB and ACF estimates are negative, which may result from the increased difficulty of calculating the convergence point, even though the BB and ACF estimates are consistent in theory. The BB method is sensitive to measurement error, which may also result in negative coefficients.

2.4.2 Productivity growth

The productivity of manufacturing firms always grows, as is confirmed by the pattern exhibited in Figure 2-1. The growth of TFP in each firm is defined as the difference between the log of productivity and its lag. TFP growth in the manufacturing sector is the sum of the TFP growth rates of individual firms, using firms' sales revenues as weights. In Figure 2-1, the dashed line represents the growth of productivity, based on the OLS estimates; the solid and dotted lines denote the growth of productivity, based on the ACF and BB estimates. The three lines indicate similar time trends, while the BB estimate yields the highest growth rate. This is confirmed by the findings in Table 2-3. The average growth rate over the 1998-2007 period is 5.99%, according to the BB estimates, while the number is only 3.75%, according to the ACF estimates. The OLS estimates produce a number between the two aforementioned numbers: 4.16%. The difference in productivity growth may originate from the larger materials coefficient, obtained by the ACF estimates. TFP growth in the Chinese economy, reported by Zhu (2012) for the same period, is 4.68%, which is quite close to our number. In the meta-analysis of Tian and Yu (2012), productivity growth in the Chinese economy is only 2% since 1978. There are fluctuations in TFP growth across the years. For 1999 and 2000, the growth rate is stable. However, there is a large drop in 2001. After that, the growth rate increases through 2005. Beginning in 2006, the growth rate falls again. In addition, in 2007, the weighted productivity growth remains at approximately 3%, based on the OLS approach.

Figure 2-2 depicts TFP growth in three industries: textiles, raw chemical materials and chemical products, and electronics and telecommunications equipment. For all three industries, the time patterns of productivity growth, based on the OLS, ACF and BB estimates, are consistent with each other. However, for the textiles industry, productivity growth based on the OLS estimates is the highest, which is different from the pattern found in the manufacturing sector.

Table 2-3 provides detailed information about TFP growth in each industry, including the mean, standard deviation, maximum value and minimum value of productivity growth. The information suggests significant variation in productivity growth across industries. In the petroleum industry and the nonferrous metals industry, average productivity growth rates, based on the OLS and ACF approaches, are negative. The medical and pharmaceutical industry, the nonmetal mineral industry, the plastics industry, the electronics and telecommunications industry and the timber bamboo industry are found to have the highest average productivity growth rates. The petroleum industry, the nonferrous metals industry and the electric industry have the lowest average productivity growth rates. Among the 29 industries considered, the productivity growth rates of 17 industries exhibit the following order: BB > OLS > ACF. Among the other 12 industries, 5 industries exhibit the following order: OLS > ACF.

Table 2-4 reports the standard deviation of productivity across years. For the whole manufacturing sector, the dispersion of productivity levels generally declines significantly under the OLS and ACF estimates. In these three industries, productivity levels also exhibit a trend toward convergence during the 1998-2007 period under all three estimation methods[2]. The findings suggest that highly productive firms experience relatively lower productivity growth than less productive ones. The exit of unproductive firms and the entry of new firms also

[2] We also find that there is a significantly negative relationship between the standard deviation of productivity and years at the 4-digit industry level, where ACF and OLS are used to estimate the production function.

contribute to this change.

2.4.3 The role of resource reallocation

To examine the contribution of resource reallocation to productivity growth, we decompose the weighted industry-level productivity measure into two parts: the unweighted productivity measure and the covariance between a firm's productivity and its revenue share, following Olley and Pakes (1996) and Pavcnik (2002). The covariance represents the contribution of the reallocation of resources from low-productivity firms to high-productivity firms within an industry. Table 2-5 reports the decomposition results for the three industries. The numbers in 1998 are always zero, as 1998 serves as a benchmark year. Other numbers can be treated as measures of productivity growth relative to the base year, 1998.

In the textile industry, the OLS estimates indicate that reallocation mainly occurred in 1999-2002. The contribution of reallocation has decreased over the years, and since 2003, the contribution of reallocation has been less than in 1998. In the raw chemical material industry, the ACF estimate reveals productivity growth in 2002 to be 9.0% higher than in 1998, with reallocation contributing 4.5% of this growth. In particular, the contribution of reallocation increases through 2002, then decreases, while the BB estimates indicate a relatively lower contribution of reallocation to productivity growth. In the electronics and telecommunications industry, the contribution of reallocation reaches a peak in 2003, then approaches zero in 2006, based on the ACF and OLS estimates.

In comparing these three industries, we can conclude that reform and reallocation occurred earlier in the textile industry than in the other industries. Productivity in the electronics and telecommunications industry has increased at the fastest pace.

2.4.4 Productivity determinants

After obtaining the three measures of productivity, we pool all the industries together to investigate what factors drive productivity. The OLS regression is used in this section. The robust standard error is employed to control for heterogeneity.

Gross effect

Tables 2-6, 2-7 and 2-8 report the gross effects of the determinants that we are interested in, including firm entry and exit, firm age, exporting status, firm location and ownership of the firm.

The findings for the gross effects under the OLS estimates are the same as under the ACF estimates, if we focus only on the signs and order of the coefficients, not on the absolute values of the coefficients. The gross effect of the entry dummy is significantly positive. Previous studies, such as Brandt, Van Biesebroeck and Zhang (2012) and Jefferson et al. (2008), show that newly entering firms contribute to productivity growth. Our results are consistent with those findings. After years of expansion, firms become more productive than when they first appear in the data set. Exiting firms are relatively less productive, as shown in the second column, a result that is consistent with Pavcnik (2002) and Brandt, Van Biesebroeck and Zhang (2012).

On average, exporters have higher productivity than non-exporters, as shown in the third column of Table 2-6. This finding is consistent with Baldwin and Gu (2003) and the stylized facts about exporters, as summarized by Bernard et al. (2003).

The fourth column focuses on regional disparities, with the central regions providing a baseline. Businesses located in the coastal regions are found to have the highest productivity; firms in the northeastern provinces have higher productivity than those in the central areas, while firms located in the western regions lag somewhat behind those in the central provinces. Hence, firms in the western part of China exhibit poorer performance than those in the central region. The economy of the coastal region is more market-oriented and open, which forces firms in that region to achieve higher productivity growth to retain their competitive advantage. Fan, Kanbur and Zhang (2011) find that international trade and financial decentralization have significant effects on regional disparities. Firms in the central region can learn from their peers in the east. Jefferson, Rawski and Zhang (2008) find that TFP among central-region firms is higher than that among firms in the northeast. The econometric inconsistency problem in their paper may contribute to this difference in order. Fu, Zhu and Gong (2009) divide China into three regions—east, central and west—that follow the order of productivity levels.

The productivity ordering by ownership type is as follows: FIE>HMT>DPE>OTHER>COE, where SOE is a reference point. After years of reform, SOEs still exhibit the lowest productivity levels, although Zhang et al. (2002) find that SOEs experienced higher productivity growth during 1996-1998. FIEs and HMTs generally have technological and marketing advantages over other firms.

The gross effects analysis, using BB estimates, differs only with respect to the order of the region dummies, while the magnitude is usually 1.5 times that obtained under the OLS and ACF estimates. The order of the western provinces and central provinces now is reversed: firms in the western regions have significantly higher productivity than those in central areas. If we accept that R-squared represents the level of explanatory power, then ownership is the most important factor affecting productivity levels.

Net effect

We now identify the net effect of these determinants. In columns 1, 4 and 7 of Table 2-9, the positive relationship between firm entry and productivity is confirmed after controlling for industry composition and year. In column 3 of Table 2-9, the magnitudes of the entry dummies are very small, even insignificantly different from zero when other factors are controlled for. The ACF and BB estimates produce similar patterns, although Table 2-10 reveals that approximately two-thirds of productivity growth is driven by newly entering firms, according to the Haltiwanger decomposition. Based on the formula in Haltiwanger (1997) and previous results, we may conclude that the Haltiwanger decomposition indicates the gross contribution of firm entry to productivity growth is large. Exiting firms are found to be -4.5%, -2.2% and 7.4% less productive under the OLS, ACF and BB estimations, respectively. Hence, firm's exit plays a key role in productivity growth, as the exit of firms is directly related to resource reallocation, as highlighted in Song, Storesletten and Zilibotti (2011) and Zhu (2012).

The net effect of exporting on firm productivity is significant but slightly negative, based on the ACF estimates, while the OLS and BB estimates yield significant positive coefficients for the exporting variable. It is clear that the net effect of exporting should be checked, using different estimation methods. Lu (2010) also finds that Chinese exporters' productivity is unexceptional in labor-intensive industries.

Table 2-9 indicates that the productivity advantage of firms in the coastal region is robust, although the magnitude of the coefficient is smaller than the gross effect. Another reason for the productivity advantage of firms in the coastal region is that local governments in the coastal region are more willing to provide services to attract investment and manage larger fiscal budgets, as noted by Jin, Qian, and Weingast (2005). Infrastructure in the coastal provinces is better, which can reduce logistical costs and lead to higher-quality intermediate inputs. Firms in the northeastern region rank second, while the northeastern dummy becomes insignificant. The coefficient for the western region dummy is consistently negative across all three estimates. Under the OLS and ACF estimates, the productivity advantage of firms in the central provinces, compared with firms in the northeastern provinces, is not significant, while it is significant under the BB estimates.

FIEs are found to be the most productive firms, based on all three estimates, which is consistent with the findings of Jefferson et al. (2000), Jefferson et al. (2003) and Sun and Hong (2011). The order of HMTs relative to other private ownership types is not robust to the estimation method. SOEs are always the least productive, which is consistent with the results of Su and He (2012). They find that state ownership is significantly negatively related to productive efficiency. Lin et al. (1998) argue that the corporate governance problem and social burdens may explain the low efficiency of SOEs. Lin and Tan (1999) further note the soft budget constraint problem of SOEs, which can also lead to lower productivity. Hsieh and Klenow (2009) believe the reason for the low efficiency of SOEs is that they do not fully utilize their capital.

2.4.5 Typical industries analysis

The previous section has focused on the whole manufacturing sector. We now turn to an analysis of three typical industries. Table 2-11 shows the extent of heterogeneity across different industries.

For the textile industry, the net effect of firm entry, based on the OLS estimates, is significantly negative, while it is significantly positive when based on the ACF and BB estimates. The net effect of firm exit is significantly negative only under the OLS estimates. The net effect of exporting is always significantly positive, based on all three methods. HMTs have the highest productivity.

In the raw chemical materials industry, new entrants generally possess higher productivity under the ACF and BB estimates. The productivity advantage persists. The exporting effect is insignificant, based on the ACF estimates, while it is significantly negative under the BB estimates. The productivity advantage of firms in the coastal regions is not found to be robust. HMTs also exhibit the highest productivity.

In the electronics and telecommunications industry, firm's entry is positively related to productivity, based on the ACF and BB estimates. The exit of firms also contributes strongly to productivity growth. The exporting effect is always significantly negative. In Ding, Guariglia, and Harris (2016), 17 of 26 industries are found to exhibit a negative exporting effect. FIEs and firms under other types of ownership experience a productivity premium.

2.4.6 Robustness checks

In this section, we conduct robustness checks of the above findings for the whole manufacturing sector, with the results presented in Table 2-9. First, we modify the productivity process to a linear form, a second-order polynomial form, and a third-order polynomial form in the ACF estimation, obtaining three estimates of productivity, respectively. We then use difference general method of moment (GMM) under the constant returns to scale assumption to obtain another set of coefficients. Table 2-12 presents the results.

The net effects of entry and exit of firms are robust to the changes in the productivity process in the ACF model: new entrants are more productive, while exiting firms are less productive. Under difference GMM, the net effect of firm's entry is positive but insignificant. Firm age is found to be significantly negative, with a small absolute value, according to all four estimates. Except for the ACF estimates with a linear form productivity process, the net contribution of exporting is significantly negative, which suggests that a linear form productivity process may be too simple.

The ordering by net effect of the regional dummies is similar to the findings for the ACF estimate, except in the case of the third-order polynomial process: Coastal > Northeastern > Central > Western. The net effect of the northeastern dummy is not significantly larger than that of the central region dummy under the third-order polynomial process of the ACF estimate. As for the ownership variable, FIEs are still found to be the most productive firms, while SOEs remain the least productive.

The last robustness check we do is to examine whether our results are sensitive to the 9% depreciation rate. We only change the depreciation rate to be 5%, while the specifications of the estimations remain the same as the main body. The results are reported in Table 2-13. The results of ACF and OLS models are quite similar with that in Table 2-9. For BB model, the entry dummy now is significantly negative.

2.5 Conclusion

Since 1978, the Chinese economy has enjoyed a high growth rate, especially during the period from 1998 to 2007. We are interested in the contribution of TFP to this high economic growth rate. As analysis of aggregate-level data generates varying findings, we employ firm-level data instead. To obtain a proper measure of productivity, proxy method and dynamic panel production function estimation method are used. The proxy approach has a more flexible production function, while the dynamic panel approach can control for firm heterogeneity. The OLS estimation serves as a benchmark.

We first estimate the production function before calculating productivity as the Solow residual. Next, we examine factors that may affect productivity and its growth rate, including firm entry and exit, exporting activities, ownership type, and region. We find that exporters' productivity advantage relative to non-exporters is sensitive to the production function estimation method used. The ordering of productivity levels between central and northeastern regions exhibits similar problems.

For Chinese manufacturing firms, we also report some robust findings. First, productivity always grows over the 1998-2007 period, based on all three estimates, with the growth rate relatively low in 2001. Second, we find that exiting firms have lower productivity, while the net effect on productivity of newly entering firms is positive. Third, we find that firms in the coastal provinces have the highest productivity, while those in the western regions remain the least productive. Fourth, SOEs are less productive than firms under other ownership types, while foreign ownership is associated with higher levels of TFP. Finally, we find that firm age is significantly and negatively related to productivity, although the magnitude of the effect is close to zero. The role of reallocation in promoting productivity growth in the manufacturing sector is significant only in 1998-2002. We confirm that there is heterogeneity across industries. Our results suggest that future research in this area should consider more than one production function estimation method to check the robustness of findings.

One limitation of the study is that we show only correlations between productivity and its potential determinants. It will be of future interest to explore possible causality between them. Theoretical econometric papers are also needed to provide more insight into these issues.

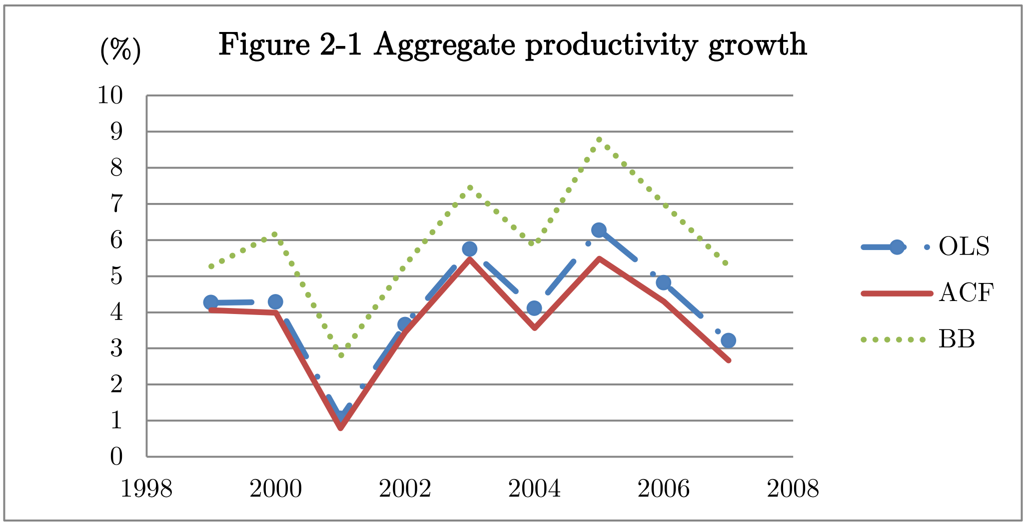


Figure 2-1 Aggregate productivity growth

Note: 1. This figure reports revenue-weighted aggregate productivity growth of all manufacturing industries.

2. OLS, ACF and BB represent productivity estimates based on OLS, Ackerberg, Caves and Frazer (2006), and Blundell and Bond (2000) approaches, respectively.

Figure 2-2a Productivity growth: textile

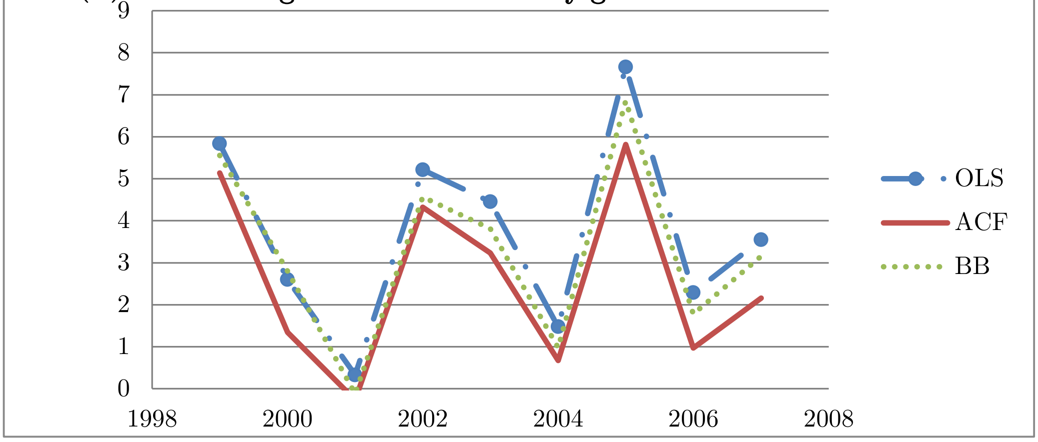


Figure 2-2b Productivity growth: raw chemical materials

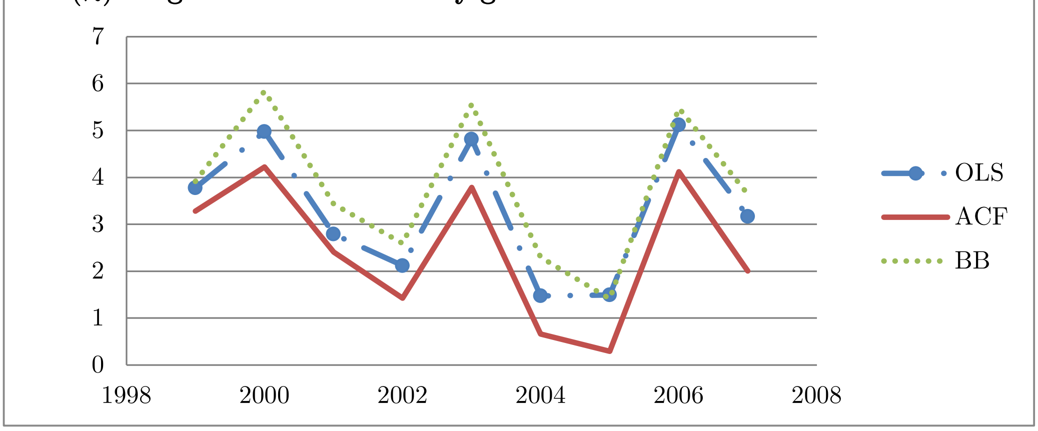
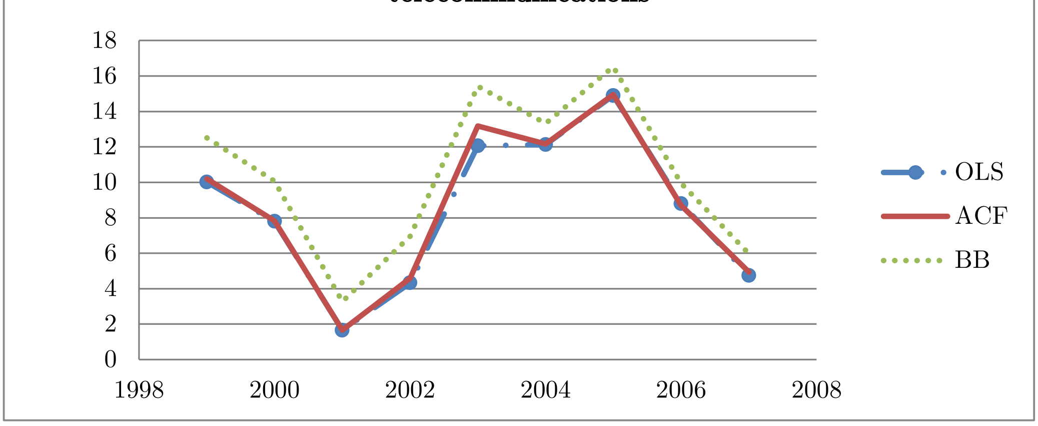


Figure 2-2c Productivity growth: electronic and telecommunications



Note: 1. Figures 2-2a, 2-2b and 2-2c report revenue-weighted productivity growths of industries of textile, raw chemical materials, and electronic and telecommunications equipment, respectively.

2. For the definition of OLS, ACF and BB, please refer to Figure 1.

Table 2-1 Summary statistics of variables

Symbol	Definition and variables	Unit	Mean	Std. D	Form in regression	# of Obs.
l	Number of employees		4.739	1.165	log	2,019,897
m	Intermidiate input minus financial costs	1000 yuan	9.477	1.449	log	2,004,491
k	Capital stock following Brandt et al. (2012	1000 yuan	8.453	1.658	log	2,014,493
y	Revenues	1000 yuan	9.789	1.432	log	2,010,324
	Entry	dummy	0.187	0.390		2,049,297
	Exit	dummy	0.104	0.306		2,049,297
	Exporting	dummy	0.269	0.443		2,049,297
	Regional variables:					
	Central	dummy	0.175	0.380		2,049,297
	Costal	dummy	0.677	0.468		2,049,297
	Western	dummy	0.084	0.277		2,049,297
	Northeastern	dummy	0.064	0.245		2,049,297
	Ownership variables:					
	SOE	dummy	0.118	0.322		2,049,297
	COE	dummy	0.120	0.325		2,049,297
	DPE	dummy	0.359	0.480		2,049,297
	HMT	dummy	0.108	0.310		2,049,297
	FIE	dummy	0.098	0.297		2,049,297
	OTHER	dummy	0.197	0.398		2,049,297

Data source: National Bureau of Statistics of China over years of 1998-2007.

Table 2-2 Production function estimation

Industry	OLS β_l	OLS β_k	OLS β_m	ACF β_l	ACF β_k	ACF β_m	BB β_l	BB β_k	BB β_m	# of obs.
13	0.054	0.040	0.892	0.043	0.035	0.910	0.111	-0.007	0.932	122,720
14	0.046	0.047	0.910	0.006	0.051	0.938	0.134	0.035	0.909	48,640
15	0.053	0.054	0.900	-0.063	0.055	0.998	-0.090	0.106	0.848	33,534
16	0.119	0.214	0.785	0.620	0.251	0.542	0.404	0.401	0.541	2,397
17	0.038	0.032	0.888	0.002	0.014	0.979	0.064	0.161	0.824	170,680
18	0.103	0.043	0.823	0.162	-0.014	0.893	0.112	0.073	0.824	95,148
19	0.082	0.027	0.875	0.070	0.008	0.940	0.160	0.140	0.685	47,176
20	0.030	0.039	0.882	0.133	-0.032	0.982	0.040	0.281	0.771	42,771
21	0.087	0.039	0.872	0.067	0.025	0.923	0.159	0.009	0.617	22,984
22	0.011	0.047	0.905	0.070	0.078	0.835	0.092	0.164	0.789	58,947
23	-0.006	0.104	0.890	0.222	0.040	0.845	-0.133	0.387	0.565	41,749
24	0.071	0.056	0.843	0.095	0.026	0.905	0.175	-0.040	0.529	26,066
25	0.059	0.061	0.855	0.129	0.044	0.836	0.015	0.214	0.680	17,400
26	0.031	0.054	0.876	0.017	0.031	0.938	0.161	0.064	0.823	144,141
27	0.000	0.092	0.883	0.088	0.146	0.764	0.152	0.152	0.551	41,182
28	0.027	0.032	0.916	0.006	0.018	0.957	0.214	0.022	0.766	10,009
29	0.043	0.050	0.870	-0.006	0.028	0.971	0.439	0.439	0.439	23,516
30	0.050	0.048	0.863	0.060	0.063	0.856	-0.005	0.054	0.869	92,200
31	-0.004	0.048	0.920	0.088	0.157	0.810	0.005	0.079	0.901	169,436
32	0.052	0.039	0.897	0.051	0.013	0.946	0.098	0.167	0.657	47,344
33	0.085	0.030	0.871	-0.010	0.013	0.953	0.026	0.045	0.709	35,214
34	0.054	0.047	0.869	0.062	0.031	0.923	0.017	0.082	0.797	107,054
35	0.021	0.045	0.893	-0.011	0.039	0.950	0.071	0.034	0.704	149,652
36	0.004	0.045	0.904	0.068	0.076	0.824	0.253	0.285	0.524	82,886
37	0.054	0.049	0.874	0.215	-0.028	0.891	0.184	0.149	0.654	94,958
39	0.066	0.042	0.866	0.051	0.038	0.903	-0.089	0.173	0.758	117,375
40	0.076	0.050	0.858	0.052	0.162	0.779	0.119	0.170	0.657	65,487
41	0.038	0.053	0.852	0.097	0.011	0.891	0.070	-0.008	0.240	27,950
42	0.080	0.042	0.847	0.081	0.038	0.868	0.226	0.198	0.642	38,510

Note: 1.For the definition of OLS, ACF and BB, please refer to Figure 2-1.

2. Number of observations refers to number of observations used in OLS estimation of production function.

Table 2-3 Annual aggregate productivity growth during 1999-2007 (%)

Ind code	Industry	OLS average (1)	OLS std (2)	OLS max (3)	OLS min (4)	ACF average (5)	ACF std (6)	ACF max (7)	ACF min (8)	BB average (9)	BB std (10)	BB max (11)	BB min (12)
	all-industry	**4.16**	1.51	6.27	1.06	**3.75**	1.43	5.48	0.79	**5.99**	1.69	8.79	2.78
13	Food processing	3.14	4.71	7.91	-6.31	2.90	4.78	7.89	-6.72	2.60	4.80	7.72	-7.17
14	Food manufacturing	3.12	3.05	6.89	-1.89	2.80	3.06	6.61	-2.14	2.71	3.13	6.88	-2.34
15	Beverage	3.14	2.70	8.08	-0.37	2.16	2.84	7.89	-1.57	4.20	3.12	8.75	0.23
16	Tobacco	1.97	3.45	7.07	-2.23	4.02	3.58	9.30	-1.50	3.39	3.71	7.99	-1.59
17	Textile	3.71	2.31	7.66	0.33	2.60	2.14	5.81	-0.26	3.26	2.21	6.85	-0.12
18	Garments and fiber	4.55	2.08	8.15	1.05	3.70	1.90	6.44	0.28	4.10	2.00	7.40	0.65
19	Leather, furs	3.33	1.11	4.82	0.81	2.46	1.07	3.96	0.13	4.79	1.57	6.54	2.05
20	Timber, bamboo	10.90	9.28	23.01	-4.89	9.92	9.71	23.17	-5.83	9.32	8.28	20.26	-5.07
21	Furniture	5.95	3.75	13.92	1.14	5.48	3.93	13.88	0.59	10.12	3.30	16.70	5.63
22	Papermaking and paper	5.24	3.10	12.50	1.46	5.71	3.06	12.82	1.82	5.30	2.95	12.00	1.60
23	Printing	4.47	3.53	8.50	-2.30	4.70	3.17	8.14	-1.80	6.51	3.49	10.75	-0.38
24	Cultural, educational	4.92	3.08	10.19	0.62	4.24	3.00	9.17	0.16	9.65	4.06	17.73	4.26
25	Petroleum	-1.92	5.43	4.29	-11.83	-1.52	5.44	4.36	-11.35	0.59	5.39	7.79	-9.55
26	Raw chemical materials	3.30	1.45	5.12	1.47	2.47	1.48	4.22	0.29	3.80	1.57	5.84	1.41
27	Medical and pharmaceutica	6.30	2.19	9.44	2.82	6.88	2.02	10.34	3.52	7.68	2.12	12.00	4.41
28	Chemical fiber	2.08	6.15	10.09	-8.69	1.54	6.28	9.59	-9.87	4.11	5.95	12.82	-4.55
29	Rubber	4.71	2.64	7.51	0.69	3.44	2.52	6.05	-0.26	10.31	4.38	18.34	1.91
30	Plastic	6.44	3.37	13.96	2.25	6.30	3.34	13.77	2.21	6.71	3.39	14.26	2.38
31	Nonmetal mineral	6.42	4.09	10.68	0.64	6.78	3.90	10.82	1.32	6.40	4.03	10.59	0.69
32	Ferrous metals	2.17	4.50	9.71	-4.24	1.37	4.73	9.34	-5.44	5.84	3.78	11.17	0.43
33	Nonferrous metals	-0.94	6.44	7.55	-10.24	-2.25	7.17	7.65	-13.14	3.05	4.43	8.03	-3.37
34	Metal products	3.41	0.91	4.60	1.92	2.56	0.79	3.66	1.25	4.57	1.21	5.89	2.37
35	Ordinary machinery	3.25	1.42	6.14	0.78	2.30	1.29	4.93	0.04	6.94	2.38	11.61	3.41
36	Special purpose equipment	3.91	2.14	6.47	0.30	4.81	2.06	7.25	1.24	7.48	2.09	9.88	4.32
37	Transport	4.05	2.34	6.56	-0.34	3.32	1.98	5.45	-0.59	7.04	2.73	10.38	3.76
39	Electric	1.47	2.41	5.26	-2.29	0.85	2.57	4.71	-3.19	3.34	2.07	6.65	0.24
40	Electronic and telecom	8.49	4.30	14.90	1.66	8.69	4.40	14.95	1.67	10.44	4.45	16.52	3.28
41	Instruments, meters	4.98	1.92	9.74	3.21	4.08	1.84	8.68	2.49	17.16	3.98	22.23	9.27
42	Other manufacturing	3.65	1.80	5.31	0.57	3.32	1.76	5.09	0.32	3.92	2.13	6.24	0.80

Note: For the definition of OLS, ACF and BB, please refer to Figure 2-1.

Table 2-4 Dispersion of productivity

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Manufacturing										
OLS	0.577	0.556	0.529	0.517	0.558	0.444	0.400	0.381	0.382	0.399
ACF	0.608	0.585	0.556	0.544	0.582	0.478	0.443	0.421	0.423	0.440
BB	1.185	1.179	1.178	1.188	1.214	1.169	1.159	1.161	1.160	1.172
Textile										
OLS	0.560	0.505	0.499	0.473	0.483	0.384	0.298	0.280	0.274	0.243
ACF	0.579	0.516	0.510	0.487	0.497	0.401	0.315	0.293	0.285	0.253
BB	0.588	0.536	0.531	0.504	0.510	0.414	0.349	0.325	0.319	0.294
Raw chemical materials										
OLS	0.503	0.509	0.494	0.473	0.502	0.419	0.347	0.315	0.335	0.325
ACF	0.518	0.520	0.503	0.480	0.508	0.428	0.355	0.318	0.340	0.332
BB	0.524	0.524	0.508	0.488	0.511	0.431	0.365	0.335	0.353	0.340
Electronic and telecommunications										
OLS	0.639	0.584	0.560	0.522	0.501	0.426	0.533	0.399	0.383	0.360
ACF	0.650	0.606	0.580	0.548	0.525	0.454	0.543	0.423	0.406	0.379
BB	0.684	0.660	0.626	0.593	0.567	0.504	0.546	0.457	0.441	0.406

Note: The numbers in this table are the standard deviations of productivity.

Table 2-5 Decomposition of aggregate productivity growth: 3 industries

		OLS			ACF			BB		
		Aggregate	Unweighted	Covariance	Aggregate	Unweighted	Covariance	Aggregate	Unweighted	Covariance
Industry	year	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Textile	1998	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	1999	0.050	0.024	0.026	0.040	0.019	0.021	0.041	0.025	0.016
	2000	0.067	0.048	0.019	0.045	0.030	0.014	0.066	0.065	0.002
	2001	0.055	0.048	0.007	0.026	0.023	0.003	0.069	0.089	-0.020
	2002	0.095	0.089	0.006	0.057	0.058	-0.001	0.113	0.140	-0.027
	2003	0.121	0.129	-0.008	0.073	0.091	-0.017	0.142	0.192	-0.049
	2004	0.107	0.147	-0.040	0.063	0.106	-0.043	0.171	0.256	-0.085
	2005	0.176	0.208	-0.032	0.115	0.156	-0.041	0.226	0.302	-0.076
	2006	0.185	0.220	-0.035	0.117	0.162	-0.045	0.240	0.321	-0.082
	2007	0.215	0.253	-0.038	0.136	0.185	-0.050	0.275	0.359	-0.084
Raw chemical materials	1999	0.025	0.012	0.013	0.014	0.011	0.004	0.006	0.016	-0.010
	2000	0.082	0.048	0.034	0.057	0.040	0.017	0.081	0.066	0.015
	2001	0.105	0.061	0.044	0.074	0.046	0.028	0.119	0.097	0.023
	2002	0.127	0.068	0.058	0.090	0.046	0.045	0.153	0.118	0.035
	2003	0.176	0.131	0.045	0.126	0.103	0.023	0.217	0.191	0.026
	2004	0.175	0.136	0.039	0.117	0.103	0.014	0.244	0.227	0.017
	2005	0.167	0.136	0.031	0.101	0.097	0.004	0.240	0.224	0.016
	2006	0.198	0.176	0.022	0.126	0.133	-0.007	0.287	0.273	0.014
	2007	0.215	0.195	0.020	0.136	0.144	-0.008	0.319	0.301	0.018
Electronic and telecommu	1999	0.059	-0.011	0.070	0.068	-0.010	0.078	0.106	0.001	0.105
	2000	0.144	0.048	0.095	0.151	0.057	0.094	0.218	0.084	0.133
	2001	0.130	0.041	0.089	0.151	0.056	0.095	0.247	0.093	0.154
	2002	0.120	0.070	0.050	0.147	0.091	0.056	0.254	0.138	0.116
	2003	0.243	0.139	0.104	0.296	0.169	0.126	0.428	0.234	0.194
	2004	0.393	0.312	0.081	0.449	0.359	0.090	0.585	0.403	0.182
	2005	0.465	0.437	0.029	0.511	0.472	0.039	0.643	0.525	0.118
	2006	0.545	0.539	0.006	0.583	0.573	0.010	0.718	0.633	0.085
	2007	0.576	0.610	-0.034	0.609	0.648	-0.038	0.741	0.712	0.028

Note: 1. The decomposition is based on Olley and Pakes (1996) and Pavcnik (2002).
2. For the definition of OLS, ACF and BB, please refer to Figure 2-1.
3. The numbers in 1998 are always 0.

Table 2-6 Gross effect of determinants of productivity: OLS

Dependent variable: productivity	OLS (1)	(2)	(3)	(4)	(5)	(6)
Entry (t_0)	0.031***					
	(0.001)					
Exit		-0.106***				
		(0.002)				
Age			-0.000***			
			(0.000)			
Exporting				0.111***		
				(0.001)		
Region:						
Costal					0.106***	
					(0.001)	
Western					-0.053***	
					(0.002)	
Northeastern					0.035***	
					(0.002)	
Ownership:						
COE						0.158***
						(0.002)
DPE						0.284***
						(0.002)
HMT						0.317***
						(0.002)
FIE						0.359***
						(0.002)
OTHER						0.222***
						(0.002)
Observations	1,977,126	1,977,126	1,976,355	1,977,126	1,977,126	1,977,126
R-squared	0.001	0.004	0.002	0.011	0.014	0.043

Notes: 1.Robust standard errors are reported in parentheses. The stars, *, ** and *** indicate the significance level at 10%, 5% and 1%, respectively.
2. COE stands for collective owned enterprises,
DPE for domestic private-owned enterprises,
HMT for HongKong, Macau or Taiwan owned enterprises,
FIE for foreign-invested enterprises,
OTHER for other ownership types.
3. The baseline group for region is Central and the baseline group for ownership is SOE.

Table 2-7 Gross effect of determinants of productivity: ACF

Dependent variable: productivity	ACF (1)	(2)	(3)	(4)	(5)	(6)
Entry (t_0)	0.044***					
	(0.001)					
Exit		-0.079***				
		(0.002)				
Age			-0.000***			
			(0.000)			
Exporting				0.046***		
				(0.001)		
Region:						
Costal					0.077***	
					(0.001)	
Western					-0.041***	
					(0.002)	
Northeastern					0.047***	
					(0.002)	
Ownership:						
COE						0.108***
						(0.002)
DPE						0.222***
						(0.002)
HMT						0.242***
						(0.002)
FIE						0.300***
						(0.002)
OTHER						0.189***
						(0.002)
Observations	1,977,126	1,977,126	1,976,355	1,977,126	1,977,126	1,977,126
R-squared	0.001	0.002	0.001	0.002	0.006	0.025

Notes: 1.Robust standard errors are reported in parentheses. The stars, *, ** and *** indicate the significance level at 10%, 5% and 1%, respectively.
2. For the definition of COE, DPE, HMT, FIE and OTHER, please refer to Table 2-6.
3. The baseline group for region is Central and the baseline group for ownership is SOE.

Table 2-8 Gross effect of determinants of productivity: BB

Dependent variable: productivity	BB (1)	(2)	(3)	(4)	(5)	(6)
Entry (t_0)	0.059***					
	(0.002)					
Exit		-0.185***				
		(0.003)				
Age			-0.000***			
			(0.000)			
Exporting				0.223***		
				(0.002)		
Region:						
Costal					0.324***	
					(0.002)	
Western					0.010***	
					(0.003)	
Northeastern					0.184***	
					(0.004)	
Ownership:						
COE						0.267***
						(0.004)
DPE						0.434***
						(0.003)
HMT						0.539***
						(0.004)
FIE						0.670***
						(0.004)
OTHER						0.413***
						(0.003)
Observations	1,977,126	1,977,126	1,976,355	1,977,126	1,977,126	1,977,126
R-squared	0.000	0.002	0.001	0.007	0.014	0.020

Notes: 1.Robust standard errors are reported in parentheses. The stars, *, ** and *** indicate the significance level at 10%, 5% and 1%, respectively.

2. For the definition of COE, DPE, HMT, FIE and OTHER, please refer to Table 2-6.

3.The baseline group for region is Central and the baseline group for ownership is SOE.

Table 2-9 Determinants of productivity: all industries

Dependent variable: productivity	OLS (1)	(2)	(3)	ACF (4)	(5)	(6)	BB (7)	(8)	(9)
Entry (t_0)	0.007***	0.029***	0.003***	0.040***	0.056***	0.032***	0.035***	0.044***	0.012***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
t+1	0.010***	0.046***	0.004***	0.034***	0.064***	0.025***	0.047***	0.071***	0.022***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
t+2	0.008***	0.065***	0.002*	0.027***	0.078***	0.019***	0.043***	0.092***	0.018***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
t+3	0.004***	0.085***	-0.002**	0.018***	0.094***	0.010***	0.036***	0.116***	0.012***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
t+4	0.009***	0.092***	(0.002)	0.019***	0.098***	0.011***	0.036***	0.118***	0.012***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Exit		-0.074***	-0.045***		-0.051***	-0.022***		-0.108***	-0.074***
		(0.001)	(0.001)		(0.001)	(0.001)		(0.002)	(0.002)
Age		-0.000***	-0.000***		-0.000***	-0.000***		-0.000***	-0.000***
		(0.000)	(0.000)		(0.000)	(0.000)		(0.000)	(0.000)
Exporting		0.011***	0.013***		-0.005***	-0.003***		0.032***	0.034***
		(0.001)	(0.001)		(0.001)	(0.001)		(0.001)	(0.001)
Region:									
Costal		0.012***	0.014***		0.013***	0.015***		0.046***	0.048***
		(0.001)	(0.001)		(0.001)	(0.001)		(0.001)	(0.001)
Western		-0.025***	-0.023***		-0.033***	-0.031***		-0.046***	-0.043***
		(0.002)	(0.002)		(0.002)	(0.002)		(0.002)	(0.002)
Northeastern		0.005***	-0.002		0.010***	0.002		-0.008***	-0.017***
		(0.002)	(0.002)		(0.002)	(0.002)		(0.002)	(0.002)
Ownership:									
COE		0.100***	0.103***		0.101***	0.104***		0.267***	0.270***
		(0.002)	(0.002)		(0.002)	(0.002)		(0.002)	(0.002)
DPE		0.175***	0.088***		0.170***	0.086***		0.362***	0.259***
		(0.002)	(0.002)		(0.002)	(0.002)		(0.002)	(0.002)
HMT		0.161***	0.105***		0.153***	0.100***		0.321***	0.256***
		(0.002)	(0.002)		(0.002)	(0.002)		(0.002)	(0.002)
FIE		0.216***	0.146***		0.206***	0.139***		0.404***	0.322***
		(0.002)	(0.002)		(0.002)	(0.002)		(0.002)	(0.002)
OTHER		0.153***	0.094***		0.142***	0.086***		0.312***	0.242***
		(0.002)	(0.002)		(0.002)	(0.002)		(0.002)	(0.002)
Industry dummy	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year dummy	Y	N	Y	Y	N	Y	Y	N	Y
# of obs.	1,977,126	1,976,355	1,976,355	1,977,126	1,976,355	1,976,355	1,977,126	1,976,355	1,976,355
R-squared	0.200	0.175	0.208	0.257	0.235	0.262	0.833	0.832	0.839

Notes: 1. Robust standard errors are reported in parentheses. The stars, *, ** and *** indicate the significance level at 10%, 5% and 1%, respectively.

2. For the definition of OLS, ACF and BB, please refer to Figure 2-1.

3. For the definition of COE, DPE, HMT, FIE and OTHER, please refer to Table 2-6.

4. The baseline group for region is Central and the baseline group for ownership is SOE.

Table 2-10 Haltiwanger decomposition: all industries 1998-2007

	productivity growth (1)	within firm (2)	between firm (3)	cross firm (4)	exitors (5)	**enterers (6)**
OLS	28.0	9.1	-1.5	0.4	-0.9	**19.1**
						(68.2)
ACF	29.0	8.3	-0.8	0.1	-0.7	**20.8**
						(71.7)
BB	56.2	11.8	-1.2	3.6	-5.7	**36.4**
						(64.7)

Notes: 1. For the decomposition method, please refer to Haltiwanger (1997).
2. The numbers in parentheses are the contribution of new entering firms to productivity growth over a 10-year period of 1998-2007.
3. For the definition of OLS, ACF and BB, please refer to Figure 2-1.
4. All the numbers are in %.

Table 2-11 Determinants of productivity: 3 industries

Dependent variable: productivity	Textile			Raw chemical materials			Electronic and telecom		
	OLS	ACF	BB	OLS	ACF	BB	OLS	ACF	BB
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Entry (t_0)	-0.009***	0.016***	0.122***	-0.001	0.019***	0.055***	0.007	0.070***	0.018***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.006)	(0.006)	(0.006)
t+1	-0.001	0.009***	0.104***	0.008**	0.016***	0.065***	0.012**	0.065***	0.035***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.006)	(0.006)	(0.006)
t+2	0.004	0.009***	0.086***	0.009**	0.015***	0.059***	-0.002	0.041***	0.016**
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.006)	(0.006)	(0.006)
t+3	-0.001	0.001	0.062***	0	0.003	0.042***	-0.004	0.028***	0.010
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.006)	(0.006)	(0.007)
t+4	0.007**	0.008**	0.049***	0.012**	0.014***	0.045***	-0.009	0.014*	0.011
	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.008)	(0.008)	(0.009)
Exit	-0.031***	0.000	0.002	-0.052***	-0.025***	-0.030***	-0.027***	-0.035***	-0.089***
	(0.004)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.009)	(0.010)	(0.010)
Age	0.000	0.000	-0.000***	0.000	0.000	-0.000***	0.000	0.000	-0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Exporting	0.028***	0.011***	0.019***	0.020***	0.001	-0.036***	-0.036***	-0.054***	-0.027***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.004)	(0.005)
Region:									
Costal	0.014***	-0.009**	0.030***	0.000	-0.021***	0.066***	0.094***	0.132***	0.153***
	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.010)	(0.010)	(0.011)
Western	-0.046***	-0.033***	-0.093***	-0.030***	-0.025***	-0.040***	0.051***	0.031**	0.046***
	(0.008)	(0.009)	(0.009)	(0.005)	(0.005)	(0.005)	(0.014)	(0.015)	(0.016)
Northeastern	-0.062***	-0.048***	-0.082***	-0.014**	-(0.008)	0.011*	0.054***	0.042***	0.050***
	(0.009)	(0.009)	(0.009)	(0.006)	(0.006)	(0.006)	(0.015)	(0.016)	(0.017)
Ownership:									
COE	0.124***	0.059***	0.303***	0.087***	0.041***	0.203***	0.121***	0.262***	0.358***
	(0.009)	(0.009)	(0.009)	(0.006)	(0.006)	(0.006)	(0.015)	(0.015)	(0.016)
DPE	0.118***	0.048***	0.309***	0.076***	0.031***	0.194***	0.120***	0.273***	0.393***
	(0.009)	(0.009)	(0.009)	(0.005)	(0.005)	(0.005)	(0.013)	(0.013)	(0.013)
HMT	0.143***	0.083***	0.249***	0.108***	0.061***	0.236***	0.137***	0.229***	0.356***
	(0.009)	(0.009)	(0.009)	(0.006)	(0.006)	(0.006)	(0.013)	(0.013)	(0.013)
FIE	0.166***	0.103***	0.302***	0.150***	0.097***	0.284***	0.210***	0.286***	0.472***
	(0.009)	(0.009)	(0.009)	(0.006)	(0.007)	(0.006)	(0.013)	(0.013)	(0.013)
OTHER	0.134***	0.066***	0.256***	0.077***	0.032***	0.149***	0.200***	0.307***	0.443***
	(0.009)	(0.009)	(0.009)	(0.005)	(0.005)	(0.005)	(0.013)	(0.013)	(0.014)
Year dummy	Y	Y	Y	Y	Y	Y	Y	Y	Y
# of obs.	170,646	170,646	170,646	144,101	144,101	144,101	65,461	65,461	65,461
R-squared	0.061	0.030	0.130	0.034	0.016	0.097	0.208	0.228	0.245

Notes: 1. Robust standard errors are reported in parentheses. The stars, *, ** and *** indicate the significance level at 10%, 5% and 1%, respectively.

2. For the definition of OLS, ACF and BB, please refer to Figure 2-1.

3. For the definition of COE, DPE, HMT, FIE and OTHER, please refer to Table 2-6.

4. The baseline group for region is Central and the baseline group for ownership is SOE.

Table 2-12 Robustness checks

Dependent variable: productivity	ACF 1st	ACF 2nd	ACF 3rd	BB_DIF
	(1)	(3)	(3)	(4)
Entry (t_0)	0.011***	0.017***	0.021***	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Exit	-0.032***	-0.028***	-0.024***	-0.089***
	(0.001)	(0.002)	(0.001)	(0.002)
Age	-0.000***	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Exporting	0.003***	-0.008***	-0.005***	-0.025***
	(0.001)	(0.001)	(0.001)	(0.001)
Region:				
Costal	0.018***	0.026***	0.019***	0.121***
	(0.001)	(0.001)	(0.001)	(0.001)
Western	-0.027***	-0.040***	-0.034***	-0.075***
	(0.002)	(0.002)	(0.002)	(0.002)
Northeastern	0.004**	0.004**	0.002	0.008***
	(0.002)	(0.002)	(0.002)	(0.002)
Ownership:				
COE	0.081***	0.125***	0.126***	0.460***
	(0.002)	(0.002)	(0.002)	(0.002)
DPE	0.067***	0.114***	0.113***	0.472***
	(0.002)	(0.002)	(0.002)	(0.002)
HMT	0.085***	0.127***	0.124***	0.432***
	(0.002)	(0.002)	(0.002)	(0.002)
FIE	0.115***	0.175***	0.169***	0.544***
	(0.002)	(0.002)	(0.002)	(0.002)
OTHER	0.068***	0.110***	0.109***	0.415***
	(0.002)	(0.002)	(0.002)	(0.002)
Industry dummy	Y	Y	Y	Y
Year dummy	Y	Y	Y	Y
# of obs.	1,976,355	1,976,355	1,976,355	1,976,355
R-squared	0.437	0.731	0.337	0.582

Notes: 1. Robust standard errors are reported in parentheses. The stars, *, ** and *** indicate the significance level at 10%, 5% and 1%, respectively.
2. 1st, 2nd and 3rd represent productivity processes in ACF approach that are of linear form, 2nd and 3rd order polynomials, respectively.
3. BB_DIF refers to productivity estimate obtained by first-diffenerce GMM in Blundell and Bond (2000).
4. For the definition of COE, DPE, HMT, FIE and OTHER, please refer to Table 2-6.
5. The baseline group for region is Central and the baseline group for ownership is SOE.

Table 2-13 Robustness checks-5% depreciation rate

Dependent variable productivity	OLS (1)	ACF (2)	BB (3)
Entry (t_0)	0.004***	0.021***	-0.013***
	(0.001)	(0.001)	(0.001)
Exit	-0.045***	-0.021***	-0.087***
	(0.001)	(0.001)	(0.002)
Age	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)
Exporting	0.012***	-0.010***	0.042***
	(0.001)	(0.001)	(0.001)
Region:			
Costal	0.014***	0.012***	0.048***
	(0.001)	(0.001)	(0.001)
Western	-0.023***	-0.019***	-0.037***
	(0.002)	(0.002)	(0.002)
Northeastern	-0.002	0.004**	-0.014***
	(0.002)	(0.002)	(0.002)
Ownership:			
COE	0.103***	0.089***	0.255***
	(0.002)	(0.002)	(0.002)
DPE	0.092***	0.080***	0.255***
	(0.002)	(0.002)	(0.002)
HMT	0.110***	0.097***	0.268***
	(0.002)	(0.002)	(0.002)
FIE	0.152***	0.140***	0.343***
	(0.002)	(0.002)	(0.002)
OTHER	0.097***	0.078***	0.247***
	(0.002)	(0.002)	(0.002)
Industry dummy	Y	Y	Y
Year dummy	Y	Y	Y
# of obs.	1,978,141	1,978,141	1,978,141
R-squared	0.208	0.321	0.843

Notes: 1. Robust standard errors are reported in parentheses. The stars, *, ** and *** indicate the significance level at 10%, 5% and 1%, respectively.
2. For the definition of OLS, ACF and BB, please refer to Figure 2-1.
3. For the definition of COE, DPE, HMT, FIE and OTHER, please refer to Table 2-6.
4. The baseline group for region is Central and the baseline group for ownership is SOE.

Chapter 3

Estimating productivity of public infrastructure investment

3.1 Introduction

Adequate infrastructure is one of the crucial prerequisites for economic growth in developing countries. The Chinese government spends a lot of energy on propagating the importance of infrastructure. In the 1990s, we often saw such an advertisement on the wall of rural house: to get rich, build roads first. Yu et al. (2012) report that 80.56% of the total budgetary fiscal revenue of the Chinese central government is devoted to infrastructure during 1995–2008. The investment accounts for 5.28% of the averaged GDP. India also improves their infrastructure through substantial investment, for example, the Golden Quadrilateral Project. Li, Mengistae and Xu (2011) indicate that the infrastructure in India lags far behind China. Dani Rodrik (2016) argues that India benefit a lot from the public infrastructure investment. He further contends that Ethiopia and Bolivia manage to have high economic growth rates through a massive increase in public investment, which can reduce the transaction cost and attract foreign direct investment. For the developing countries, the main problem is that there is an insufficient fund for infrastructure construction.

Infrastructure investment is also considered to be a good economic stimulus tool when the economy of developed country is in recession. Before the 2015 G20 meeting, the American president, Barack Obama, wrote an article in the Financial Times. He suggested that governments should increase expenditures on infrastructure to stimulate short-term demand as well as to raise long-term productivity. Lawrence Summers also published a paper in the Financial Times in 2014 to call for larger public infrastructure investment. These politicians anticipated that public investment would promote both the short-run and long-run economic growth. In this way, the world economy could achieve its potential. However, developed countries have fiscal constraint problems. Thus, the key problem for both developing and developed countries is the return rate of infrastructure investment.

Although the investment in infrastructure can probably lead to a higher GDP growth rate, in a poll about infrastructure investment conducted by the Booth Business School in 2014, Abhijit Banerjee questioned whether the effect was just the temporary Keynesian demand effect, though he agrees that there may be quite a positive return rate. Daron Acemoglu argued that waste and corruption would decrease the return rate.

In this chapter, we first estimate the return rate of infrastructure investment. If the return rate of infrastructure investment is not lower than that of private investment, then the government should expand fiscal expenditure on infrastructure investment. Second, we distinguish long-run productivity effect from short-run Keynesian demand effect, because the long-run productivity effect brings a sustainable growth. Third, in our model, there is a heterogeneous effect across firms brought by the infrastructure investment, which may shed light on who benefits more from infrastructure investment.

Since Aschauer (1989), many studies have investigated the role of public infrastructure in promoting economic growth using macro-level data. In those studies, public capital is usually treated as the input into the gross production function, while there may be measurement errors in the public capital stock. Aschauer (1989) finds that the coefficient of public capital to range from 0.38-0.56. The return rate is found to be more than 100%. The reverse causality problem between economic growth and public investment is neglected in Aschauer (1989). Munnell (1992) and Gramlich (1994) argue that the macro variables tend to be non-stationary and drift over time. If the time trend has not been removed, the positive relationship between investment in public capital and GDP found by studies in the early 1990s may be a result of spurious correlations. Another econometric problem is the simultaneity bias due to unobserved shocks, which might simultaneously affect the aggregate output and the factor inputs.

This chapter aims to address these econometric problems in the literature. The reverse causality problem between public infrastructure investment and economic growth is avoided by matching firm-level data with province-level public infrastructure investment data. As the infrastructure investment is determined by aggregate-level public finance, the influence of individual firms is trivial. Furthermore, as in Doraszelski and Jaumandreu (2013), past infrastructure investment is added into a first-order Markov productivity process, which can avoid measurement error in the stock variable. Second, with the development in production function estimation techniques using firm-level data, we are able to solve the endogeneity problem between factor inputs and unobserved productivity. We use the intermediate inputs as the proxy for unobserved productivity to control for its influence, following Ackerberg, Caves and Frazer (2006). Third, the framework of De Loecker (2011) is used to distinguish the quantity total factor productivity (TFPQ hereafter) from the revenue total factor productivity (TFPR hereafter). The effect of public infrastructure investment on the TFPR contains both the short-run demand effect and the productivity effect of public infrastructure, while the TFPQ captures only the long-run productivity effect. To our knowledge, this approach is new to the literature on this topic.

We find that the average return rate of public infrastructure investment in China is 9.2% over 1998-2007, while 2.5% is from the long-run productivity effect. When we take into account the spillover effects from the other provinces' infrastructure investment, the average total return rate becomes 28.3%, which is slightly larger than the private investment return rate in the literature. In addition, the long-run productivity effect almost triples to 7.2%.

The estimation results about the return rate are robust to the model changes. We first broaden the measure of public infrastructure investment, while the model structure does not change. Then, we continue to use the old measure while we modify the productivity process. These two checks of robustness present similar patterns for estimations of coefficients and return rates. We also check the robustness of the spillover effects model, in which the firms only get positive externality from neighboring provinces. We also find a relatively high return rate with this setting. These processes characterize the role of public infrastructure investment in promoting economic growth.

We also find that more productive firms benefit more from public infrastructure investment.

In particular, younger, smaller, non-state-owned, exporting firms located in the eastern area have larger output elasticities than other firms.

Our empirical results have policy implications. Public infrastructure investment has much higher short-run stimulus effect than the long-run productivity effect on economy. Other policies should be designed to support the long run growth, as the contribution of infrastructure investment to productivity is not very high.

In the next section, we will provide a brief literature review. Detailed descriptions of the models will be given in section 3. Section 4 describes the data. Section 5 discusses the results for estimation and return rate. Section 6 examines the spillover effects. Section 7 presents robustness checks. Section 8 investigates who benefits more from infrastructure investment. Finally, section 9 concludes.

3.2 Literature review

In this section, we will provide a review of the econometric problems encountered in the estimation, which will be solved in the empirical model section. As in Aschauer (1989), public infrastructure capital stock is treated as the input of an aggregate production function as follows:

$$Q = AoF(K, L, B) \tag{3.1}$$

where Q is the aggregate output; K, L and B are private capital, labor force and public infrastructure capital respectively. Ao represents the TFP.

B evolves according to the following:

$$B_t = (1 - \delta_b)B_{t-1} + G_t \tag{3.2}$$

δ_b is the depreciation rate of public capital, G_t represents the public investment. while Previous researches usually assume that equation 3.1 has a Cobb–Douglas form. We rewrite it in the log form under that assumption.

$$\ln Q_{it} = \alpha_0 + \alpha_b \ln B_{it} + a_k \ln K_{it} + \alpha_l \ln L_{it} + \varepsilon_{it} \tag{3.3}$$

where ε_{it} denotes idiosyncratic shocks.

To estimate this function, we need the measure for B, public infrastructure capital. To construct it, detailed information about public infrastructure investment history and the initial capital stock are needed. The depreciation rate will have to be assumed. If there is any measurement error in this time series, its influence will be persistent.

We need to take note that the aggregate level data tend to be non-stationary and drift over time, as noted by Munnell (1992) and Gramlich (1994). The high return rate and large α_b may be the result of spurious correlations. Tatom (1991) uses the first differences in data to check the robustness of the result obtained from the level equation. The coefficient of public capital becomes much smaller and insignificant.

Another problem with studies using macro data is that the public investment and GDP level affect each other rather than operate in a one-way direction. With more government investment, the GDP will be higher. With higher GDP, the government collects more taxes, which may again lead to a larger public investment. Pereira and Andraz (2013) argue that the production function method is a single-equation and static approach, which cannot address the simultaneity problem. It is also impossible to identify the causality direction.

A common method to address reverse causality is to use the instrumental variable approach. However, most of external instrumental variables are weak instruments. Holtz-Eakin (1994) obtains a very low return rate using the internal instruments to address the reverse causality problem. To address this two-way causality, Fernald (1999) focuses on the highway using industry-level data. He argues that vehicle-intensive industries will benefit more from the building of highways than other industries. Fernald's logic is intuitive yet hard to apply to other infrastructure types. Furthermore, the framework he used is restrictive on the cost and demand forms. Röller and Waverman (2001) use the structural equation model to address simultaneity bias. However, their method depends on the high quality of data. They have detailed price information, which is usually not available.

3.3 Empirical models

Since Olley and Pakes (1996), the proxy approach for production function estimation becomes popular, especially with the availability of firm-level data. In this chapter, we mainly follow the method proposed by Ackerberg, Caves and Frazer (2006), in which intermediate inputs will be used as the proxy for productivity to control for the simultaneity bias. Furthermore, this approach allows for an endogenous productivity process. In particular, we assume that improvement in productivity as a result of infrastructure investment will be realized with one period lag.

In the following functions, we adopt the convention that lower-case letters denote logs and upper-case letters denote levels. The standard Cobb-Douglas production function is considered:

$$Q_{it} = L_{it}^{\alpha_L} M_{it}^{\alpha_M} K_{it}^{\alpha_K} \exp(\omega_{it} + \mu_{it}) \tag{3.4}$$

where Q represents the physical output, L is labor, M is intermediate inputs, K is capital stock, ω represents firm-specific productivity, and μ represents measurement error and idiosyncratic shock to production. To produce, the firm has to use labor, material and capital as inputs. In addition, the level of output is also influenced by the productivity as well as external shock in production faced by firms.

3.3.1 TFPQ model

However, in the data, we usually cannot observe the quantity. Generally, the revenue or value added is used as the dependent variable in previous studies. The revenue is a product determined by price and quantity. To eliminate the price effect, according to De Loecker (2011), a CES demand system function is assumed:

$$Q_{it} = Q_{sjt} \left(\frac{P_{it}}{P_{st}} \right)^{-\sigma_s} \exp(\xi_{it}) \tag{3.5}$$

where Q_{sjt} represents the total demand in industry s in province j to which this firm belongs; P_{st} represents the price index of industry s; σ_s is the substitution elasticity of industry s; and ξ_{it} represents the demand shock. Therefore, the demand for a firm depends on three factors, namely, industry output, individual firm's product price and industry average price.

As in Doraszelski and Jaumandreu (2013), the past infrastructure investment affects productivity in the following function:

$$\omega_{it} = h_t(\omega_{it-1,}g_{jt-1}) + v_{it} \tag{3.6}$$

where g_{jt-1} is the logarithm of province j's infrastructure investment in year $t-1$; and v_{it} represents the firm-specific productivity innovation. This specification employs past infrastructure investment rather than public capital stock. There is a time lag for the infrastructure investment to take effect. The influence of past infrastructure investment is persistent thorough the ω. The causality direction is now much clearer when we match the firm-level data with the province-level infrastructure data, as an individual firm's influence on the decision of province-level infrastructure investment should be trivial.

To control for the demand effect brought by the current year infrastructure investment, we decompose the ξ_{it} into two parts:

$$\xi_{it} = \tau g_{jt} + \tilde{\xi}_{it} \tag{3.7}$$

where g_{jt} is the logarithm of province j's infrastructure investment in year t; and $\tilde{\xi}_{it}$now denotes the unobservable firm-specific demand shocks. Hence, ω_{it} represents the quantity total factor productivity, such that the instantaneous Keynesian demand effect is already purified.

Then, the revenue deflated by the industrial price index is as follows:

$$r_{it} = \ln \frac{P_{it}Q_{it}}{P_{st}} = \left(1 - \frac{1}{\sigma_s}\right) q_{it} + \frac{1}{\sigma_s} q_{sjt} + \frac{1}{\sigma_s} \xi_{it} \tag{3.8}$$

where $q_{it} = \ln(Q_{it})$ and $q_{sjt} = \ln(Q_{sjt})$.

Then, we substitute the production function into this revenue function and find the following:

$$r_{it} = \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \beta_s q_{sjt} + \beta_g g_{jt} + \omega^*_{it} + \varepsilon_{it} \tag{3.9}$$

where $\varepsilon_{it} = \left(1 - \frac{1}{\sigma_s}\right) \mu_{it} + \frac{1}{\sigma_s} \tilde{\xi}_{it}$. Notice that $\beta_s = \frac{1}{\sigma_s}, \beta_g = \frac{\tau}{\sigma_s}, \beta_l = \left(1 - \frac{1}{\sigma_s}\right) \alpha_L, \beta_k =$

$\left(1-\frac{1}{\sigma_s}\right)\alpha_K$, and $\beta_m = \left(1-\frac{1}{\sigma_s}\right)\alpha_M$. Denote $\omega^*_{it} = \left(1-\frac{1}{\sigma_s}\right)\omega_{it}$.

If we use the OLS to estimate the previous function, there will be simultaneity bias as a result of the correlation between l_{it}, k_{it}, m_{it} and ω^*_{it}. Following Ackerberg, Caves and Frazer (2006), we use the same time assumptions at which the input is determined. Capital is assumed to be a quasi-fixed input chosen at $t-1$ and labor is set before the productivity is released, but after capital has been chosen. We can almost assume that labor is chosen at $t-0.5$. The optimization process done by the firms will find that intermediate inputs are a function of capital, labor, productivity and the demand variables q_{sjt} and g_{jt}, including infrastructure investment and industry output. Then,

$$m_{it} = m'_t\left(l_{it}, k_{it}, \omega^*_{it}, q_{sjt}, g_{jt}\right) \tag{3.10}$$

De Loecker (2011) assumes that, under imperfect competition, this function is monotonically increasing in productivity. Then, the proxy function of productivity is as follows:

$$\omega^*_{it} = h'_t\left(l_{it}, k_{it}, m_{it}, q_{sjt}, g_{jt}\right) \tag{3.11}$$

The estimation procedure consists of two stages. The first stage is to substitute equation 3.11 into structure equation 3.9. Now revenue is a function of $l_{it}, k_{it}, m_{it}, q_{sjt}$ and g_{jt}:

$$r_{it} = \phi'_t\left(l_{it}, k_{it}, m_{it}, q_{sjt}, g_{jt}\right) + \varepsilon_{it}$$

Now, for example, a polynomial function of (l_{it}, k_{it}, m_{it}), together with q_{sjt}, their interaction terms and g_{jt} can be used to approximate revenue.

De Loecker (2013) argues that the influence of policies should be estimated with one step rather than two steps. With two steps, he means that productivity is assumed to follow an exogenous process. The impact of policies is estimated after we already obtain the measure of productivity. However, the coefficients will be biased with an exogenous process. We add the public infrastructure investment lag into the productivity process. In particular, productivity is assumed to follow a first-order Markov process,

$$\omega_{it} = \rho_1\omega_{it-1} + \rho_2\omega_{it-1}^2 + \rho_3\omega_{it-1}^3 + \rho_4\omega_{it-1}^4 + \rho_5 g_{jt-1} + \rho_6 g_{jt-1}\omega_{it-1} + v_{it} \tag{3.12}$$

This process allows for heterogeneity in benefiting from infrastructure investment across firms:

$$e_{it}^{TFPQ} = \frac{\partial \omega_{it}}{\partial g_{jt-1}} = \rho_5 + \rho_6\omega_{it-1}$$

With any initial value of coefficients, we can obtain the augmented productivity TFPQ as:

$$\omega_{it} = [\hat{\phi}_{it}^{'} - \beta_l l_{it} - \beta_k k_{it} - \beta_m m_{it} - \beta_s q_{sjt} - \beta_g g_{jt}]/[1 - \frac{1}{\sigma_s}] \tag{3.13}$$

After running the equation 3.12, the shock to productivity v_{it} is get, which is orthogonal to $l_{it-1}, k_{it}, m_{it-1}, q_{st-1}$ and g_{jt}.Then, the moment conditions are as follows:

$$E\left(v_{it}\left(\beta_l, \beta_k, \beta_m, \beta_s, \beta_g\right) \begin{pmatrix} l_{it-1} \\ k_{it} \\ m_{it-1} \\ q_{sjt-1} \\ g_{jt} \end{pmatrix} = 0 \right) \tag{3.14}$$

GMM is employed to get a consistent estimation of the related coefficients. Then, we can back out the real total factor productivity measure, after which the influence of the infrastructure investment can be estimated.

3.3.2 TFPR model

Without the framework of De Loecker (2011), previous literature usually uses the deflated revenue as the proxy for physical product, as in Pavcnik (2002) and Yu (2015). The empirical model is as follows:

$$r_{it} = \theta_l l_{it} + \theta_k k_{it} + \theta_m m_{it} + z_{it} + e_{it} \tag{3.15}$$

where r_{it} represents the revenue of firm i in one industry and period t, l_{it} is labor, k_{it} is capital, m_{it} is intermediate material, and z_{it} is the unobserved productivity of the revenue. P_{it} is the price of products of firm i in period t, for which we do not have records in the data, P_{st} is the price level of industry s. and e_{it} represents the IID random shocks to firms.

Compared with the equation 3.9, z_{it} should be the sum of quantity total factor productivity and the demand effect brought by the total output and public infrastructure, if we treat $(\theta_l, \theta_k, \theta_m)$ as $(\alpha_L, \alpha_K, \alpha_M)$. We define z_{it} as TFPR. Hence, the return rate calculated thorough z_{it} should be the sum of short-run demand effect and the long-run productivity effect. z_{it} also follows a first-order Markov process:

$$z_{it} = f(z_{it-1,}g_{jt-1}) + \zeta_{it} \tag{3.16}$$

As in the TFPQ model, m_{it} is used as the proxy for productivity, which then is a function of labor, capital and productivity:

$$m_{it} = m_t \left(l_{it}, k_{it}, z_{it} \right) \tag{3.17}$$

This function is also assumed to be strictly monotonic of productivity, then invertible:

$$z_{it} = h_t \left(l_{it}, k_{it}, m_{it} \right) \tag{3.18}$$

Now revenue is only a function of labor, capital stock and material, shown as follows:

$$r_{it} = \phi_t \left(l_{it}, k_{it}, m_{it} \right) + e_{it} \tag{3.19}$$

Then, a polynomial function of labor, capital stock and material is used to obtain $\hat{\phi_t}$, i.e., get rid of e_{it}.

z_{it} is assumed to follow a first-order Markov process. Lagged public investment promotes productivity in the following way:

$$z_{it} = \lambda_1 z_{it-1} + \lambda_2 z_{it-1}^2 + \lambda_3 z_{it-1}^3 + \lambda_4 z_{it-1}^4 + \lambda_5 g_{jt-1} + \lambda_6 g_{jt-1} z_{it-1} + \zeta_{it} \tag{3.20}$$

The inclusion of lagged public infrastructure investment recognizes that the public sector affects the evolution of private firms' productivity by increasing the investment in infrastructure. In addition, the innovation to productivity between $t-1$ and t is independent with the k_{it}, l_{it-1} and m_{it-1}.

Our primary interest is that

$$e_{it}^{TFPR} = \frac{\partial z_{it}}{\partial g_{jt-1}} = \lambda_5 + \lambda_6 z_{it-1} \tag{3.21}$$

With a guess for θ_l, θ_k,and θ_m, z_{it} and z_{it-1} can be calculated. Then, ζ_{it} will be obtained. In addition, according to the time assumption, the relative moment conditions are as follows:

$$E\left(\zeta_{it}\left(\theta_l, \theta_k, \theta_m\right)\begin{pmatrix} l_{it-1} \\ k_{it} \\ m_{it-1} \end{pmatrix} = 0\right) \tag{3.22}$$

With these moment conditions, these coefficients can be estimated with GMM. Then, we can get the key variable of interest e_{it}^{TFPR}, which contains both a Keynesian demand effect and a productivity effect of public infrastructure investment.

3.4 Data and Variables

3.4.1 Main data

The main data we use is the same as that used in the first study, which comes from the Annual Survey of Industrial Firms conducted by China's National Bureau of Statistics, covering 1998-2007. Firms above scale are included in samples. They are either state-owned or are non-state firms with sales above 5 million RMB per year. These data have been widely used in research, such as Song, Storesletten and Zilibotti (2011), Yu (2015), and Hsu et al. (2016). Firm characteristics, output and input data, and balance sheet information are contained in the data. We follow Brandt, Van Biesebroeck and Zhang (2012) to construct the panel data and calculate the capital stock. The definitions of the variables can be found in the data section of the first study.

In Table 3-1, the first two columns show industrial codes and industry names, respectively. The third column indicates the average annual number of observations of the corresponding industry. The average number of observations of the manufacturing industry is 7,067. The median of labor productivity growth and the median of capital productivity growth are reported in the fourth and fifth columns. The last column reports the output deflator of 2007. Industry code 25, which is petroleum processing and coking, and industry code 33, which is smelting and pressing of nonferrous metals, have been affected heavily by inflation. The high inflation in output price may explain the low labor productivity growth and capital productivity growth of those two industries. Hence, we will drop industries 25 and 33 in our estimation.

3.4.2 Information about public infrastructure investment

According to Aschauer (1989), the core infrastructure has the highest explanatory power for productivity. The content of core infrastructure is highways, mass transit, airports, electrical and gas facilities, water and sewers. With the development of the economy, telecommunication and the internet take on a more important role, which is emphasized by Röller and Waverman (2001) and Grimes et al. (2012). We focus on investment in these productive infrastructures, including (1) investment in the production and supply of electricity, gas and water; (2) investment in transport, storage and post; and (3) investment in information transmission, computer services and software. Shi and Huang (2014) add another item, (4) investment in the management of water conservancy, environment, and public facilities, which is relatively less productive compared to the first 3 types of infrastructure investment. Zhang et al. (2007) use the sum of (1), (2) and (4). The detailed computation process can be found in the appendix. In our estimation, the sum of the first three items serves as benchmark. During the robustness check, the fourth item will be added. We call it broad infrastructure investment. Investment data are deflated by the price indices of investments in fixed assets by province. The information about GDP is found in the China Statistics Yearbook 2013. The GDP deflator is constructed using the information in the China Statistics Yearbook 2013.

Table 3-2 provides descriptive statistics about infrastructure investment. The core infrastructure investment continually grew during 1998-2007. The growth rate reached its peak in 2005, which was approximately 21.37%. The ratios of infrastructure investment to industrial GDP and total GDP were relatively stable at approximately 21% and 9%, respectively. The average growth rate of the broad infrastructure investment was relatively larger at 13.16%. After 2003, the ratio between broad infrastructure investment to industrial GDP became higher, at more than 28%.

3.5 Results of TFPR and TFPQ

3.5.1 Production function coefficients

The 2003 China government report announced that the reform of the state-owned enterprise was almost finished. Before 2003, SOEs used to have the responsibility of ensuring the level of employment, which means that there may have been many unproductive workers in SOEs. Due to the corporate governance problem and government protection, the productive capital may have been much lower than the number on the balance sheet. These problems are pointed by Lin, Cai and Li (1998) and Lin and Tan (1999).

Within the SOE system, there tends to be a negative relationship between labor and productivity, as the more money spent on unproductive labor, the less productive the firm will be; however, it is hard to conclude whether there is a positive or negative relationship between labor and productivity, as more productive firms may also hire more workers..

Olley and Pakes (1998) argue that the capital is negatively related to productivity, which is drawn from the analysis on firms' exit decisions. However, when the productivity is high, firms may also invest more in capital. Therefore, whether productivity and capital move in the same direction or opposite directions is unknown. There are also two opposing forces in determining capital coefficients.

Table 3-3 shows estimates of coefficients of TFPR, while the estimated coefficients using the OLS model are also reported. With the OLS model, there are two negative labor coefficients. There are also three negative capital coefficients and one negative labor coefficient with the TFPR model. These results are obtained from the abovementioned 10-year panel. If we use the subsample since 2003, all coefficients for both the OLS and TFPR models in Table 3-A1 are properly defined and positive. The finding agrees with the above statement that there may be unproductive workers during 1998-2002.

Compared with the TFPR model, we can find that the labor coefficient of OLS is smaller for fifteen industries, using the 10-year panel. However, using the panel since 2003, the labor coefficient of OLS is larger in most of industries, which is consistent with the theoretical prediction of Ackerberg, Caves and Frazer (2006). The measurement errors in labor and the unproductive labor force are severe during the period of 1998-2002. Since 2003, labor and firms' productivity have moved in the same direction, which follows a method of logic that allows for more labor to be employed in firms with higher productivity.

Regarding capital coefficient, more than half become smaller than OLS model when TFPR model is employed. If we focus the panel since 2003, all except one capital coefficients become smaller. Since 2003, the positive relationship between productivity and capital dominates.

The TFPR model only controls the simultaneity between productivity and factor inputs. The omitted price bias is still unresolved. This is the task of De Loecker (2011), who can control for both simultaneity error and omitted price bias. The estimated coefficients for TFPQ model are reported in Table 3-4. In this part, we will focus on the estimation results of β_s and β_g. The inverse of β_s is the elasticity of substitution. In theory, β_s should be positive. However, we find seven negative estimates among all twenty-seven industries. This finding may provide an indicator that the CES demand function does not apply well to those seven industries. Another possible explanation is that the measure of the demand shifter Q_{sjt} may be poor. The proper measure for the Q_{sjt} should be the sum of output produced and sold in the specific province j and imports to province j from customs in other provinces. However, we do not have detailed destination province information about imports. If we only keep all the non-exporters' observations to perform the estimation, the number of negative β_s decrease, as shown in Table A2. There are twenty-two positive β_s, which indicates that it is important to address the demand effect in the TFPQ model.

3.5.2 Productivity process

In this section, we want to check the direct benefit that public investment brings to the total factor productivity. Table 3-5 reports the estimated results of the productivity process of both the TFPR and TFPQ models. We pool all the industries together. The coefficients of productivity lag and its high orders are highly significant, which indicates that the results of a simple linear productivity process model are not reliable. The coefficient of the cross term between lagged productivity and lagged infrastructure investment are significantly positive, which implies that a heterogeneous effect exists across the firms. Hence, the higher is the firm's productivity of the last period, the greater the benefit. We calculate the effect through the partial derivative of log productivity with respect to the log public investment at the median value of lagged productivity. The number for the TFPR model is 2.02%, while it is 0.88% with the TFPQ model. The positive number indicates that the public investment has a long-run impact on economic growth, though Keynesian demand effect may be larger.

Table 3-6 continues to show that there is heterogeneity across firms, which reports the 25th, 50th and 75th percentiles of the elasticity of productivity with respect to the public infrastructure investment lag by industry. With the TFPR model, more than 50% firms benefit from the infrastructure investment in 22 out of 27 industries. However, with the TFPQ model, only those highly productive firms gain from the infrastructure investment. Firms with the lowest 25% of productivity may suffer from the infrastructure investment. The elasticities from the TFPR model are generally larger than those from the TFPQ model as a result of the demand effect being controlled.

We must give an explanation for the negative impact of public investment from the previous period, when the industry output and public investment of the current period are controlled. There are four possible channels. The first one is negative externality of taxes. The final source of government expenditure comes from taxes. When government expenditures increase, the firm would have to afford more taxes. Another candidate would be the existence of the interest rate crowding-out effect. The interest rate for private firms would increase with more public investment, as they are both competing for loans. Alternatively, there may not be enough financial credit given to private firms when the financial market is not open and developed enough, which was true for the Chinese economy in that period. This mechanism is already noted by Aschauer (1989). He finds that there is 1:1 crowding-out effect between public and private investment. This mechanism is also confirmed by other studies. Voss (2002) finds that there is no crowding-in effect on private investment in both America and Canada. The innovation toward public investment tends to crowd out private investment. This phenomenon is more severe in developing countries because developing countries have relatively fewer financial resources and less mature financial systems than developed countries. Cavallo and Daude (2011) demonstrate that the crowding-out effect also dominates, with a panel of 116 developing countries covering 1980-2006. IMF 2014 report states that the return rate to public investment would be lower if a developed country were growing with a high growth rate. Though China is a developing country, its GDP growth rate is extremely high during our sample period. The IMF 2014 report also emphasizes the importance of monetary policy. The benefit brought by public investment would be higher with monetary policy support. The third channel would be the inefficiency and corruption during the process of building the infrastructure. Auriol, Straub and Flochel (2016) believe that corruption is popular in developing countries during the process of public procurement of goods and services. The direct impact is that public procurement of raw material would be bought at high prices. In addition, the related firms would focus more on the relationship rather than the quality and cost of their products. Mauro (1998) finds that the investment in infrastructure construction is a priority choice, compared with other types of public investment. It would be easy for the corrupted politician to engage in bribery. This finding is also confirmed by De la Croix and Delavallade (2009). In China, there are many senior officials who have been jailed for corruption during recent years, quite a few of whom are from the public infrastructure sector. Even the budgetary government revenue is used for the correct purpose; the final service that it can produce depends on the efficiency. The final channel would be the reallocation of resources. With better infrastructure, labor with relatively high education and skill may move to the central cities, when they used to remain in the small cities. With high immigration to large cities, the local economy of small cities would suffer, as both capital and labor are shifting to the central areas. This mechanism is confirmed by Faber (2014), who finds that large-scale inter-regional transport infrastructure can lead to a reduction in industrial and total output growth among connected peripheral regions relative to non-connected ones.

3.5.3 Return rate

Our final aim is to calculate the return rate to the infrastructure investment, which is discussed in Ansar et al. (2016). Based on the individual firms' output elasticities e_{it}^{TFPQ} and e_{it}^{TFPR}, we first aggregate them into the industry average, using the revenue of each firm as the weight, which is shown in the brackets. To calculate the return rate at the sector level, we have to first transfer it into the ratio between the added value and the infrastructure investment as follows:

$$
\begin{aligned}
e_{st}^{TFPQ} &= \frac{dv_{st}^{TFPQ}}{dg_{t-1}} = \frac{dv_s}{dr_s}\left(\sum_i e_{it}^{TFPQ}\frac{R_{ist}}{R_{st}}\right) \\
e_{st}^{TFPR} &= \frac{dv_{st}^{TFPR}}{dg_{t-1}} = \frac{dv_s}{dr_s}\left(\sum_i e_{it}^{TFPR}\frac{R_{ist}}{R_{st}}\right)
\end{aligned}
$$

where $\frac{dv_s}{dr_s}$ is obtained by the fixed-effect regression of log value-added on log sales revenue for industry s. $\frac{R_{ist}}{R_{st}}$ is the revenue weight of that firm in that industry. The results are reported in the top rows of Tables 3-7 and 3-8.

Next, we use the value-added as the weight to calculate the average elasticity of manufacturing sector:

$$
\begin{aligned}
e_t^{TFPQ} &= \sum_s e_{st}^{TFPQ}\frac{V_{st}}{V_t} \\
e_t^{TFPR} &= \sum_s e_{st}^{TFPR}\frac{V_{st}}{V_t}
\end{aligned}
$$

where $\frac{V_{st}}{V_t}$ represents the industry s's value-added as the share of total value-added of the manufacturing sector. e_t^{TFPQ} and e_t^{TFPR} can be found at the fifth-last row of Tables 3-7 and 3-8.

Now, the average rate of return can be obtained by multiplying the average elasticities of the manufacturing sector by the ratio between the GDP and infrastructure investment:

$$
\begin{aligned}
r_t^{TFPQ} &= e_t^{TFPQ}\frac{GDP_t}{G_{t-1}} \\
r_t^{TFPR} &= e_t^{TFPR}\frac{GDP_t}{G_{t-1}}
\end{aligned}
$$

We report the ratio of both industrial GDP to infrastructure investment and total GDP to infrastructure investment in the fourth- and third-last row of Table 3-7. The return of infrastructure investment to the industrial sector can be found in the second-last row. The last row reports the return rate to the entire economy if we assume that those 27 industries are fair indicators of the Chinese economy.

With the TFPR model, the average return rate for the Chinese economy is much higher at 9.2%, which can be found in Table 3-7. Even for the industrial sector, the average return rate with the TFPR model is approximately 3.8%. Based on the TFPQ model, the average return rate of public infrastructure investment for the entire Chinese economy over 1999-2007 is 2.5%, as shown in Table 3-8. There is an inverted-U shape in the return rate across years. The return rate reaches its peak of 4.5% in 2004. Hence, there is a long-run productivity gain from the infrastructure investment, though the return rate mainly comes from the Keynesian demand effect.

3.6 Spillover effects

The TFPR model mainly addresses the reverse causality problem in the literature. The TFPQ model further controls the demand effect brought by public infrastructure investment. However, firms not only benefit from the public infrastructure investment of the province in which they are located but also from the investment of the other provinces, especially the neighboring provinces. Holtz-Eakin and Schwartz (1995) also count the public infrastructure of neighboring regions as part of the total effective public capital. Firms may also increase their output as the other provinces increase their fiscal budget on public infrastructure.

To model the spillover effects, the productivity in the TFPQ model evolves as follows:

$$\omega_{it} = h_t(\omega_{it-1}, \bar{g}_{jt-1}) + v_{it} \tag{3.23}$$

Here, the $\bar{g}_{jt-1}$ is the logarithm of $\bar{G}_{jt-1}$.$\bar{G}_{jt}$ is the distance weighted-average of G_{kt}:

$$\bar{G}_{jt} = \sum w_{jk} * G_{kt} \tag{3.24}$$

The demand system also becomes as follows:

$$Q_{it} = \bar{Q}_{sjt} \left(\frac{P_{it}}{P_{st}} \right)^{-\sigma_s} \exp\left(\xi_{it}\right) \tag{3.25}$$

where the demand shifter ξ_{it} is revised into the following:

$$\xi_{it} = \tau\bar{g}_{jt} + \tilde{\xi}_{it} \tag{3.26}$$

$\bar{Q}_{sjt}$ is also the weighted-average of Q_{skt}:

$$\bar{Q}_{sjt} = \sum w_{jk} * Q_{skt} \tag{3.27}$$

where j is the province in which the firm i is located. $k \neq j$ represents the other provinces.

Following the Ertur and Koch (2007), we construct the weighting matrix as follows:

$$\begin{aligned} w_{jk} &= \frac{\frac{1}{d_{jk}}}{\sum_{k \neq j} \frac{1}{d_{jk}}} \\ w_{jj} &= 1 \end{aligned} \tag{3.28}$$

where the d_{jk} represents the physical distance between two provincial capitals. The spillover effects are negatively related with the distance between the two provinces. For example, a firm of Shanghai may benefit more from public infrastructure investment of Zhejiang province than that of Yunnan province. The firm can directly benefit from the public infrastructure investment of their provinces.

Similarly, the productivity process in the TFPR model becomes as follows:

$$z_{it} = f(z_{it-1}, \bar{g}_{jt-1}) + \zeta_{it} \tag{3.29}$$

3.6.1 Results with spillover effects

Table 3-A2 reports the estimated coefficients of the TFPR model with spillover effects, while Table 3-A3 lists the estimated coefficients of the TFPQ model with spillover effects. Table 3-9 also suggests that the productivity processes in both the TFPR model with spillover effects and the TFPQ model with spillover effects are also highly nonlinear, which echoes the findings in Table 3-5. The numbers in Table 3-10 are generally larger than the numbers in Table 3-6.

Table 3-11 and Table 3-12 report the weighted elasticities of each industry, the average elasticities of the manufacturing sector and the return rates of the TFPR and TFPQ models with spillover effects. The time pattern is quite consistent with the benchmark model. There is also an inverted-U shape trend of return rates across time. However, the return rate to the whole economy almost triples in both the TFPR model and the TFPQ model. This finding is consistent with findings in Pereira and Andraz (2013), which state that the return rate of public investment at the regional level is usually smaller than that at the national level. Our results suggest there are significantly positive externalities from the infrastructure investment in China. In the literature, Fernald (1999) and Li and Li (2013) both highlight the importance of the spillover effects of the road networks. The network externality in the telecommunication infrastructure emphasized by Röller and Waverman (2001) may also contribute to the spillover effects in our model.

3.7 Robustness Checks

In this section, we check the robustness of the return rate to public infrastructure investment. First, we add another item, investment in the management of water, conservancy, environment and public facilities, to the previous measure of public infrastructure investment. We call it broad infrastructure investment. This new item will in theory focus more on the living environment, rather than productivity only. Therefore, we would expect a lower return rate with this broad infrastructure investment. Table 3-13.1 reports the return rates. Compared to the return in the benchmark model, the average return rate for the entire economy in the TFPQ model decreases to 0.9%; the corresponding return rate from the TFPR model is 7.8%. The time pattern is also similar to that of the benchmark model.

Second, we stick to the old measure of infrastructure investment, with a slight modification to the productivity process. In equation 3.12 and equation 3.20, we use the fourth polynomial extension of lagged productivity, lagged public investment, the cross term between lagged productivity and lagged public investment as the factors that can enhance current productivity. Now, in order to check robustness, we will drop the fourth order of lagged productivity, while all others remain the same. We refer to it as the third-order polynomial model. Table 3-13.2 lists the return rate after this change. The average return rates for the entire economy of the TFPQ and TFPR models are 3% and 6.5%, respectively. We also try the linear productivity process, which means that current productivity is only a function of lagged productivity and lagged public investment. The return rates of the TFPR model are very large, while those of the TFPQ model are negative.

The third robustness check is to change the measure in the spillover effects model. In the benchmark spillover effects model, we assume that firms can benefit from the public infrastructure investment of all the provinces in China. Now we assume that the firms can only benefit from the infrastructure investment of its own province and neighboring provinces. For example, a firm in Shanghai may now improve their productivity as the result of the infrastructure investment only in Jiangsu, Zhejiang and Shanghai. Table 3-13.3 gives the new results. The average return of the TFPQ model for the entire economy is 3%, which is smaller than that of the benchmark spillover effect model. The average return of the TFPR model also follows the same pattern as before.

To control for the self-selection problem, we use the balance panel to the estimation again. We also drop the firms that have changed their registered province. The results are reported in the Table 3-14.1. We can find that the TFPR model has higher return rates, while TFPQ model has a slightly negative average return. This indicates that the firms who have survived over the ten years only gain through the demand effect.

The last robustness check is to change the time pattern in the productivity process. Now we assume that infrastructure will take three years to be effective. The results are reported in the Table 3-14.2. The average return rate of TFPR model is lower than that of TFPQ model, which may indicate that this specification is not correct.

3.8 Who benefits more?

The preceding results confirm that the Chinese economy benefits overall from the infrastructure investment through the productivity channel. At the firm level, firms with higher productivity benefit more from the infrastructure investment, as confirmed in Tables 3-5 and 3-6. The least productive firms will suffer from the infrastructure investment. As we have detailed information about firms, the output elasticities can be linked with the observable firm characteristics, such as ownership, exporting status, firm age, size and geographic location. We use the logarithm of the number of employees to measure the size. Table 3-15 reports the results. Firms that are younger, smaller, non-state-owned, exporting and located in the eastern provinces have larger output elasticities. The coefficients of age square are around zeros. Capital intensity is significantly and positively related with output elasticities of spillover effects models, while its coeffcient is significantly negative for the TFPR model.

3.9 Conclusion

The role of infrastructure investment to promote economic growth has attracted the attention of many economists since Aschauer (1989). Now, politicians also hope that the government can help the economy recover from the financial crisis with more expenditure on productive infrastructure. The return rate on public infrastructure investment, however, is not certain, as there are several challenges in estimating an aggregate production function.

Our research matches the firm-level data with the province-level infrastructure investment data, which can address the reverse causality problem. Imposing a CES demand system to the individual production function helps separate the short-run Keynesian demand effect from the long-run productivity effect. With the proxy method, the endogeneity problem between factor inputs decision and unobserved productivity can also be solved.

There are several findings as follows. First, we prove that there is a robust productivity effect brought by public infrastructure investment. Public infrastructure investment is efficient if we consider the spillover effects in the estimation. Second, the short-run Keynesian effect dominates the long-run productivity effect, which accounts for more than two-thirds of the return rate. Third, with the firm-level data, we find that it is the younger, non-state-owned, exporting firms located in the eastern provinces that benefit more from infrastructure investment.

In the future, we may use the new data to check the long-run impact of public investment. With a high growth rate, the Chinese economy still is on its way to a steady state. There may be new findings with new data.

3.10 Appendix

3.10.1 Computation of infrastructure investment

This appendix presents the method that we employ to calculate the investment to infrastructure.

In 2003, there was a change in the statistical caliber of investment in fixed assets. Before 2003, the first item, investment in the production and supply of electricity, gas and water, already existed. However, we have to allocate investment toward transport, storage, postal and telecommunications services to approximate the sum of the second and third investment items. The fourth investment item is measured by the sum of investments in geographic prospecting and water conservancy and investment in social services.

For 2003-2007, the website of the National Bureau of Statistics of China provides detailed information about the total investment in fixed assets. For 1998 and 2002, the Fixed Assets Yearbooks also provide information about the total investment in fixed assets.

However, we do not have the exact information about total investment in fixed assets for years 1999, 2000 and 2001. Nonetheless, the China Statistics Yearbooks of these years provide information about capital construction and innovation. In terms of the channel of management, the total investment in fixed assets can be grouped as capital construction, innovation, real estate development and others. For the years 1996, 1997, 1998 and 2002, we have the information about total investment in fixed assets, capital construction and innovation.

To get an appropriate approximation of total investment in fixed assets, we first calculate the ratio of the sum of capital construction and innovation for the years 1996, 1997, 1998 and 2002. Then, we take an average of these four ratios. After that, we use this number and the sum of capital construction and innovation to determine the total investment in fixed assets for the years 1999, 2000 and 2001.

3.10.2 Robustness Checks Details

New measure: Broad infrastructure investment The coefficients of the TFPR model presented in Table 3-A5 are very similar to that of the core infrastructure investment. For the TFPQ model, β_s becomes negative in industry 18 and industry 30; the other estimated coefficients do not vary much. This finding confirms that our econometric models are robust to the measure of public infrastructure investment.

In Table 3-A6, among all twenty-seven medians of elasticities of productivity with respect to the public infrastructure investment lag calculated with the TFPR model, four are negative. For the TFPQ model, the medians are negative in fourteen industries. The pattern is very similar to that of the findings of the benchmark model.

Third-order polynomial productivity process Table 3-A7 lists the coefficients obtained using this new productivity process. Compared with the numbers in Table 3-3, most of the coefficients of various industries with the TFPR model are robust to the small change in the productivity process. For the TFPQ model, we also have similar findings.

Compared to the findings of benchmark model, there are three more negative medians in the elasticities of productivity with respect to public infrastructure investment, as shown in Table 3-A8. The difference decreases with the TFPQ model.

Spillover effects from neighboring provinces The last robustness check is on the measure of spillover effects. Now the firms only get positive externalities from neighboring provinces rather than from all the other provinces.

In Table 3-A9, there are 2 negative capital coefficients and 1 negative labor coefficient estimated by the TFPR model with the entire panel. For the TFPQ model, there are seven negative β_s. The last column also confirms that we should control for the demand effect.

In Table 3-A10, the elasticities of productivity, with respect to the new weighted infrastructure investment of the TFPR model, are higher than the numbers of the benchmark model without spillover effects in most of industries. For TFPQ model, the spillover effects from neighboring provinces are not very obvious.

Table 3-1 Firm-level data description

code	industry definition	col (1)	col (2)	col (3)	col (4)
13	Food processing	13029	6.91	11.18	126.72
14	Food manufacturing	5246	6.73	10.62	106.94
15	Beverage manufacturing	3590	8.22	11.07	102.26
16	Tobacco processing	264	6.39	9.00	121.75
17	Textile industry	17562	7.01	11.96	109.13
18	Garments & other fiber products	9725	5.57	9.87	103.03
19	Leather, furs, down & related products	4861	6.72	9.80	109.42
20	Timber processing, bamboo, cane, palm fiber	4453	10.99	15.31	108.26
21	Furniture manufacturing	2365	7.22	11.12	104.87
22	Papermaking & paper products	6124	7.40	10.68	105.03
23	Printing industry	4361	4.52	7.14	93.40
24	Cultural, educational & sports goods	2658	4.82	9.81	107.00
25	*Petroleum processing & coking*	*1802*	*1.63*	*8.49*	*201.03*
26	Raw chemical materials & chemical products	14970	7.47	12.06	122.16
27	Medical & pharmaceutical products	4303	8.36	13.05	96.49
28	Chemical fiber	1031	6.57	9.19	122.58
29	Rubber products	2427	7.29	10.42	111.31
30	Plastic products	9446	5.36	8.57	114.49
31	Nonmetal mineral products	17594	10.30	13.20	106.08
32	Smelting & pressing of ferrous metals	4948	8.76	15.33	133.74
33	*Smelting & pressing of nonferrous metals*	*3643*	*1.80*	*6.13*	*196.66*
34	Metal products	11018	6.13	10.82	114.41
35	Ordinary machinery	15358	8.73	13.71	105.55
36	Special purpose equipment	8606	7.20	12.39	106.39
37	Transport equipment	9896	7.45	12.30	96.11
39	Electric equipment & machinery	12025	4.67	9.89	117.62
40	Electronic & telecommunications equipment	6766	7.51	11.94	83.49
41	Instruments, meters, cultural & office equipmen	2907	6.26	10.96	92.19
42	Other manufacturing	3952	2.35	8.53	117.17
	average	7067	6.56	10.85	115.01

Notes:

col (1): # observations per year: (number of total firms for each industry during 1998-2007)/10

col (2): labor productivity growth (%): median real growth rate of value-added/employees

col (3): capital productivity growth (%): median real growth rate of value-added/capital stock

col (4): output deflator (1998 = 100): from Brandt et al. (2012)

Table 3-2 Data description on infrastructure investment

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	average
core infrastructure investment											
volume (billion Yuan, 1998 pric	729.4	778.0	845.9	884.6	891.9	1058.9	1284.6	1559.1	1847.6	1961.5	1184.1
real growth rate (%)	..	6.7	8.7	4.6	0.8	18.7	21.3	21.4	18.5	6.2	11.9
investment/industrial GDP (%)	21.5	21.1	20.9	20.1	18.5	19.4	21.1	23.0	24.2	22.3	21.2
investment/total GDP (%)	8.6	8.5	8.5	8.2	7.6	8.2	9.1	9.9	10.4	9.7	8.9
broad infrastructure investment											
volume (billion Yuan, 1998 pric	929.1	1022.4	1120.5	1194.5	1272.8	1472.2	1734.5	2106.5	2545.0	2797.9	1619.5
real growth rate (%)	..	10.0	9.6	6.6	6.6	15.7	17.8	21.4	20.8	9.9	13.2
investment/industrial GDP (%)	27.4	27.8	27.7	27.2	26.3	27.0	28.6	31.1	33.3	31.8	28.8
investment/total GDP (%)	10.9	11.2	11.3	11.1	10.9	11.4	12.2	13.3	14.3	13.8	12.1

Notes:

1. Data are from China Statistics Yearbooks and China Fixed Investment Statistical Yearbooks.
2. Infrastructure investment data are deflated by the price indices of investment in fixed assets by province.
3. Industrial GDP and total GDP data are deflated by the corresponding GDP deflators.

Table 3-3 Estimates for the revenue equations

	TFPR model						OLS		
code	θ_l	$s.e.(\theta_l)$	θ_k	$s.e.(\theta_k)$	θ_m	$s.e.(\theta_m)$	θ_l	θ_k	θ_m
13	0.042	0.006	0.035	0.003	0.912	0.005	0.054	0.040	0.892
14	0.023	0.019	0.052	0.006	0.922	0.011	0.046	0.047	0.910
15	-0.054	0.099	0.057	0.040	0.988	0.123	0.053	0.054	0.900
16	0.458	1.219	0.193	0.118	0.692	0.576	0.119	0.214	0.785
17	0.012	0.059	0.014	0.015	0.971	0.088	0.038	0.032	0.888
18	0.213	0.091	-0.002	0.008	0.813	0.083	0.103	0.043	0.823
19	0.064	0.033	0.014	0.014	0.934	0.050	0.082	0.027	0.875
20	0.132	0.026	-0.032	0.019	0.989	0.034	0.030	0.039	0.882
21	0.066	0.045	0.025	0.036	0.918	0.049	0.087	0.039	0.872
22	0.062	0.013	0.071	0.015	0.842	0.026	0.011	0.047	0.905
23	0.295	0.082	0.123	0.039	0.652	0.083	-0.006	0.104	0.890
24	0.065	0.042	0.058	0.021	0.859	0.066	0.071	0.056	0.843
26	0.018	0.013	0.032	0.003	0.937	0.011	0.031	0.054	0.876
27	0.077	0.038	0.152	0.051	0.747	0.073	0.000	0.092	0.883
28	0.014	0.012	0.020	0.008	0.949	0.013	0.027	0.032	0.916
29	0.052	0.073	0.043	0.037	0.896	0.090	0.043	0.050	0.870
30	0.060	0.010	0.063	0.015	0.857	0.018	0.050	0.048	0.863
31	0.082	0.004	0.117	0.013	0.843	0.005	-0.004	0.048	0.920
32	0.048	0.012	0.014	0.008	0.948	0.012	0.052	0.039	0.897
34	0.103	0.034	0.010	0.026	0.935	0.044	0.054	0.047	0.869
35	0.000	0.007	0.043	0.005	0.934	0.010	0.021	0.045	0.893
36	0.062	0.022	0.061	0.025	0.864	0.036	0.004	0.045	0.904
37	0.171	0.045	-0.011	0.040	0.893	0.030	0.054	0.049	0.874
39	0.049	0.007	0.032	0.003	0.913	0.006	0.066	0.042	0.866
40	0.094	0.015	0.117	0.019	0.809	0.025	0.076	0.050	0.858
41	0.086	0.039	0.031	0.031	0.895	0.059	0.038	0.053	0.852
42	0.084	0.039	0.039	0.004	0.864	0.039	0.080	0.042	0.847

Note: All standard errors for TFPR model are bootstrapped using 1000 replications.

Table 3-4 Estimates for the revenue equations

TFPQ model

code	β_l	$s.e.(\beta_l)$	β_k	$s.e.(\beta_k)$	β_m	$s.e.(\beta_m)$	β_s	$s.e.(\beta_s)$	β_g	$s.e.(\beta_g)$
13	0.046	0.005	0.032	0.003	0.911	0.005	0.027	0.002	0.129	0.019
14	0.087	0.031	0.046	0.019	0.874	0.029	0.072	0.011	0.043	0.009
15	0.277	0.050	-0.037	0.035	0.799	0.041	-0.837	0.031	0.170	0.017
16	0.690	0.492	0.233	0.230	0.535	0.255	-0.128	0.054	0.108	0.105
17	0.017	0.006	0.013	0.003	0.960	0.008	-0.006	0.002	0.008	0.009
18	0.066	0.083	0.008	0.012	0.943	0.074	0.001	0.006	0.070	0.009
19	0.186	0.035	0.023	0.012	0.799	0.032	-0.075	0.014	0.062	0.021
20	-0.091	0.045	0.131	0.032	0.786	0.043	0.125	0.015	0.243	0.026
21	-0.009	0.054	0.118	0.056	0.785	0.075	0.095	0.023	0.112	0.048
22	0.059	0.023	0.092	0.022	0.791	0.027	0.060	0.019	0.069	0.020
23	0.270	0.052	0.061	0.063	0.748	0.049	0.105	0.022	0.073	0.023
24	0.118	0.077	0.034	0.016	0.861	0.091	-0.038	0.017	0.018	0.021
26	0.020	0.029	0.031	0.005	0.935	0.023	0.014	0.010	0.017	0.011
27	0.144	0.039	0.093	0.066	0.784	0.027	0.173	0.020	0.089	0.042
28	0.021	0.010	0.027	0.006	0.937	0.010	-0.012	0.006	-0.010	0.021
29	0.172	0.083	0.132	0.082	0.622	0.088	0.153	0.026	0.037	0.038
30	0.050	0.018	0.063	0.073	0.860	0.034	0.046	0.029	0.095	0.062
31	0.112	0.049	0.052	0.116	0.846	0.026	0.153	0.044	0.081	0.014
32	0.045	0.005	0.021	0.003	0.936	0.005	0.015	0.002	-0.041	0.020
34	0.019	0.072	0.031	0.013	0.943	0.054	0.023	0.011	0.023	0.014
35	0.217	0.038	0.036	0.028	0.772	0.034	0.066	0.011	-0.008	0.006
36	-0.110	0.055	0.062	0.045	1.005	0.046	0.017	0.018	0.026	0.015
37	0.052	0.025	0.058	0.040	0.876	0.025	0.097	0.013	0.028	0.021
39	0.078	0.069	0.028	0.011	0.893	0.064	0.045	0.006	-0.022	0.013
40	0.138	0.040	0.006	0.045	0.877	0.019	0.127	0.025	0.037	0.073
41	0.106	0.049	0.102	0.055	0.718	0.060	0.099	0.014	-0.022	0.024
42	0.196	0.057	0.028	0.007	0.778	0.049	-0.001	0.006	0.043	0.017

Note: All standard errors are bootstrapped using 1000 replications.

Table 3-5 Nonparametric estimates of the productivity processes

Panel A: TFPR				Panel B: TFPQ		
	Estimate	Standard error			Estimate	Standard error
$z_{i,t-1}$	-0.809 ***	0.187		$\omega_{i,t-1}$	0.332 ***	0.017
$z^2_{i,t-1}$	-0.022 ***	0.005		$\omega^2_{i,t-1}$	-0.016 ***	0.002
$z^3_{i,t-1}$	0.000 ***	0.000		$\omega^3_{i,t-1}$	-0.001 *	0.001
$z^4_{i,t-1}$	0.000 ***	0.000		$\omega^4_{i,t-1}$	0.000 *	0.000
$g_{j,t-1}$	-0.027 ***	0.005		$g_{j,t-1}$	0.020 ***	0.001
$z_{i,t-1}g_{j,t-1}$	0.088 ***	0.010		$\omega_{i,t-1}g_{j,t-1}$	0.021 ***	0.001
$\partial z_{i,t} / \partial g_{j,t-1}$ at median $z_{i,t-1}$				$\partial \omega_{i,t} / \partial g_{j,t-1}$ at median $\omega_{i,t-1}$		
	0.020				0.009	
Number of observations				Number of observations		
	1,347,547				1,347,547	
R-squared				R-squared		
	0.770				0.991	

Note:
1. Industrial dummies are included.
2. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 3-6 Nonparametric estimates of the output elasticities

Panel A: TFPR					Panel B: TFPQ			
code	25th pct	50th pct	75th pct		code	25th pct	50th pct	75th pct
13	-0.003	-0.002	0.000		13	-0.058	-0.058	-0.057
14	0.021	0.021	0.021		14	-0.027	-0.017	-0.006
15	-0.001	0.004	0.008		15	0.056	0.057	0.058
16	0.033	0.035	0.039		16	0.030	0.032	0.034
17	-0.001	0.005	0.014		17	0.011	0.017	0.021
18	0.026	0.026	0.027		18	-0.001	-0.001	0.000
19	0.002	0.006	0.014		19	0.023	0.026	0.029
20	-0.011	0.004	0.020		20	-0.030	-0.016	-0.003
21	-0.015	0.000	0.020		21	-0.004	0.007	0.016
22	0.013	0.016	0.020		22	0.002	0.008	0.016
23	0.040	0.043	0.046		23	-0.009	0.002	0.013
24	0.012	0.021	0.030		24	0.020	0.035	0.049
26	0.001	0.002	0.003		26	-0.014	-0.012	-0.010
27	0.017	0.024	0.033		27	-0.012	-0.010	-0.007
28	0.005	0.015	0.024		28	0.032	0.036	0.041
29	-0.023	0.005	0.015		29	-0.011	-0.004	0.001
30	-0.003	0.001	0.002		30	-0.016	-0.006	0.003
31	0.014	0.021	0.028		31	0.013	0.017	0.020
32	-0.006	-0.004	-0.002		32	0.015	0.018	0.020
34	-0.015	-0.008	-0.002		34	-0.020	-0.015	-0.011
35	0.009	0.018	0.022		35	-0.009	-0.004	0.002
36	0.003	0.009	0.013		36	-0.003	-0.002	0.000
37	0.002	0.008	0.013		37	-0.013	-0.009	-0.004
39	-0.027	-0.025	-0.024		39	-0.049	-0.047	-0.045
40	0.020	0.020	0.020		40	0.009	0.032	0.053
41	-0.024	-0.008	0.017		41	-0.013	-0.008	-0.002
42	-0.001	0.001	0.003		42	-0.013	-0.003	0.009
average	0.003	0.009	0.016		average	-0.003	0.003	0.009

Table 3-7 Output elasticities and average rates of return: TFPR

code	1999	2000	2001	2002	2003	2004	2005	2006	2007	average
13	0.000	0.000	-0.001	-0.001	-0.002	-0.003	-0.003	-0.004	-0.004	-0.002
14	0.018	0.018	0.018	0.017	0.018	0.017	0.016	0.017	0.017	0.017
15	0.000	0.002	0.004	0.004	0.007	0.004	0.006	0.007	0.010	0.005
16	0.024	0.025	0.024	0.024	0.024	0.025	0.026	0.026	0.025	0.025
17	0.016	0.013	0.013	0.012	0.010	0.007	0.005	-0.020	0.005	0.007
18	0.023	0.023	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.022
19	0.014	0.016	0.013	0.013	0.012	0.007	0.004	0.002	0.002	0.009
20	0.035	0.030	0.020	0.022	0.022	0.014	0.005	-0.005	-0.011	0.014
21	0.022	0.023	0.019	0.018	0.016	0.010	0.002	-0.011	-0.017	0.009
22	0.011	0.012	0.013	0.013	0.014	0.015	0.018	0.021	0.022	0.016
23	0.034	0.034	0.035	0.035	0.035	0.036	0.037	0.038	0.039	0.036
24	0.026	0.027	0.024	0.025	0.024	0.020	0.012	0.008	0.006	0.019
26	0.003	0.002	0.002	0.002	0.002	0.001	0.001	0.000	0.000	0.001
27	0.020	0.019	0.022	0.022	0.024	0.025	0.032	0.034	0.038	0.026
28	0.011	0.023	0.018	0.017	0.005	0.022	0.024	0.012	-0.006	0.014
29	-0.021	-0.020	-0.015	-0.014	-0.011	0.002	0.012	0.017	0.018	-0.004
30	-0.003	-0.003	-0.002	-0.002	-0.002	0.000	0.002	0.002	0.003	0.000
31	0.011	0.010	0.012	0.012	0.012	0.015	0.020	0.023	0.026	0.016
32	-0.006	-0.005	0.007	0.003	0.006	0.000	-0.011	-0.010	-0.004	-0.002
34	0.004	0.005	0.001	0.001	0.000	-0.004	-0.008	-0.008	-0.010	-0.002
35	0.004	0.017	0.014	0.008	0.014	0.018	0.020	0.017	0.028	0.016
36	0.003	0.003	0.004	0.004	0.005	0.006	0.010	0.012	0.013	0.007
37	-0.001	0.000	0.001	0.001	0.002	0.004	0.008	0.010	0.012	0.004
39	-0.027	-0.025	-0.027	-0.028	-0.027	-0.026	-0.011	-0.018	-0.028	-0.024
40	0.017	0.017	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018
41	0.027	0.023	0.017	0.011	0.005	-0.003	-0.013	-0.024	-0.028	0.002
42	-0.002	-0.001	0.000	0.000	0.001	0.002	0.003	0.003	0.004	0.001
average elasticity	0.006	0.007	0.008	0.007	0.007	0.007	0.008	0.006	0.008	0.007
industrial GDP/G	5.048	5.196	5.193	5.461	6.107	5.736	5.276	4.906	4.757	5.298
total GDP/G	12.525	12.733	12.682	13.229	14.437	13.385	12.285	11.406	10.992	12.630
return to industry	0.032	0.039	0.040	0.038	0.045	0.042	0.042	0.029	0.038	0.038
return to economy	0.080	0.095	0.099	0.092	0.107	0.098	0.097	0.067	0.088	0.092

Notes:

1. The numbers in the upper panel are the industry weighted average elasticities and their 9-year averages.
2. Average elasticity denotes the weighted average elasticity of the manufacturing sector.
3. Return to industry is the product of sector elasticity and industrial GDP/G.
4. Return to economy is the product of average elasticity and total GDP/G.

Table 3-8 Output elasticities and average rates of return: TFPQ

code	1999	2000	2001	2002	2003	2004	2005	2006	2007	average
13	-0.045	-0.045	-0.045	-0.045	-0.045	-0.044	-0.044	-0.044	-0.044	-0.045
14	-0.017	-0.017	-0.013	-0.010	-0.014	-0.009	-0.005	-0.004	-0.003	-0.010
15	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.048	0.048	0.047
16	0.023	0.022	0.023	0.023	0.022	0.022	0.021	0.022	0.022	0.022
17	0.007	0.008	0.010	0.009	0.011	0.016	0.015	0.024	0.022	0.014
18	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.001	0.000
19	0.024	0.025	0.024	0.023	0.022	0.022	0.019	0.019	0.018	0.022
20	-0.006	-0.011	-0.023	-0.017	-0.015	-0.020	-0.021	-0.028	-0.033	-0.020
21	0.006	0.005	0.004	0.004	0.004	0.000	-0.003	-0.009	-0.011	0.000
22	0.006	0.008	0.010	0.010	0.011	0.013	0.018	0.021	0.024	0.013
23	-0.003	-0.003	-0.001	-0.001	0.000	0.001	0.007	0.011	0.013	0.003
24	0.044	0.047	0.041	0.041	0.040	0.035	0.023	0.016	0.013	0.033
26	-0.008	-0.009	-0.011	-0.011	-0.012	-0.014	-0.013	-0.012	-0.014	-0.012
27	-0.008	-0.008	-0.009	-0.008	-0.009	-0.009	-0.010	-0.010	-0.011	-0.009
28	0.033	0.028	0.037	0.039	0.031	0.031	0.031	0.028	0.024	0.031
29	-0.007	-0.008	-0.009	-0.009	-0.011	-0.013	-0.013	-0.014	-0.014	-0.011
30	0.004	0.003	0.002	0.001	0.001	-0.009	-0.013	-0.016	-0.018	-0.005
31	0.016	0.017	0.016	0.016	0.017	0.015	0.013	0.012	0.011	0.015
32	0.018	0.020	0.021	0.020	0.021	0.021	0.017	0.018	0.023	0.020
34	-0.010	-0.009	-0.012	-0.012	-0.012	-0.015	-0.016	-0.016	-0.016	-0.013
35	-0.008	-0.008	-0.004	-0.004	-0.003	0.000	0.002	0.004	0.006	-0.002
36	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.001	-0.001	0.000	-0.002
37	-0.006	-0.005	-0.004	-0.004	-0.006	-0.003	-0.003	-0.001	-0.001	-0.004
39	-0.042	-0.042	-0.044	-0.043	-0.043	-0.044	-0.044	-0.043	-0.042	-0.043
40	0.027	0.029	0.022	0.032	0.030	0.031	0.024	0.010	0.002	0.023
41	-0.005	-0.004	-0.003	-0.002	0.000	0.002	0.003	0.005	0.006	0.000
42	-0.006	-0.007	-0.001	-0.003	0.000	0.007	0.009	0.013	0.018	0.003
average elasticity	0.002	0.002	0.002	0.003	0.002	0.003	0.002	0.001	0.000	0.002
industrial GDP/G	5.048	5.196	5.193	5.461	6.107	5.736	5.276	4.906	4.757	5.298
total GDP/G	12.525	12.733	12.682	13.229	14.437	13.385	12.285	11.406	10.992	12.630
return to industry	0.010	0.012	0.009	0.014	0.015	0.019	0.009	0.003	0.000	0.010
return to economy	0.026	0.031	0.023	0.035	0.036	0.045	0.020	0.007	0.000	0.025

Note: See Table 3-7.

Table 3-9 Nonparametric estimates of the productivity processes with spillover effects

Panel A: TFPR			Panel B: TFPQ		
	Estimate	Standard error		Estimate	Standard error
$z_{i,t-1}$	-1.487 ***	0.250	$\omega_{i,t-1}$	0.339 ***	0.016
$z^2_{i,t-1}$	-0.020 ***	0.005	$\omega^2_{i,t-1}$	-0.024 ***	0.001
$z^3_{i,t-1}$	0.000 ***	0.000	$\omega^3_{i,t-1}$	-0.001 ***	0.000
$z^4_{i,t-1}$	0.000 ***	0.000	$\omega^4_{i,t-1}$	0.000 ***	0.000
$g_{j,t-1}$	-0.010	0.007	$g_{j,t-1}$	0.038 ***	0.001
$z_{i,t-1}g_{j,t-1}$	0.119 ***	0.013	$\omega_{i,t-1}g_{j,t-1}$	0.012 ***	0.000
$\partial z_{i,t} / \partial g_{j,t-1}$ at median $z_{i,t-1}$			$\partial \omega_{i,t} / \partial g_{j,t-1}$ at median $\omega_{i,t-1}$		
	0.057			0.020	
Number of observations			Number of observations		
	1,347,547			1,347,547	
R-squared			R-squared		
	0.783			0.997	

Note:
1. Industrial dummies are included.
2. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3-10 Nonparametric estimates of the output elasticities with spillover effects

Panel A: TFPR				Panel B: TFPQ			
code	25th pct	50th pct	75th pct	code	25th pct	50th pct	75th pct
13	-0.007	0.003	0.017	13	-0.132	-0.130	-0.129
14	0.060	0.061	0.061	14	-0.046	-0.034	-0.022
15	0.030	0.039	0.050	15	-0.015	-0.005	0.006
16	0.075	0.078	0.081	16	0.002	0.005	0.008
17	0.021	0.030	0.040	17	0.037	0.041	0.044
18	0.053	0.060	0.069	18	0.051	0.058	0.065
19	0.016	0.023	0.039	19	0.067	0.071	0.079
20	-0.001	0.026	0.055	20	-0.051	-0.031	-0.009
21	-0.002	0.025	0.058	21	-0.017	-0.006	0.007
22	0.044	0.048	0.053	22	0.013	0.016	0.019
23	0.072	0.080	0.090	23	-0.039	-0.017	0.006
24	0.041	0.060	0.080	24	0.102	0.103	0.103
26	0.015	0.017	0.019	26	-0.022	-0.020	-0.019
27	0.016	0.024	0.032	27	-0.053	-0.051	-0.049
28	0.030	0.044	0.057	28	0.049	0.059	0.071
29	-0.061	-0.007	0.022	29	-0.038	-0.038	-0.038
30	0.006	0.008	0.012	30	-0.022	-0.012	-0.005
31	0.046	0.049	0.053	31	0.019	0.036	0.053
32	0.000	0.001	0.002	32	0.056	0.058	0.060
34	-0.015	-0.008	-0.001	34	-0.021	-0.017	-0.013
35	0.029	0.051	0.061	35	-0.018	-0.011	-0.002
36	0.017	0.018	0.018	36	-0.014	-0.010	-0.006
37	0.014	0.026	0.036	37	-0.041	-0.030	-0.018
39	-0.042	-0.040	-0.038	39	-0.091	-0.089	-0.087
40	0.042	0.049	0.057	40	0.001	0.078	0.156
41	0.025	0.031	0.036	41	-0.012	0.000	0.013
42	0.005	0.008	0.010	42	-0.012	0.008	0.035
average	0.020	0.030	0.040	average	-0.009	0.001	0.012

Table 3-11 Output elasticities and average rates of return with spillover effects: TFPR

code	1999	2000	2001	2002	2003	2004	2005	2006	2007	average
13	0.015	0.012	0.007	0.005	0.001	-0.010	-0.006	-0.015	-0.016	-0.001
14	0.050	0.050	0.050	0.050	0.050	0.050	0.049	0.049	0.049	0.050
15	0.027	0.030	0.034	0.035	0.041	0.036	0.040	0.042	0.049	0.037
16	0.056	0.055	0.055	0.055	0.055	0.054	0.053	0.053	0.054	0.054
17	0.039	0.035	0.034	0.033	0.030	0.026	0.024	-0.006	0.023	0.027
18	0.058	0.059	0.055	0.054	0.056	0.053	0.045	0.042	0.042	0.052
19	0.037	0.040	0.034	0.033	0.031	0.023	0.015	0.012	0.011	0.026
20	0.079	0.070	0.051	0.055	0.055	0.041	0.025	0.007	-0.004	0.042
21	0.057	0.057	0.049	0.048	0.045	0.033	0.019	-0.002	-0.013	0.033
22	0.039	0.040	0.041	0.041	0.043	0.044	0.047	0.051	0.052	0.044
23	0.063	0.062	0.066	0.063	0.065	0.070	0.073	0.076	0.079	0.069
24	0.067	0.069	0.063	0.064	0.062	0.054	0.038	0.027	0.024	0.052
26	0.017	0.017	0.016	0.015	0.015	0.013	0.013	0.012	0.011	0.014
27	0.010	0.009	0.010	0.010	0.011	0.013	0.020	0.022	0.025	0.014
28	0.041	0.055	0.047	0.046	0.030	0.052	0.054	0.037	0.013	0.042
29	-0.067	-0.066	-0.054	-0.053	-0.049	-0.023	0.002	0.011	0.014	-0.032
30	0.011	0.011	0.010	0.010	0.010	0.007	0.006	0.005	0.004	0.008
31	0.039	0.039	0.040	0.040	0.040	0.041	0.044	0.045	0.047	0.042
32	-0.001	0.000	0.007	0.005	0.006	0.002	-0.004	-0.003	0.000	0.002
34	0.005	0.006	0.002	0.001	0.000	-0.004	-0.008	-0.009	-0.010	-0.002
35	0.017	0.047	0.040	0.028	0.041	0.053	0.056	0.051	0.077	0.046
36	0.014	0.014	0.014	0.014	0.014	0.014	0.015	0.015	0.015	0.015
37	0.010	0.013	0.014	0.015	0.018	0.021	0.031	0.036	0.040	0.022
39	-0.041	-0.038	-0.040	-0.043	-0.041	-0.040	-0.022	-0.030	-0.043	-0.038
40	0.050	0.049	0.047	0.047	0.044	0.041	0.038	0.034	0.032	0.043
41	0.027	0.027	0.029	0.030	0.033	0.035	0.037	0.040	0.041	0.033
42	0.002	0.003	0.005	0.005	0.006	0.008	0.009	0.010	0.011	0.007
average elasticity	0.022	0.024	0.023	0.022	0.022	0.022	0.023	0.020	0.023	0.022
industrial GDP/G	5.048	5.196	5.193	5.461	6.107	5.736	5.276	4.906	4.757	5.298
total GDP/G	12.525	12.733	12.682	13.229	14.437	13.385	12.285	11.406	10.992	12.630
return to industry	0.113	0.127	0.119	0.121	0.137	0.126	0.121	0.097	0.107	0.119
return to economy	0.280	0.311	0.292	0.293	0.323	0.293	0.283	0.225	0.248	0.283

Note: See Table 3-7.

Table 3-12 Output elasticities and average rates of return with spillover effects: TFPQ

code	1999	2000	2001	2002	2003	2004	2005	2006	2007	average
13	-0.102	-0.102	-0.103	-0.103	-0.103	-0.104	-0.102	-0.102	-0.102	-0.102
14	-0.018	-0.020	-0.017	-0.014	-0.022	-0.020	-0.020	-0.022	-0.022	-0.019
15	-0.002	-0.002	-0.002	-0.002	0.002	-0.002	0.004	0.008	0.007	0.001
16	0.005	0.004	0.004	0.004	0.004	0.004	0.003	0.004	0.005	0.004
17	0.031	0.032	0.033	0.033	0.035	0.036	0.037	0.039	0.041	0.035
18	0.045	0.043	0.046	0.046	0.046	0.048	0.053	0.057	0.060	0.049
19	0.069	0.070	0.068	0.065	0.063	0.061	0.058	0.057	0.055	0.063
20	-0.002	-0.009	-0.032	-0.021	-0.019	-0.026	-0.027	-0.037	-0.046	-0.024
21	-0.014	-0.014	-0.013	-0.011	-0.011	-0.011	-0.009	-0.016	-0.016	-0.013
22	0.017	0.017	0.018	0.018	0.017	0.017	0.014	0.013	0.011	0.016
23	0.005	-0.001	-0.002	-0.011	-0.014	-0.017	-0.009	-0.003	-0.002	-0.006
24	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.091	0.092
26	-0.017	-0.017	-0.018	-0.018	-0.019	-0.020	-0.020	-0.019	-0.020	-0.019
27	-0.045	-0.045	-0.044	-0.044	-0.044	-0.043	-0.044	-0.043	-0.043	-0.044
28	0.055	0.040	0.060	0.065	0.046	0.044	0.049	0.044	0.034	0.049
29	-0.032	-0.032	-0.032	-0.032	-0.032	-0.032	-0.032	-0.032	-0.032	-0.032
30	-0.010	-0.009	-0.009	-0.009	-0.009	-0.016	-0.017	-0.018	-0.018	-0.013
31	0.024	0.020	0.024	0.020	0.018	0.025	0.038	0.044	0.049	0.029
32	0.052	0.053	0.053	0.053	0.054	0.054	0.051	0.053	0.056	0.053
34	-0.014	-0.012	-0.015	-0.014	-0.015	-0.017	-0.018	-0.018	-0.018	-0.016
35	-0.007	-0.012	-0.004	-0.009	-0.008	-0.004	-0.001	0.001	0.002	-0.005
36	-0.004	-0.005	-0.005	-0.005	-0.006	-0.005	-0.003	-0.003	-0.003	-0.005
37	-0.006	-0.009	-0.008	-0.008	-0.011	-0.010	-0.013	-0.012	-0.014	-0.010
39	-0.080	-0.080	-0.081	-0.081	-0.081	-0.082	-0.081	-0.080	-0.077	-0.080
40	0.019	0.041	0.047	0.078	0.088	0.117	0.112	0.094	0.090	0.076
41	0.013	0.014	0.015	0.016	0.019	0.024	0.026	0.030	0.030	0.021
42	0.012	0.008	0.017	0.016	0.022	0.031	0.036	0.042	0.049	0.026
average elasticity	-0.001	-0.001	0.001	0.004	0.005	0.011	0.012	0.011	0.009	0.006
industrial GDP/G	5.048	5.196	5.193	5.461	6.107	5.736	5.276	4.906	4.757	5.298
total GDP/G	12.525	12.733	12.682	13.229	14.437	13.385	12.285	11.406	10.992	12.630
return to industry	-0.007	-0.003	0.006	0.022	0.033	0.065	0.062	0.054	0.044	0.031
return to economy	-0.017	-0.007	0.014	0.054	0.079	0.151	0.144	0.124	0.102	0.072

Note: See Table 3-7.

Table 3-13 Output elasticities and average rates of return from robustness checks

Table 3-13.1 Broad infrastructure investment

Panel A: TFPR

year	1999	2000	2001	2002	2003	2004	2005	2006	2007	average
average elasticity	0.007	0.008	0.009	0.008	0.008	0.008	0.009	0.008	0.009	0.008
total GDP/G	9.832	9.689	9.574	9.798	10.116	9.627	9.098	8.442	7.980	9.351
return to economy	0.071	0.082	0.083	0.077	0.085	0.081	0.084	0.064	0.075	0.078

Panel B: TFPQ

year	1999	2000	2001	2002	2003	2004	2005	2006	2007	average
average elasticity	0.000	0.000	0.000	0.001	0.001	0.003	0.002	0.001	0.000	0.001
total GDP/BG	9.832	9.689	9.574	9.798	10.116	9.627	9.098	8.442	7.980	9.351
return to economy	-0.002	0.003	0.001	0.012	0.014	0.027	0.015	0.007	0.001	0.009

Table 3-13.2 Third-order polynomial

Panel A: TFPR

year	1999	2000	2001	2002	2003	2004	2005	2006	2007	average
average elasticity	0.004	0.004	0.005	0.005	0.004	0.005	0.006	0.007	0.007	0.005
total GDP/G	12.525	12.733	12.682	13.229	14.437	13.385	12.285	11.406	10.992	12.630
return to economy	0.051	0.057	0.058	0.062	0.064	0.070	0.080	0.075	0.071	0.065

Panel B: TFPQ

year	1999	2000	2001	2002	2003	2004	2005	2006	2007	average
average elasticity	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.002	0.001	0.002
total GDP/G	12.525	12.733	12.682	13.229	14.437	13.385	12.285	11.406	10.992	12.630
return to economy	0.022	0.029	0.026	0.039	0.044	0.045	0.037	0.020	0.009	0.030

Table 3-13.3 Spillover effects from neighbouring provinces

Panel A: TFPR

year	1999	2000	2001	2002	2003	2004	2005	2006	2007	average
average elasticity	0.015	0.017	0.015	0.014	0.014	0.014	0.015	0.012	0.016	0.015
total GDP/G	12.525	12.733	12.682	13.229	14.437	13.385	12.285	11.406	10.992	12.630
return to economy	0.192	0.213	0.186	0.191	0.207	0.189	0.182	0.138	0.176	0.186

Panel B: TFPQ

year	1999	2000	2001	2002	2003	2004	2005	2006	2007	average
average elasticity	-0.004	-0.002	-0.001	0.001	0.002	0.006	0.006	0.006	0.007	0.002
total GDP/G	12.525	12.733	12.682	13.229	14.437	13.385	12.285	11.406	10.992	12.630
return to economy	-0.045	-0.028	-0.016	0.016	0.034	0.082	0.071	0.073	0.080	0.030

Note: See Table 3-7.

Table 3-14 Robustness checks

Table 3-14.1 Banlancing panel

Panel A: TFPR										
year	1999	2000	2001	2002	2003	2004	2005	2006	2007	average
average elasticit	0.006	0.006	0.007	0.007	0.006	0.007	0.009	0.010	0.011	0.008
total GDP/G	12.525	12.733	12.682	13.229	14.437	13.385	12.285	11.406	10.992	12.630
return to econor	0.073	0.074	0.083	0.087	0.090	0.091	0.116	0.110	0.119	0.094
Panel B: TFPQ										
year	1999	2000	2001	2002	2003	2004	2005	2006	2007	average
average elasticit	-0.001	-0.002	-0.002	-0.002	-0.003	-0.002	0.000	0.001	0.000	-0.001
total GDP/G	12.525	12.733	12.682	13.229	14.437	13.385	12.285	11.406	10.992	12.630
return to econor	-0.016	-0.021	-0.023	-0.032	-0.038	-0.023	-0.005	0.008	-0.003	-0.017

Table 3-14.2 Three years lag

Panel A: TFPR								
year	2001	2002	2003	2004	2005	2006	2007	average
average elasticit	0.002	0.003	0.001	0.001	0.002	0.000	-0.002	0.001
total GDP/G	14.709	15.043	15.221	16.022	17.695	16.795	15.810	15.899
return to econor	0.025	0.038	0.015	0.013	0.028	0.001	-0.028	0.013
Panel B: TFPQ								
year	2001	2002	2003	2004	2005	2006	2007	average
average elasticit	0.000	0.002	0.002	0.005	0.003	0.002	0.001	0.002
total GDP/G	14.709	15.043	15.221	16.022	17.695	16.795	15.810	15.899
return to econor	0.005	0.035	0.029	0.073	0.059	0.039	0.013	0.036

Table 3-15 Output elasticities and firm characteristics

Dependant variable: output elasticities*1000

model	TFPR	TFPQ	TFPR-spillover	TFPQ-spillover
age	-0.014***	-0.034***	-0.030***	-0.034***
	(0.002)	(0.001)	(0.004)	(0.003)
age square	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Capital intensity	-0.231***	0.017	0.060**	0.150***
	(0.013)	(0.013)	(0.025)	(0.029)
lnemp	-0.073***	-0.123***	-0.141***	-0.148***
	(0.019)	(0.015)	(0.040)	(0.035)
NSOE	1.004***	1.177***	0.184	0.188
	(0.078)	(0.061)	(0.168)	(0.142)
EXPORT	0.737***	0.460***	0.650***	1.545***
	(0.026)	(0.027)	(0.049)	(0.059)
EASTERN	0.487***	1.944***	0.139**	0.842***
	(0.029)	(0.028)	(0.061)	(0.059)
observations	1,346,897	1,346,897	1,346,897	1,346,897
R-squared	0.49	0.774	0.48	0.774

Note:

1. age: age of firm
2. lnemp: log of number of employees
3. NSOE: non-SOE dummy, non-SOEs = 1, SOEs = 0
4. EXPORT: exporters dummy, exporters = 1, nonexporters = 0
5. EASTERN: location dummy, eastern province = 1, noneastern province = 0
6. Industry dummies and year dummies are included in all the regressions.
7. Robust standard errors are reported in parentheses.
8. *** p<0.01, ** p<0.05, * p<0.1

Table 3-A1 Re-estimating Table 3 Panel B using 2003-2007 subsample

	TFPR			OLS		
code	θ_l	θ_k	θ_m	θ_l	θ_k	θ_m
13	0.038	0.022	0.928	0.057	0.035	0.886
14	0.035	0.027	0.936	0.047	0.040	0.901
15	0.062	0.025	0.931	0.066	0.037	0.895
16	0.154	0.145	0.836	0.105	0.186	0.818
17	0.036	0.005	0.965	0.062	0.035	0.875
18	0.093	0.021	0.887	0.115	0.048	0.807
19	0.062	0.026	0.919	0.087	0.044	0.852
20	0.050	0.020	0.916	0.045	0.040	0.880
21	0.049	0.025	0.915	0.088	0.041	0.849
22	0.030	0.017	0.953	0.053	0.043	0.879
23	0.068	0.064	0.872	0.057	0.073	0.865
24	0.089	0.039	0.871	0.091	0.055	0.827
26	0.015	0.030	0.947	0.047	0.051	0.871
27	0.042	0.026	0.950	0.062	0.057	0.864
28	0.022	0.020	0.947	0.042	0.028	0.915
29	0.051	0.028	0.920	0.078	0.054	0.842
30	0.059	0.022	0.934	0.068	0.051	0.854
31	0.038	0.018	0.937	0.022	0.039	0.906
32	0.035	0.012	0.958	0.059	0.035	0.900
34	0.274	0.063	0.694	0.068	0.050	0.852
35	0.025	0.027	0.950	0.052	0.050	0.866
36	0.029	0.035	0.928	0.051	0.049	0.855
37	0.047	0.043	0.899	0.072	0.052	0.856
39	0.048	0.022	0.931	0.080	0.048	0.846
40	0.092	0.031	0.892	0.096	0.060	0.828
41	0.061	0.040	0.879	0.067	0.057	0.821
42	0.089	0.022	0.903	0.092	0.037	0.844

Table3-A2 Re-estimating Table 3 Panel A using non-exporters subsample

code	β_l	β_k	β_m	β_s	β_g
13	0.047	0.032	0.910	0.021	0.142
14	0.000	0.051	0.928	0.061	0.055
15	0.017	0.047	0.944	0.001	0.139
16	-0.306	0.265	0.987	-0.058	0.229
17	-0.011	0.014	0.983	0.012	-0.004
18	0.107	0.002	0.891	0.047	0.021
19	0.081	0.016	0.914	0.030	0.045
20	-0.100	0.171	0.685	0.194	0.220
21	0.000	0.087	0.821	0.061	0.116
22	0.078	0.083	0.788	0.066	0.064
23	0.271	0.073	0.733	0.127	0.080
24	0.023	0.050	0.912	0.001	0.005
26	0.019	0.029	0.929	0.021	0.019
27	0.184	0.043	0.832	0.173	0.114
28	0.006	0.024	0.946	-0.004	-0.014
29	0.002	0.014	0.984	0.017	0.085
30	0.061	0.054	0.867	0.027	0.089
31	0.134	0.036	0.851	0.211	0.102
32	0.045	0.018	0.933	0.004	-0.029
34	0.007	0.033	0.936	0.038	0.029
35	0.268	0.051	0.660	0.149	-0.023
36	0.160	0.040	0.768	0.155	0.016
37	0.085	0.055	0.844	0.115	0.032
39	0.044	0.027	0.908	0.037	-0.009
40	0.210	-0.008	0.939	-0.198	-0.008
41	0.042	0.094	0.728	0.144	0.027
42	0.042	0.049	0.887	0.008	0.096

Table A3 Estimates for the revenue equations with spillover effects: TFPR

code	θ_l	$s.e.(\theta_l)$	θ_k	$s.e.(\theta_k)$	θ_m	$s.e.(\theta_m)$
13	0.041	0.005	0.034	0.003	0.915	0.004
14	0.043	0.017	0.052	0.005	0.905	0.010
15	0.003	0.038	0.057	0.011	0.943	0.035
16	0.444	0.764	0.187	0.100	0.699	0.425
17	0.038	0.010	0.019	0.003	0.936	0.013
18	0.142	0.048	0.017	0.004	0.847	0.044
19	0.062	0.020	0.022	0.008	0.919	0.030
20	0.101	0.058	-0.012	0.045	0.980	0.074
21	0.037	0.036	0.047	0.024	0.896	0.036
22	0.064	0.030	0.062	0.027	0.848	0.036
23	0.092	0.167	0.113	0.020	0.798	0.119
24	0.080	0.069	0.059	0.012	0.838	0.088
26	0.026	0.007	0.034	0.003	0.927	0.007
27	0.118	0.031	-0.003	0.041	0.994	0.072
28	0.028	0.012	0.024	0.008	0.935	0.014
29	0.051	0.061	0.011	0.030	0.951	0.072
30	0.061	0.012	0.058	0.019	0.861	0.025
31	0.090	0.008	0.061	0.022	0.864	0.005
32	0.052	0.013	0.014	0.008	0.945	0.012
34	0.093	0.034	0.014	0.023	0.935	0.045
35	0.017	0.006	0.045	0.005	0.914	0.009
36	0.064	0.021	0.037	0.022	0.912	0.032
37	0.125	0.037	0.027	0.020	0.874	0.028
39	0.045	0.007	0.031	0.004	0.917	0.008
40	0.129	0.026	0.080	0.023	0.820	0.027
41	0.094	0.058	0.114	0.039	0.727	0.092
42	0.087	0.035	0.039	0.004	0.859	0.035

Note: All standard errors are bootstrapped using 1000 replications.

Table 3-A4 Estimates for the revenue equations with spillover effects: TFPQ

code	β_l	$s.e.(\beta_l)$	β_k	$s.e.(\beta_k)$	β_m	$s.e.(\beta_m)$	β_s	$s.e.(\beta_s)$	β_g	$s.e.(\beta_g)$
13	0.042	0.020	0.031	0.004	0.913	0.019	0.036	0.007	0.274	0.071
14	0.128	0.027	0.040	0.021	0.842	0.028	0.147	0.017	0.113	0.015
15	-0.029	0.029	0.052	0.029	0.969	0.019	-0.021	0.025	0.155	0.022
16	0.622	0.499	0.190	0.282	0.615	0.302	0.036	0.041	0.308	0.194
17	0.160	0.047	0.033	0.022	0.780	0.070	-0.015	0.037	0.038	0.027
18	0.198	0.036	0.009	0.004	0.806	0.031	-0.083	0.008	0.153	0.016
19	0.192	0.012	0.032	0.007	0.781	0.024	-0.248	0.010	0.153	0.020
20	-0.080	0.072	0.061	0.049	0.937	0.077	0.021	0.028	0.619	0.054
21	0.017	0.074	0.074	0.073	0.826	0.100	0.167	0.026	0.213	0.064
22	-0.029	0.036	0.000	0.041	1.038	0.055	-0.024	0.030	0.162	0.038
23	-0.054	0.035	0.111	0.066	0.889	0.038	0.134	0.016	0.207	0.023
24	0.297	0.029	0.033	0.007	0.679	0.038	-0.219	0.015	0.150	0.024
26	0.029	0.036	0.035	0.008	0.919	0.028	0.027	0.021	0.052	0.015
27	0.032	0.038	0.057	0.060	0.916	0.032	0.235	0.016	0.201	0.027
28	0.033	0.009	0.029	0.005	0.923	0.011	-0.025	0.008	0.014	0.037
29	0.046	0.084	0.034	0.062	0.914	0.060	0.078	0.021	0.156	0.025
30	0.045	0.100	0.052	0.107	0.874	0.177	0.126	0.020	0.220	0.104
31	0.144	0.013	-0.003	0.035	0.891	0.011	0.100	0.011	0.231	0.017
32	0.046	0.006	0.019	0.003	0.937	0.006	0.018	0.004	-0.103	0.080
34	0.023	0.062	0.034	0.016	0.931	0.053	0.025	0.017	0.055	0.010
35	0.016	0.043	0.039	0.012	0.928	0.043	0.034	0.025	0.068	0.016
36	0.017	0.104	0.068	0.051	0.873	0.073	0.151	0.038	0.075	0.032
37	0.204	0.026	0.058	0.047	0.755	0.030	0.260	0.018	0.045	0.020
39	0.061	0.087	0.027	0.013	0.905	0.085	0.077	0.010	-0.019	0.033
40	0.114	0.034	-0.008	0.035	0.930	0.016	0.231	0.012	0.183	0.020
41	0.044	0.069	0.128	0.094	0.721	0.109	0.167	0.034	-0.038	0.041
42	0.250	0.076	0.035	0.014	0.708	0.070	-0.011	0.014	0.102	0.020

Note: All standard errors are bootstrapped using 1000 replications.

Table 3-A5 Estimates with broad infrastucture investment

	TFPR			TFPQ				
code	θ_l	θ_k	θ_m	β_l	β_k	β_m	β_s	β_g
13	0.042	0.035	0.911	0.048	0.033	0.909	0.022	0.140
14	0.026	0.053	0.919	0.065	0.049	0.888	0.061	0.055
15	-0.051	0.057	0.985	-0.055	0.052	0.995	-0.023	0.080
16	0.451	0.189	0.697	0.685	0.227	0.544	-0.129	0.109
17	0.015	0.014	0.967	0.023	0.014	0.952	-0.016	0.049
18	0.211	-0.001	0.813	0.078	0.008	0.930	-0.013	0.103
19	0.064	0.014	0.934	0.181	0.026	0.801	-0.075	0.110
20	0.131	-0.032	0.989	-0.055	0.115	0.795	0.118	0.291
21	0.064	0.026	0.918	0.001	0.108	0.795	0.086	0.194
22	0.057	0.072	0.841	0.067	0.084	0.799	0.038	0.099
23	0.280	0.124	0.658	0.281	0.067	0.732	0.075	0.117
24	0.062	0.055	0.870	0.099	0.035	0.883	-0.063	0.050
26	0.019	0.032	0.936	0.021	0.032	0.933	0.007	0.038
27	0.075	0.148	0.755	0.151	0.093	0.777	0.161	0.124
28	0.015	0.021	0.948	0.024	0.027	0.934	-0.014	0.065
29	0.051	0.052	0.883	0.179	0.132	0.617	0.148	0.057
30	0.060	0.058	0.863	0.045	0.054	0.881	-0.018	0.112
31	0.080	0.110	0.848	0.114	0.052	0.846	0.099	0.101
32	0.047	0.014	0.948	0.046	0.021	0.935	0.013	-0.024
34	0.102	0.013	0.930	0.018	0.032	0.942	0.014	0.042
35	0.002	0.044	0.930	0.220	0.036	0.769	0.058	0.017
36	0.059	0.058	0.874	-0.098	0.062	0.996	0.007	0.065
37	0.158	-0.005	0.895	0.056	0.059	0.872	0.099	0.036
39	0.047	0.033	0.913	0.074	0.028	0.896	0.049	-0.029
40	0.092	0.115	0.812	0.133	0.017	0.875	0.130	0.083
41	0.082	0.034	0.893	0.110	0.105	0.707	0.100	-0.006
42	0.089	0.039	0.858	0.223	0.028	0.750	-0.010	0.068

Table 3-A6 Nonparametric estimates of the output elasticities with broad infrastucture investment

Panel A: TFPR					Panel B: TFPQ			
code	25th pct	50th pct	75th pct		code	25th pct	50th pct	75th pct
13	-0.002	0.000	0.003		13	-0.057	-0.056	-0.056
14	0.020	0.021	0.022		14	-0.025	-0.016	-0.005
15	-0.001	0.005	0.010		15	-0.012	-0.005	0.002
16	0.039	0.040	0.041		16	0.032	0.035	0.037
17	0.001	0.006	0.013		17	0.011	0.017	0.021
18	0.027	0.028	0.029		18	0.002	0.002	0.002
19	0.003	0.006	0.014		19	0.018	0.021	0.024
20	-0.012	0.003	0.018		20	-0.043	-0.027	-0.010
21	-0.014	0.001	0.021		21	-0.012	0.002	0.014
22	0.014	0.018	0.022		22	0.004	0.011	0.019
23	0.042	0.046	0.050		23	-0.002	0.008	0.019
24	0.011	0.021	0.032		24	0.027	0.041	0.054
26	0.002	0.003	0.003		26	-0.014	-0.012	-0.011
27	0.017	0.025	0.033		27	-0.014	-0.011	-0.007
28	0.006	0.015	0.025		28	0.011	0.015	0.019
29	-0.015	0.010	0.020		29	-0.011	-0.003	0.003
30	0.003	0.004	0.004		30	-0.006	-0.004	0.001
31	0.016	0.022	0.028		31	0.019	0.020	0.021
32	-0.006	-0.004	-0.002		32	0.011	0.013	0.015
34	-0.013	-0.007	-0.001		34	-0.019	-0.015	-0.012
35	0.009	0.019	0.024		35	-0.008	-0.002	0.006
36	0.004	0.010	0.014		36	-0.005	-0.003	0.000
37	0.004	0.009	0.014		37	-0.013	-0.010	-0.006
39	-0.026	-0.024	-0.022		39	-0.047	-0.046	-0.045
40	0.020	0.022	0.022		40	0.009	0.037	0.063
41	-0.024	-0.008	0.018		41	-0.015	-0.009	-0.001
42	-0.001	0.003	0.005		42	-0.010	0.002	0.016
average	0.005	0.011	0.017		average	-0.006	0.000	0.007

Table 3-A7 Estimates with third-order polynomialsproductivity process

	TFPR			TFPQ				
code	θ_l	θ_k	θ_m	β_l	β_k	β_m	β_s	β_g
13	0.039	0.032	0.920	0.045	0.032	0.912	0.024	0.128
14	0.043	0.062	0.891	0.004	0.055	0.922	0.057	0.042
15	0.145	0.024	0.880	0.209	0.076	0.741	0.086	0.071
16	1.461	0.386	-0.030	0.603	0.236	0.593	-0.133	0.158
17	0.127	0.009	0.860	0.189	0.004	0.814	-0.013	-0.019
18	0.128	-0.026	0.956	0.010	0.005	1.010	-0.001	0.077
19	0.250	0.004	0.775	0.198	0.018	0.815	-0.105	0.066
20	0.128	-0.033	0.993	0.116	-0.026	0.985	-0.049	0.222
21	0.103	-0.012	0.920	0.121	0.009	0.900	0.064	0.083
22	0.056	0.081	0.835	0.049	0.101	0.791	0.035	0.060
23	0.086	0.050	0.914	0.156	0.080	0.804	0.092	0.074
24	0.054	0.072	0.828	0.119	0.019	0.879	-0.088	0.037
26	0.010	0.031	0.944	0.018	0.033	0.935	0.012	0.021
27	0.080	0.165	0.733	0.171	0.080	0.793	0.185	0.086
28	0.003	0.022	0.956	0.013	0.028	0.941	-0.009	-0.006
29	0.051	0.073	0.843	0.046	0.018	0.941	0.027	0.059
30	0.059	0.062	0.859	0.058	0.059	0.862	0.043	0.090
31	0.086	0.120	0.834	0.116	0.052	0.840	0.110	0.084
32	0.042	0.018	0.942	0.044	0.020	0.937	0.014	-0.044
34	0.145	0.018	0.885	0.198	0.024	0.819	0.030	0.011
35	0.110	0.014	0.911	0.108	0.002	0.933	0.023	-0.020
36	0.061	0.045	0.894	0.058	0.083	0.813	0.103	0.014
37	-0.061	0.044	0.983	0.030	0.078	0.868	0.095	0.025
39	0.054	0.033	0.906	0.071	0.027	0.900	0.042	-0.022
40	0.128	0.130	0.750	0.115	0.057	0.860	0.119	0.039
41	0.100	0.036	0.873	0.168	0.092	0.685	0.085	-0.010
42	0.084	0.041	0.857	0.081	0.032	0.885	0.001	0.047

Table 3-A8 Nonparametric estimates of the output elasticities with third-order polynomials

Panel A: TFPR				Panel B: TFPQ			
code	25th pct	50th pct	75th pct	code	25th pct	50th pct	75th pct
13	-0.013	-0.009	-0.003	13	-0.055	-0.055	-0.054
14	-0.004	0.008	0.020	14	-0.033	-0.023	-0.011
15	0.004	0.007	0.011	15	0.006	0.011	0.016
16	0.012	0.025	0.044	16	0.024	0.024	0.025
17	0.004	0.009	0.012	17	0.010	0.021	0.031
18	0.000	0.007	0.014	18	-0.008	-0.006	-0.004
19	0.002	0.009	0.018	19	0.027	0.033	0.036
20	-0.014	0.002	0.019	20	-0.006	0.004	0.014
21	-0.015	-0.004	0.009	21	-0.015	-0.004	0.003
22	0.010	0.015	0.021	22	0.012	0.015	0.018
23	0.007	0.009	0.012	23	-0.012	-0.001	0.011
24	0.013	0.015	0.017	24	0.033	0.039	0.043
26	-0.005	-0.004	-0.002	26	-0.014	-0.013	-0.012
27	0.019	0.028	0.037	27	-0.009	-0.009	-0.009
28	0.002	0.011	0.019	28	0.027	0.031	0.034
29	-0.012	0.004	0.012	29	-0.019	-0.016	-0.013
30	-0.004	-0.003	-0.003	30	-0.016	-0.007	0.003
31	0.011	0.020	0.031	31	0.014	0.018	0.023
32	-0.001	0.000	0.001	32	0.017	0.018	0.019
34	-0.005	-0.004	-0.002	34	-0.010	-0.010	-0.010
35	-0.004	-0.001	0.003	35	-0.014	-0.006	0.002
36	0.000	0.003	0.004	36	-0.007	-0.004	0.000
37	-0.004	0.002	0.007	37	-0.012	-0.007	-0.002
39	-0.025	-0.024	-0.023	39	-0.049	-0.046	-0.044
40	0.027	0.028	0.028	40	0.011	0.038	0.058
41	-0.018	-0.006	0.013	41	-0.017	-0.006	0.006
42	-0.007	0.000	0.004	42	-0.023	-0.016	-0.007
average	-0.001	0.005	0.012	average	-0.005	0.001	0.007

Table 3-A9 Estimates with spillover effects from neighboring provinces

	TFPR			TFPQ				
code	θ_l	θ_k	θ_m	β_l	β_k	β_m	β_s	β_g
13	0.039	0.035	0.916	0.047	0.034	0.902	0.046	0.275
14	0.019	0.054	0.925	0.027	0.044	0.916	0.091	0.144
15	-0.032	0.058	0.970	0.237	-0.033	0.869	-0.706	0.458
16	0.619	0.251	0.542	0.988	0.279	0.316	-0.207	0.390
17	0.023	0.018	0.954	-0.045	-0.003	1.056	-0.002	-0.022
18	0.138	0.014	0.859	0.168	0.007	0.855	0.026	0.136
19	0.068	0.021	0.918	0.147	0.027	0.843	-0.066	0.127
20	0.132	-0.024	0.980	0.017	0.144	0.835	-1.363	1.119
21	0.052	0.039	0.908	0.069	0.059	0.833	0.144	0.266
22	0.074	0.074	0.818	0.177	-0.032	0.936	0.019	0.156
23	0.375	0.114	0.613	0.052	0.085	0.859	0.145	0.281
24	0.064	0.054	0.881	0.151	0.031	0.853	0.036	0.188
26	0.021	0.033	0.932	0.013	0.030	0.941	0.008	0.023
27	0.189	-0.026	0.994	0.179	0.124	0.691	0.311	0.152
28	0.021	0.023	0.940	0.026	0.034	0.917	-0.002	-0.023
29	0.063	0.062	0.851	0.021	0.016	0.969	0.024	0.196
30	0.061	0.062	0.858	0.031	0.091	0.829	0.059	0.240
31	0.096	0.099	0.839	0.116	0.064	0.825	-0.423	0.441
32	0.049	0.013	0.947	0.048	0.020	0.934	0.024	-0.141
34	0.084	0.014	0.942	0.036	0.033	0.933	0.039	0.040
35	0.004	0.043	0.929	0.149	0.017	0.874	0.001	0.050
36	0.070	0.053	0.869	0.070	0.070	0.825	0.126	0.090
37	0.152	0.008	0.880	0.065	0.038	0.893	0.119	0.090
39	0.045	0.034	0.914	0.070	0.033	0.896	0.038	0.006
40	0.101	0.114	0.792	0.048	0.096	0.879	0.174	0.272
41	0.069	0.051	0.871	0.073	0.147	0.674	0.093	0.059
42	0.081	0.038	0.868	0.180	0.026	0.808	0.016	0.057

Table 3-A10 Output elasticities with spillover from neighboring provinces

Panel A: TFPR					Panel B: TFPQ			
code	25th pct	50th pct	75th pct		code	25th pct	50th pct	75th pct
13	-0.009	-0.001	0.012		13	-0.136	-0.125	-0.117
14	0.026	0.033	0.040		14	-0.052	-0.047	-0.044
15	0.013	0.019	0.026		15	0.038	0.062	0.091
16	0.010	0.013	0.015		16	-0.032	-0.020	-0.011
17	0.008	0.019	0.034		17	-0.021	-0.009	0.001
18	0.043	0.051	0.060		18	0.002	0.010	0.016
19	0.016	0.027	0.051		19	0.040	0.041	0.043
20	-0.012	0.013	0.040		20	0.063	0.100	0.137
21	-0.002	0.011	0.028		21	-0.022	0.003	0.020
22	0.029	0.040	0.051		22	0.008	0.019	0.030
23	0.044	0.062	0.078		23	-0.048	-0.016	0.003
24	0.026	0.048	0.071		24	0.012	0.034	0.052
26	0.010	0.011	0.013		26	-0.015	-0.013	-0.011
27	0.011	0.015	0.019		27	-0.042	-0.029	-0.016
28	0.023	0.036	0.048		28	0.044	0.050	0.057
29	-0.036	0.023	0.051		29	-0.046	-0.034	-0.025
30	0.008	0.008	0.009		30	-0.011	-0.003	0.005
31	0.032	0.038	0.045		31	0.021	0.049	0.091
32	-0.004	-0.003	-0.002		32	0.071	0.073	0.074
34	-0.013	-0.008	-0.003		34	-0.024	-0.019	-0.015
35	0.019	0.033	0.040		35	-0.002	0.000	0.002
36	0.012	0.014	0.016		36	-0.018	-0.003	0.007
37	0.003	0.016	0.028		37	-0.018	-0.014	-0.011
39	-0.033	-0.032	-0.031		39	-0.062	-0.060	-0.059
40	0.037	0.040	0.044		40	0.040	0.083	0.109
41	-0.013	0.003	0.028		41	0.000	0.001	0.001
42	0.006	0.008	0.012		42	-0.013	-0.005	0.006
average	0.009	0.020	0.030		average	-0.008	0.005	0.016

Chapter 4

The dynamic learning by exporting effect in Chinese manufacturing sector

4.1 Introduction

Opening to international trade is a key factor that promotes China's economic growth, which is emphasized by the large literature on China's economic miracle, such as the studies by Song, Storesletten and Zilibotti (2011) and Zhu (2012). However, there is no unified conclusion in the literature regarding the productivity of exporters in China. Lin (2015) notes that one percentage point expansion in exports increases productivity by approximately 0.04 percentage points. Ding, Guariglia and Harris (2016) discover that exporters appear to have higher TFP in only 9 of 26 sectors. Our second chapter shows that the productivity advantage of exporters relative to non-exporters is sensitive to the production function estimation methods. Dai, Maitra and Yu (2016) separate the exporters into two types: processing exporters and non-processing exporters. Productivity of processing exporters is lower than both non-processing exporters and non-exporters. However, this is not the case in the US, as demonstrated by Bernard, Eaton, Jensen and Kortum (2003), which suggest that exporters are a minority, and they tend to be more productive and larger in scale than other agents. These studies focus on the exporter's productivity level. However, the growth rate of productivity is more important for long-term performance. By increasing their growth rate, less productive firms can catch up with their competitors, but they may be forced to leave the market if their productivity growth remains low.

In this study, we use Chinese firm-level data to examine whether exporters have higher productivity growth. Compared with earlier studies that use Chinese data, we analyze from a dynamic perspective and consider that the evolution of productivity depends on previous exporting experience, which is similar to the analysis in De Loecker (2013). This allows us to make full use of the panel structure of the data. De Loecker (2013) uses data from Slovenia, which is a quite small country in terms of economic scale compared to China. From the value chain perspective, numerous Chinese processing trade firms solely concentrate on the production stage. However, firms in more developed countries also obtain profits during the product design and final marketing stages. By using Chinese firms' data, the effect of exporting on productivity growth can be diverse, which is new to the literature.

To quantify the learning by exporting (LBE hereafter) effect, we estimate productivity using the ACF approach, which incorporates the exporting status into the law of motion of productivity, and analyze data for Chinese industrial firms over 2003-2007. We note that the learning by exporting effect is heterogeneous across industries. Only several upstream and middle-stream industries have a significantly positive learning by exporting effect, which indicates that the exporters in these industries have higher productivity growth because they export. Other industries have a significantly negative or insignificant learning by exporting effect. These results are robust to changes in the productivity process and the estimation methods of the production function. This result contradicts De Loecker (2013), which notes that all the industries in Slovenia enjoy substantial productivity gains from exporting activities. De Loecker (2013) contends that exporters can directly learn from their customers and indirectly improve because of competition from local producers in foreign countries.

To explain the heterogeneous learning by exporting effect, we refer to prior studies. Dai, Maitra and Yu (2016) find that the processing trade should be responsible for the unexceptional performance of exporters in China. Although we do not have detailed information about the processing trade, we first show that the productivity for the current period is significantly and negatively related with the exporting intensity of the previous period for most of industries, which is robust to production function estimation methods. Furthermore, we treat firms with exporting intensity higher than 76% as a proxy for the processing trade firms because the average exporting intensity of processing trade firms reported by Dai, Maitra and Yu (2016) is 76%. Heavily exporting firms have characteristics that are similar to processing trade firms, which are described by Dai, Maitra and Yu (2016). We note that the processing trade firms have significantly lower productivity growth than other exporters and non-exporters in many industries. The number of industries with a positive learning by exporting effect increases when we compare exporters with exporting intensity less than 40% with non-exporters.

We separate the entire sample into two groups, an FIE subsample and a non-FIE subsample, to determine the difference of the learning by exporting effect because Lu, Lu and Tao (2010) note that only exporters among FIEs are less productive than non-exporters. However, we note that there is no systematic difference in the learning by exporting effect between these two subsamples.

The heterogeneous learning by exporting effect may be related to a firm's capital intensity. De Loecker (2007) reports intuitive results that indicate firms gain more from shipping their products to relatively more developed countries, which are generally considered to have comparative advantages in capital-intensive industries. Lu (2010) further argues that firms in industries that intensively use locally abundant factors face more competition in domestic markets than in foreign markets. More explicitly, the domestic market competition in the labor-intensive industries of China is fiercer than that of other countries. Hence, capital-intensive firms may learn more from foreign markets. By using a nonlinear productivity process, we can measure the learning by exporting effect for each exporter. Then, we regress the learning by exporting effect with the firm's capital intensity, which confirms the positive correlation between these two factors.

The final explanation we offer regarding the heterogeneous learning by exporting effect is the anti-competitive effect of protection policies on exporters. This occurs because they can simply charge a lower price to gain a competitive advantage rather relying on other productivity-enhancing channels. Dai, Maitra and Yu (2016) confirm that the corporate income tax is reduced for these exporters. In addition, we analyze data regarding subsidies to firms and note that these subsidies and reduced income taxes lead to a reduced learning by exporting effect.

The contribution of this study is as follows. First, we note that it is possible to have a negative learning by exporting effect, particularly for processing trade firms because they solely focus on production. They have fewer connections with final consumers and their competitors than ordinary trade firms and non-exporters. The difference between these three types of firms (non-exporters, processing exporters and ordinary exporters) offers indirect evidence regarding the learning by exporting mechanisms that are mentioned in the literature. Second, to explain the heterogeneous learning by exporting effect, we check the roles of the processing trade, capital intensity, and government protection policies. Third, our study is related to literature regarding financial constraints. Certain studies investigate the effect of financial constraints on productivity and use Chinese manufacturing data, for example, Chen and Guariglia (2013). These studies may consider the potential relation between exporting behavior and the status of financial constraints. Financial constraints induce firms to engage in the processing trade rather than the ordinary trade.

The remainder of this chapter is organized as follows. Section 2 provides a literature review. Section 3 describes the empirical specification used to estimate the dynamic effect of exporting on productivity. Section 4 provides a description of the data set we use. Section 5 presents our empirical results. Section 6 provides possible explanations for the heterogeneous learning by exporting effect. Section 7 provides the conclusion.

4.2 Literature review

4.2.1 International trade and productivity

A two-way relationship exists between exporting experience and productivity. On the one hand, more productive firms may self-select to be exporters. On the other hand, less productive firms may learn to improve their productivity by exporting.

Aw, Chung and Roberts (2000) note that the most productive firms in Taiwan choose to export. Using data from the US, Bernard and Jensen (1999) report similar findings, that good firms become exporters. These scholars note that the only benefit of exporting for firms is an increased probability of survival and exporters' productivity growth is not superior over longer horizons. Melitz (2003) incorporates this characteristic into his model. In addition, he emphasizes the exit of the less productive firms. This reallocation process promotes the productivity growth of that industry. Manova (2013) argues that more productive firms tend to become exporters because only they can afford the additional upfront expenditures. The productivity cut-off for exporting is higher for industries that are more financially vulnerable and lower for countries that are more financially developed. Dai, Maitra and Yu (2016) note that the productivity of Chinese exporters is not exceptionally high and argue that the processing trade should be responsible for the unexceptional performance of exporters. They conclude that Chinese exporters' experience is consistent with the Melitz model.

Blalock and Gertler (2004) note that productivity increased 2%-5% after Indonesian firms engage in the exporting business. Van Biesebroeck (2005) discovers that manufacturing firms in sub-Saharan African countries learn from exporting. A scale economy is found to be an important channel. De Loecker (2007) proves that the destination countries matter; if a country is significantly developed, then productivity of exporters will improve. Martins and Yang (2009) note that 18 of 33 studies that focus on the productivity effect of exporting note that there is a significant positive effect. De Loecker (2013) believes that exporters can learn from their foreign producers and customers. With this new information, they may improve the quality of their products and increase the size of shipments. In addition, specific investments can be made to improve productivity.

Pavcnik (2002) empirically demonstrates that trade liberalization forces inefficient firms to exit the market, while efficient firms expand their market shares. Yu (2010) confirms that trade liberalization significantly boosts a firm's productivity. De Loecker (2011) also notes that a reduction in quotas will lead to a reallocation process.

4.2.2 Processing trade in China

Since the 1990s, the processing trade has developed rapidly in China. In 2008, the total value of the exports and imports of the processing trade exceeded 1 trillion US dollars. Both domestic and foreign capitals are invested in the processing trade. The low wage rate and loose environmental protection policies are the primary incentives that attract foreign firms, as noted by Jiang and Zhao (2008).

The production of processing trade firms has a very strong element of seasonality due to the seasonality of foreign orders. Zeng and Zhong (2010) argue that firms receive numerous orders during winter and spring; however, the number of orders falls during summer and autumn. Compared with ordinary firms, generally, processing trade firms have less time to prepare for production. Other firms can arrange their production smoothly based on planned output. The output rate for processing trade firms should be higher than that of ordinary firms.

This production pattern also directly affects employment. During summer and autumn, firms may lay off unnecessary workers to reduce their costs. Usually, they will try to hire many new workers after the Chinese New Year celebration. In 2004, there was a shortage of rural workers in Guangdong, Fujian and Zhejiang. Hence, the labor mobility for processing trade firms should be higher than that of ordinary firms. New workers take time to become familiar with production processes, which subsequently decreases productivity.

Certain policies have been designed to help processing trade firms. First, firms are not required to pay tariffs for imported intermediate inputs that are used in the production of final products that will be exported. Second, these firms pay a lower corporate income tax if they export most of their products; generally, the threshold is 70%. For more details, please refer to Dai, Maitra and Yu (2016).

Why do Chinese firms continue to engage in the processing trade? According to a survey in Yan et al. (2009), they are attracted by the direct benefit of avoiding trade barriers. Firms can focus on production; they do not have to worry about the brand and distribution channels. In international trade, a letter of credit is used for settlement, which can effectively reduce the risk for payment recovery. For other firms, there may be excessive accounts receivables, which seriously affect the normal operation of enterprises. Yan et al. (2009) find that the profit rate is low in processing trade firms. Manova and Yu (2016) demonstrate that these firms are induced to engage more in the processing trade as a result of financial constraints.

4.3 Estimating a Firm's Productivity

Previous studies usually generate the measure of productivity first, such as Olley and Pakes (1996). Pavcnik (2002) employs Olley and Pakes' (1996) method to examine the trade liberalization effect on productivity. However, she assumes that productivity is purely exogenous. After obtaining the productivity measure, she conducts the regression with the variables of interest. De Loecker (2013) criticizes this method and states that it is problematic because it cannot distinguish various data-generating processes and generates biased estimates. He suggests that we should allow learning by exporting to occur in productivity processes. This study aligns with De Loecker (2013).

Consider the following value added production function:

$$v_{it} = \beta_l l_{it} + \beta_k k_{it} + \omega_{it} + \varepsilon_{it} \tag{4.1}$$

where v, l, and k represent the log of value added, labor and capital respectively. ω denotes total factor productivity, and ε represents the random shock to that firm's value added.

According to Ackerberg, Caves and Frazer (2006), capital is a "quasi-fixed" input chosen in period $t-1$. Labor is determined before material but after capital has been chosen. Labor can be supposed to be chosen at time $t-0.5$. Intermediate inputs are assumed to be chosen after ω_{it} is realized. Given these time assumptions, the intermediate inputs are a function of capital, labor and productivity as shown by the following:

$$m_{it} = f(l_{it}, k_{it}, \omega_{it}) \tag{4.2}$$

where m represents the log of intermediate inputs. This function is assumed to be invertible by Ackerberg, Caves and Frazer (2006), which means that:

$$\omega_{it} = g(l_{it}, k_{it}, m_{it}) \tag{4.3}$$

Now, the unobservable productivity is a function of labor, capital, and material. Then, output also becomes a function of labor, capital, and material:

$$v_{it} = \phi(l_{it}, k_{it}, m_{it}) + \varepsilon_{it} \tag{4.4}$$

In the first stage, the OLS model, with an expansion to the fourth order of labor, capital and material, will be employed to obtain the predicted ϕ.

To produce a consistent estimation of those coefficients, we rely on productivity's law of motion, which is assumed to follow a first-order Markov process:

$$\omega_{it} = f(\omega_{it-1}) + \xi_{it} \tag{4.5}$$

The law of motion, which is key to identifying coefficients, is discussed in Olley and Pakes (1996), Levinsohn and Petrin (2003), and Ackerberg, Caves and Frazer (2006). However, this function does not consider the learning by exporting effect. To capture this effect, we add an exporting dummy variable into the law of motion, or more explicitly:

$$\omega_{it} = \rho_1\omega_{it-1} + \rho_2\omega_{it-1}^2 + \rho_3\omega_{it-1}^3 + \rho_4\omega_{it-1}^4 + \alpha E_{it-1} + \eta_{it} \tag{4.6}$$

where E_{it-1} represents the exporting activities of firms in $t-1$ and α represents the learning by exporting effect. De Loecker (2013) proves that the inclusion of ω_{it-1} can control for the self-selection into the export markets.

After the first stage, we have obtained the predicted ϕ. We can calculate the productivity as follows:

$$\omega_{it} = \hat{\phi}_{it} - (\beta_l l_{it} + \beta_k k_{it}) \tag{4.7}$$

Then, the OLS regression will be employed to obtain the innovation to productivity η_{it} in equation 4.6. Now, we can construct the necessary moment conditions, which are obtained as follows:

$$E\left(\eta_{it}\left(\beta_l, \beta_k\right) \ * \begin{bmatrix} l_{it-1} \\ k_t \end{bmatrix} \right) = 0 \tag{4.8}$$

4.4 Data and Variables

We use firm-level data obtained from the Annual Survey of Industrial Firms conducted by China's National Bureau of Statistics during 2003-2007. Firms are either state-owned or non-state firms with sales greater than 5 million RMB. In 2001, China became a member of the WTO. Chinese firms may need time to adjust to this significant change in the international market. In 2003, the reform of state-owned firms was almost completed. Thus, the quality of data for the later five years is expected to be higher. Before 2001, the trade barrier was still very high.

Table 4-1 provides the summary statistics and definitions of the primary variables we used in the estimation. We note that 26.4% of all firms have engaged in exporting during the study period, while the average exporting intensity is 15.4%.

4.5 Empirical Findings

4.5.1 Benchmark model findings

Table 4-2 presents the estimation results of production coefficients, the learning by exporting effect, and the estimation of the alpha in equation 4.6. Among 27 industries, 25 have reasonable labor coefficients and capital coefficients. The printing industry and the nonmetal mineral products industry have negative labor coefficients. In contrast to De Loecker (2013), 19 of these 25 industries significantly suffer from exporting. Only three industries benefit from exporting, the raw chemical materials and chemical products industry, the medical and pharmaceutical products industry and the chemical fiber industry. According to the classification of Li, Liu and Wang (2015), these are upstream and middle-stream industries, which are generally more capital intensive.

To eliminate negative labor coefficients, we only use non-state-owned enterprises (non-SOE) samples to run the estimation. The results are shown in Table 4-3. Now, all the coefficients are within a reasonable range. One additional industry has a positive LBE, the nonmetal mineral products industry, which is also a middle-stream industry.

4.5.2 Robustness checks

The previous results are based on the ACF approach with a linear relationship between productivity and the exporting status dummy. We may wonder whether the results are robust to productivity processes or not. We add an interaction term between the productivity lag and export lag dummy into productivity as follows:

$$\omega_{it} = \rho_1 \omega_{it-1} + \rho_2 \omega_{it-1}^2 + \rho_3 \omega_{it-1}^3 + \rho_4 \omega_{it-1}^4 + \alpha_1 E_{it-1} + \beta \omega_{it-1} E_{it-1} + \eta_{it} \tag{4.9}$$

Table 4-4 reports the 25th, 50th and 75th percentile of the partial derivative of productivity to the exporting dummy lag. The results are similar to the previous results that are reported in Tables 4-2 and 4-3. For industries that have a positive effect with the benchmark model, the percentiles are also very positive. In addition, the coefficient of the cross term for most of industries is significantly positive, which indicates that firms that are more productive tend to benefit more from exporting.

De Loecker (2013) conducts an additional robustness check, inspired by Aw, Roberts, and Xu (2011), and notes that exporting firms simultaneously make investments. De Loecker (2013) analyses data regarding expenditures on new technologies and the upgrade of existing production processes. Hence, we further add the investment lag into the productivity process as follows:

$$\omega_{it} = \rho_1 \omega_{it-1} + \rho_2 \omega_{it-1}^2 + \rho_3 \omega_{it-1}^3 + \rho_4 \omega_{it-1}^4 + \alpha_2 E_{it-1} + \gamma inv_{it-1} + \eta_{it} \tag{4.10}$$

The results are reported in Table 4-5. The coefficients of the export dummy lag for 12 industries remain significantly negative, while the investment lag promotes productivity in 25 industries.

We continue to explore the role of the market competition in affecting the learning by exporting effect. We use the Herfindahl index to represent the market competition, which is added into the productivity process as follows:

$$\omega_{it} = \rho_1 \omega_{it-1} + \rho_2 \omega_{it-1}^2 + \rho_3 \omega_{it-1}^3 + \rho_4 \omega_{it-1}^4 + \alpha_3 E_{it-1} + \theta Hindex_{it-1} + \eta_{it} \tag{4.11}$$

The results are reported in Table 4-6. The learning by exporting effect is also heterogeneous. the Herfindahl index is significantly negative in most industries.

Until now, we have used the ACF estimation and productivity is calculated using equation 4.7. The next robustness checks change the definition of TFP to the Solow residual. We use the linear productivity process in equation 4.6, while OLS, OP and ACF are employed in the estimation. The results are reported in Table 4-7. The numbers of industries that have significantly positive LBE effects are six, five and six for OLS, OP and ACF, respectively. The remaining industries have either a negative or insignificant LBE effect. In general, the results of the benchmark model are robust.

4.6 Possible explanations for the heterogeneous learning by exporting effect

Is a heterogeneous LBE effect possible? We should refer to the mechanisms for LBE in the literature. Von Biesebroeck (2005) argues that exporting firms interact with their customers and competitors abroad, which makes it easier for them to absorb foreign knowledge. De Loecker (2013) provides a better summary of the mechanisms, "The case study evidence points to the importance of learning from foreign markets both directly, through buyer-seller relationships, and indirectly, through increased competition from foreign producers. In particular, exporters can learn from foreign customers and rivals by improving product quality, shipment size, or, even more directly, by undertaking specific investments." Based on these mechanisms, LBE should be positive. However, the previous section confirms that the LBE effect is heterogeneous, which is inconsistent with the findings in De Loecker (2013). In the next section, we provide possible explanations for our less intuitive findings.

4.6.1 The role of processing trade

The results reported in De Loecker (2013) are based on observations from Slovenia. The processing trade is not distinguished from ordinary trade. Compared to non-exporters, firms that engage in ordinary trade have a comparative information advantage due to their connections in foreign markets because they generally distribute a larger share of their products in the domestic market. These firms can also learn from their customers and competitors in their home country. However, processing trade firms generally receive orders directly from several foreign customers and only perform the production segment of the value chain. Dai, Maitra and Yu (2016) find that most of these firms export more than 70% of their revenue abroad. The primary task for processing firms is to complete the production of the orders on time. Foreign customers generally prefer the inexpensive products made by them because the wage rate in China is relatively low. Therefore, processing trade firms receive less information from the final customers and do not have sufficient capital to renew their machines and upgrade their productivity because the profit margin is generally very low. Hence, it is possible that processing trade firms have a lower productivity growth rate than non-exporters, while ordinary exporters tend to have a higher productivity growth rate.

Dai, Maitra and Yu (2016) find that processing exporters are less productive than non-processing exporters and non-exporters. We do not have data regarding the processing trade. However, Dai, Maitra and Yu (2016) provide the summary statistics for the export intensity of different exporters. On average, processing firms export 76% of their output, while the average exporting intensity of non-processing exporters is only 40%. Hence, processing firms are generally linked with higher exporting intensity.

We revise the linear productivity process as follows to check the influence of exporting intensity:

$$\omega_{it} = \rho_1 \omega_{it-1} + \rho_2 \omega_{it-1}^2 + \rho_3 \omega_{it-1}^3 + \rho_4 \omega_{it-1}^4 + \alpha_4 EI_{it-1} + \eta_{it} \tag{4.12}$$

where EI_{it-1} represents the exporting intensity of firm i at $t-1$.

The results are reported in Table 4-8. For the OLS and OP estimations, the coefficient of exporting intensity lag is significantly or insignificantly negative. For ACF, the coefficient of exporting intensity lag is significantly negative for 19 industries. This result confirms that generally, firms with higher exporting intensity have much lower productivity growth.

Next, we split the sample into four parts: non-exporters, firms with exporting intensity less than 40%, firms with exporting intensity between 40% and 76%, and firms with exporting intensity higher than 76%. We use exporting intensity higher than 76% as a proxy for the processing trade.

Manova and Yu (2016) note that because financially constrained firms cannot finance the up-front costs required for ordinary exporters, they are forced to engage in the processing trade. Egger and Kesina (2013) provide evidence to indicate that the probability that financial constrained firms are ordinary exporters is lower. Feenstra, Li and Yu (2014) verify that the financial constraint is tighter for firms with a higher exporting ratio. First, we link the firm size, age and revenue-capital ratio with the exporting dummies because Beck et al. (2005) note that small firms are the most financially constrained. Small and young firms face more financial constraints on their growth, as noted by Oliveira and Fortunato (2006). Tables 4-9 show that firms with exporting shares larger than 76% are smaller and younger. Their revenue-capital ratio is found to be higher.

In Table 7 of Dai, Maitra and Yu (2016), they report other performance indicators of processing exporters, including log capital-labor ratio, log average wage, log total sales, profit per worker, log R&D expenditures, and the share of skilled workers (workers with at least a college education) over the total number of workers. These scholars note that processing trade firms pay lower wages, have smaller revenues and relatively low profitability. In addition, these firms conduct less R&D and have fewer skilled workers. Firms with exporting shares larger than 76% perform similarly, which is demonstrated in Table 4-10. Other exporters perform better than non-exporters on these aspects. Based on the statistics provided by Dai, Maitra and Yu (2016) and the data in Tables 4-9 and 4-10, we can treat exporting intensities that are higher than 76% as a good proxy for the processing trade.

To check the role of the processing trade in promoting productivity, we revise the productivity function as follows:

$$\omega_{it} = \rho_1 \omega_{it-1} + \rho_2 \omega_{it-1}^2 + \rho_3 \omega_{it-1}^3 + \rho_4 \omega_{it-1}^4 + \alpha_5 T_{1it-1} + \alpha_6 T_{2it-1} + \alpha_7 T_{3it-1} + \eta_{it} \quad (4.13)$$

T_1 is a dummy that represents exporting intensity that is less or equal to 40%, T_2 represents exporting intensity that is between 40% and 76%, and T_3 represents exporting intensity that is higher than 76%, a proxy variable for the processing trade.

The results are reported in Table 4-11. The coefficients of T_3 are more likely to be significantly negative. In addition, the absolute values of these coefficients generally tend to be larger. Hence, processing trade firms are less productive and have lower productivity growth. Cheung (2014) notes that the negative cost shock may cause them to go bankrupt. The results show that 9 industries have a significantly positive α_4, which indicates that firms that export less may learn from their foreign customers and competitors. Hence, the processing trade matters for the LBE effect.

4.6.2 The role of FIE

Lu, Lu and Tao (2010) find that among domestic firms, exporters are more productive than non-exporters, while among foreign international enterprises, exporters are less productive. These scholars argue that FIEs locate labor-intensive production processes in developing countries to make full use of their abundant human resources. In this subsection, the role of FIEs in promoting the LBE effect will be examined.

We split the sample into two groups: an FIE subsample and a non-FIE subsample. Then, we rerun the linear productivity process model with ACF estimation for these two subsamples. The results are reported in Table 4-12. For the FIE subsample, 13 industries have a significantly negative α and 1 industry has a significantly positive α. For the non-FIE subsample, the corresponding numbers are 18 and 4. Hence, the exporters among FIEs are less likely to suffer but they also learn less. There is no clear difference in the LBE effect between these two subsamples.

4.6.3 The role of capital intensity

Lu (2010) and De Loecker (2007) emphasize the importance of the relative competition of foreign markets in comparison with the domestic market. Lu (2010) further notes that competition in the domestic market for labor-intensive sectors is fiercer than that in the foreign market. Exporters in labor-intensive sectors export most of their output to foreign markets and are less productive than non-exporters. The situation reverses for capital-intensive sectors. Hence, we believe that the LBE effect is directly related with capital intensity. Using the benchmark model, we previously noted that industries with a significantly positive LBE effect are upstream and middle-stream industries.

In this subsection, we first calculate the LBE effect on productivity in equation 4.9 as follows:

$$LBE_{it} = \frac{\partial \omega_{it}}{\partial E_{it-1}} = \alpha_1 + \beta \omega_{it-1} \tag{4.14}$$

We now have a measure for the LBE effect of each exporter. Next, we link exporters' LBE with their capital intensity. The results are reported in Table 4-13. The coefficient of capital intensity lag is significantly positive. Column (2) shows that the coefficient of capital intensity is also significantly positive. Columns (3) and (4) further add ownership, region, industry composition and year dummies into regression. The magnitude of coefficients of capital intensity and its lag decrease but remain significant. This robust finding confirms that exporters with higher capital intensity can learn more from exporting.

4.6.4 Government protection policies

Dai, Maitra and Yu (2016) indicate that exporters pay a reduced corporate income tax rate if most of their output (generally 70%) is sold abroad. Because of this benefit, exporters can gain competitive advantages by selling their products at a lower price rather than relying on other differentiation strategies. Dai, Maitra and Yu (2016) indicate that exporters that are eligible for the tax benefits are 11% less productive than other exporters. To promote exporting, government may also provide subsidies to exporters. We surmise that the income tax rate is positively related with the LBE effect, while the subsidy ratio is negatively related with it.

These hypotheses are examined in Table 4-14. We note that both the coefficient of the income tax rate and the coefficient of the income tax rate lag are significantly positive, while the coefficient of the subsidy ratio and the coefficient of the subsidy ratio lag are significantly negative. These results are robust when we add both the income tax rate and the subsidy ratio into the regression. Our results imply that government protection policies reduce the productivity growth of exporters.

4.7 Conclusion

The role of international trade is emphasized by many important studies on the growth of the Chinese economy. There is no unique conclusion regarding the productivity of exporters. To solve this problem, Dai, Maitra, and Yu (2016) separate the processing trade from the ordinary trade and confirm that ordinary exporters are more productive. In contrast to previous studies, this study aims to identify the dynamic role of exporting on the productivity growth of the Chinese manufacturing sector. We note that the LBE effect is heterogeneous across industries, which contradicts the results reported in previous studies. Exporters with higher productivity tend to learn more from exporting, which leads to a diversion rather than a conversion in the distribution of productivity. In addition, we identify the contribution of the processing trade, ownership, and capital intensity and protection policies to the heterogeneous LBE effect.

It is worthwhile to highlight that our productivity measure captures differences in both firm-level cost and demand factors. We hope that future studies will decompose the influences of exporting behavior on cost and demand using detailed data regarding the quantity and price of the firms' products. For processing trade firms, physical productivity may be lower than that of ordinary exporters and non-exporters because they do not fully control the production processes.

This study is directly related to the industry policies of developing countries. Lin (2012) emphasizes that developing countries should develop their own industries based on their comparative advantage. The processing trade should be encouraged at the beginning phase of economic growth to make full use of labor endowments and accumulate capital in developing countries. This pattern is consistent with the history of Chinese markets. However, our results indicate that the productivity growth of processing trade firms is lower. The government may provide better financial services to firms to help them become ordinary exporters. This added support will help these firms compete with their international peers to obtain more knowledge and increase their productivity. Governments should stop distributing subsidies to mature industries. Subsidies encourage firms to remain in a comfortable zone and be less productive.

Table 4-1 Summary statistics of variables

Symbol	Definition and variables	Unit	Mean	Std. D	Form in regression	# of Obs.
l	Number of employees		4.657	1.104	log	1,236,492
m	Intermidiate input minus financial costs	log 1000 yuan	9.617	1.358	log	1,232,983
k	Capital stock following Brandt et al. (2012)	log 1000 yuan	8.411	1.634	log	1,230,106
v	Value added	log 1000 yuan	8.661	1.397	log	1,215,064
y	Revenues	log 1000 yuan	9.988	1.316	log	1,236,817
	Exporting	dummy	0.264	0.441		1,236,817
	Exporting intensity		0.154	0.321		1,236,817

Data source: National Bureau of Statistics of China over years of 2003-2007.

Table 4-2 Learning by exporting effect (LBE)

	Coeffcient		LBE		
Industry	β_l	β_k	α	$s.e.(\alpha)$	
13	0.824	0.138	-0.051	0.006	***
14	1.034	0.134	-0.028	0.009	***
15	0.875	0.201	0.017	0.012	
16	1.973	0.157	-0.061	0.065	
17	0.526	0.220	-0.028	0.003	***
18	0.958	0.103	-0.068	0.005	***
19	0.644	0.230	-0.074	0.007	***
20	0.480	0.277	-0.018	0.008	**
21	0.717	0.183	-0.045	0.009	***
22	0.838	0.176	-0.013	0.007	*
23	-0.207	0.737	0.067	0.011	***
24	0.763	0.135	-0.047	0.009	***
26	0.353	0.382	0.012	0.004	***
27	0.398	0.375	0.044	0.008	***
28	0.347	0.393	0.036	0.015	**
29	0.503	0.328	-0.029	0.009	***
30	0.517	0.299	-0.036	0.004	***
31	-0.032	0.471	0.039	0.005	***
32	0.672	0.308	0.002	0.017	
34	0.736	0.260	-0.045	0.004	***
35	0.822	0.216	-0.028	0.003	***
36	0.832	0.141	-0.016	0.005	***
37	0.931	0.202	-0.009	0.005	*
39	0.898	0.250	-0.072	0.004	***
40	0.883	0.205	-0.025	0.005	***
41	0.989	0.130	-0.060	0.009	***
42	0.860	0.138	-0.086	0.008	***

Note:1. α represents the coefficient of exporting dummy lag in equation 4.6.
2. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4-3 Learning by exporting effect (LBE) of non-SOE

	Coeffcients		LBE		
Industry	β_l	β_k	α	$s.e.(\alpha)$	
13	0.742	0.165	-0.058	0.006	***
14	0.878	0.165	-0.027	0.008	***
15	0.583	0.293	0.013	0.011	
16	0.516	0.316	0.012	0.067	
17	0.538	0.225	-0.029	0.003	***
18	0.966	0.102	-0.070	0.005	***
19	0.630	0.236	-0.076	0.007	***
20	0.491	0.270	-0.026	0.007	***
21	0.685	0.190	-0.047	0.009	***
22	0.824	0.183	-0.013	0.007	*
23	0.994	0.141	-0.042	0.010	***
24	0.699	0.158	-0.047	0.009	***
26	0.414	0.355	0.008	0.004	**
27	0.354	0.352	0.038	0.008	***
28	0.407	0.390	0.031	0.014	**
29	0.555	0.295	-0.037	0.009	***
30	0.465	0.305	-0.034	0.004	***
31	0.068	0.402	0.027	0.005	***
32	0.680	0.339	-0.006	0.012	
34	0.748	0.261	-0.050	0.004	***
35	0.950	0.175	-0.040	0.004	***
36	0.805	0.153	-0.028	0.005	***
37	0.852	0.243	-0.012	0.005	***
39	0.921	0.243	-0.077	0.004	***
40	0.923	0.195	-0.032	0.005	***
41	0.983	0.131	-0.072	0.009	***
42	0.825	0.151	-0.086	0.008	***

Note: 1. See Table 4-2.
2. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4-4 LBE with nonlinear productivity process

	Produtivity process						LBE		
Industry	α_1	*s.e.*(α_1)		β	*s.e.*(β)		25th pct	50th pct	75th pct
13	-0.185	0.036	***	0.034	0.009	***	-0.071	-0.054	-0.035
14	-0.091	0.038	**	0.023	0.014	*	-0.041	-0.030	-0.017
15	-0.016	0.071		0.010	0.021		0.012	0.017	0.022
16	0.075	0.177		0.050	0.065		-0.093	-0.055	-0.018
17	-0.252	0.027	***	0.052	0.006	***	-0.047	-0.028	-0.007
18	-0.190	0.029	***	0.044	0.011	***	-0.090	-0.075	-0.058
19	-0.208	0.041	***	0.038	0.012	***	-0.092	-0.079	-0.063
20	-0.131	0.084		0.028	0.021		-0.029	-0.019	-0.007
21	-0.223	0.068	***	0.049	0.018	***	-0.064	-0.047	-0.027
22	-0.320	0.050	***	0.092	0.015	***	-0.051	-0.012	0.029
23	0.001	0.056		0.021	0.018		0.058	0.069	0.081
24	-0.181	0.065	***	0.038	0.019	**	-0.065	-0.052	-0.037
26	-0.183	0.032	***	0.048	0.008	***	-0.007	0.014	0.035
27	-0.057	0.057		0.025	0.014	*	0.035	0.047	0.058
28	-0.201	0.155		0.062	0.040		0.015	0.042	0.067
29	-0.184	0.075	***	0.044	0.021	***	-0.043	-0.029	-0.011
30	-0.205	0.037	***	0.047	0.010	***	-0.051	-0.036	-0.019
31	-0.063	0.041		0.020	0.008	**	0.030	0.040	0.051
32	-0.125	0.143		0.039	0.044		-0.017	0.000	0.021
34	-0.210	0.025	***	0.056	0.009	***	-0.068	-0.050	-0.029
35	-0.091	0.022	***	0.021	0.007	***	-0.036	-0.029	-0.020
36	-0.169	0.036	***	0.042	0.010	***	-0.034	-0.018	0.002
37	-0.045	0.026	*	0.014	0.010		-0.015	-0.010	-0.004
39	-0.139	0.020	***	0.028	0.009	***	-0.088	-0.076	-0.063
40	-0.203	0.028	***	0.061	0.010	***	-0.056	-0.031	0.000
41	-0.158	0.042	***	0.033	0.014	**	-0.081	-0.065	-0.047
42	-0.204	0.049	***	0.037	0.016	**	-0.110	-0.096	-0.080

Notes: 1. α_1 represents the coefficient of exporting dummy lag in equation 4.9.

2. β denotes the coefficient of the cross term of exporting dummy lag and productivity lag in equation 4.9.

3. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4-5 LBE after controling for the investment

	Exporting			Investment		
Industry	α_2	*s.e.*(α_2)		γ	*s.e.*(γ)	
13	-0.048	0.009	***	0.010	0.002	***
14	0.011	0.010		0.027	0.002	***
15	0.021	0.015		0.028	0.004	***
16	0.013	0.086		0.013	0.018	
17	-0.022	0.004	***	0.016	0.001	***
18	-0.044	0.007	***	0.007	0.002	***
19	-0.048	0.009	***	0.014	0.002	***
20	-0.018	0.013		0.011	0.003	***
21	-0.030	0.011	***	0.014	0.003	***
22	-0.006	0.010		0.010	0.002	***
23	0.020	0.010	**	0.018	0.002	***
24	-0.031	0.012	**	0.013	0.003	***
26	0.000	0.005		0.017	0.001	***
27	0.040	0.009	***	0.020	0.002	***
28	0.013	0.017		0.012	0.003	***
29	-0.006	0.011		0.026	0.003	***
30	-0.043	0.005	***	0.010	0.001	***
31	0.018	0.006	***	0.020	0.001	***
32	0.003	0.019		0.017	0.003	***
34	-0.049	0.006	***	0.006	0.001	***
35	-0.002	0.004		0.023	0.001	***
36	-0.010	0.007		0.007	0.002	***
37	-0.013	0.006	**	0.005	0.001	***
39	-0.073	0.006	***	0.005	0.001	***
40	-0.028	0.007	***	0.001	0.001	
41	-0.011	0.010		0.017	0.003	***
42	-0.028	0.010	***	0.021	0.002	***

Notes: 1. α_2 represents the coefficient of exporting dummy lag in equation 4.10.

2. γ denotes the coefficient of investment lag in equation 4.10.

3. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4-6 LBE after controling for Herfindahl index

	Exporting			Herfindahl index		
Industry	α_3	$s.e.(\alpha_3)$		θ	$s.e.(\theta)$	
13	-0.056	0.006	***	-0.720	0.024	***
14	-0.028	0.009	***	-0.017	0.078	
15	0.021	0.013		-0.575	0.054	***
16	-0.062	0.065		2.275	1.463	
17	-0.028	0.003	***	-0.011	0.041	
18	-0.061	0.005	***	-21.575	0.919	***
19	-0.072	0.007	***	-1.059	0.069	***
20	-0.014	0.008	*	-1.614	0.197	***
21	-0.045	0.009	***	-1.366	0.098	***
22	-0.012	0.007	*	1.181	0.111	***
23	0.063	0.011	***	-1.844	0.191	***
24	-0.038	0.009	***	-0.268	0.022	***
26	0.009	0.004	***	-0.789	0.021	***
27	0.039	0.008	***	-5.298	0.315	***
28	0.021	0.015		-0.791	0.065	***
29	-0.032	0.009	***	1.175	0.101	***
30	-0.040	0.004	***	-8.493	0.247	***
31	0.027	0.005	***	-0.467	0.016	***
32	0.002	0.017		-4.285	0.838	***
34	-0.048	0.004	***	-2.785	0.088	***
35	-0.031	0.003	***	-0.254	0.014	***
36	-0.016	0.005	***	0.497	0.034	***
37	-0.009	0.005	*	-0.023	0.013	***
39	-0.074	0.004	***	-0.256	0.031	***
40	-0.021	0.005	***	-2.430	0.140	***
41	-0.060	0.009	***	-0.041	0.010	***
42	-0.086	0.008	***	-3.071	0.227	***

Notes: 1. α_3 represents the coefficient of exporting dummy lag in equation 4.11.

2. θ denotes the coefficient of Herfindahl indext lag in equation 4.11.

3. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4-7 Robustness check to the LBE

	OLS			OP			ACF		
Industry	α	$s.e.(\alpha)$		α	$s.e.(\alpha)$		α	$s.e.(\alpha)$	
13	-0.017	0.010	*	-0.017	0.010	*	-0.011	0.012	
14	-0.002	0.014		-0.012	0.014		-0.019	0.017	
15	0.019	0.019		0.007	0.019		0.014	0.022	
16	0.011	0.050		0.023	0.045		-0.166	0.075	**
17	-0.038	0.005	***	-0.043	0.005	***	-0.014	0.006	***
18	-0.075	0.008	***	-0.074	0.008	***	-0.098	0.010	***
19	-0.095	0.010	***	-0.097	0.010	***	-0.085	0.012	***
20	-0.040	0.012	***	-0.052	0.012	***	-0.023	0.014	
21	-0.073	0.015	***	-0.084	0.015	***	-0.043	0.019	**
22	0.011	0.014		-0.011	0.013		0.013	0.016	
23	0.048	0.017	***	0.034	0.017	**	0.102	0.021	***
24	-0.060	0.028	***	-0.058	0.015	***	-0.051	0.018	***
26	0.022	0.008	***	0.020	0.008	***	0.049	0.009	***
27	0.024	0.014	*	0.036	0.014	***	0.058	0.016	***
28	0.052	0.029	*	0.012	0.029		0.070	0.033	**
29	-0.048	0.015	***	-0.061	0.016	***	-0.015	0.017	
30	-0.053	0.008	***	-0.074	0.008	***	-0.040	0.009	***
31	0.049	0.007	***	0.048	0.008	***	0.077	0.009	***
32	0.022	0.018		0.019	0.018		0.037	0.021	*
34	-0.050	0.007	***	-0.044	0.007	***	-0.064	0.009	***
35	-0.012	0.006	**	-0.016	0.006	***	-0.035	0.007	***
36	0.009	0.009		-0.007	0.009		0.002	0.011	
37	0.026	0.009	***	0.017	0.009	*	-0.002	0.010	
39	-0.069	0.007	***	-0.068	0.007	***	-0.129	0.009	***
40	-0.012	0.010		-0.013	0.010		-0.068	0.012	***
41	-0.050	0.014	***	-0.038	0.014	***	-0.087	0.018	***
42	-0.080	0.013	***	-0.081	0.013	***	-0.072	0.016	***

Note: 1.See Table 4-2.

2. Productivity is calculated as the Solow residual.

3. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4-8 LBE: does exporting intensity matters?

	OLS			OP			ACF		
Industry	α_4	$s.e.(\alpha_4)$		α_4	$s.e.(\alpha_4)$		α_4	$s.e.(\alpha_4)$	
13	-0.118	0.014	***	-0.105	0.014	***	-0.114	0.018	***
14	-0.060	0.024	**	-0.057	0.024	**	-0.091	0.030	***
15	-0.095	0.037	**	-0.090	0.038	**	-0.057	0.045	
16	-0.473	0.451		-0.123	0.234		-0.835	0.234	***
17	-0.070	0.007	***	-0.059	0.007	***	-0.055	0.008	***
18	-0.102	0.008	***	-0.098	0.008	***	-0.126	0.011	***
19	-0.156	0.011	***	-0.154	0.011	***	-0.163	0.014	***
20	-0.099	0.017	***	-0.098	0.017	***	-0.078	0.020	***
21	-0.101	0.018	***	-0.107	0.018	***	-0.095	0.022	***
22	-0.113	0.024	***	-0.111	0.024	***	-0.147	0.029	***
23	0.020	0.029		0.009	0.029		0.138	0.035	***
24	-0.085	0.015	***	-0.080	0.015	***	-0.094	0.019	***
26	-0.042	0.015	***	-0.039	0.015	***	0.004	0.018	***
27	-0.002	0.028		0.008	0.028		0.025	0.033	
28	-0.009	0.061		-0.014	0.061		-0.001	0.066	
29	-0.117	0.023	***	-0.118	0.023	***	-0.090	0.026	***
30	-0.100	0.011	***	-0.111	0.011	***	-0.090	0.013	***
31	-0.004	0.011		0.023	0.011	**	0.046	0.014	**
32	-0.039	0.041		-0.035	0.040		-0.007	0.051	
34	-0.088	0.009	***	-0.079	0.009	***	-0.110	0.011	***
35	-0.062	0.010	***	-0.062	0.010	***	-0.071	0.012	***
36	-0.014	0.019		-0.026	0.019		-0.043	0.022	**
37	-0.014	0.015		-0.016	0.015		-0.022	0.019	
39	-0.135	0.009	***	-0.126	0.009	***	-0.204	0.012	***
40	-0.039	0.012	***	-0.036	0.012	***	-0.118	0.015	***
41	-0.106	0.018	***	-0.086	0.018	***	-0.149	0.023	***
42	-0.104	0.013	***	-0.098	0.013	***	-0.117	0.017	***

Note:1. α_3 represents the coefficient of exporting intensity lag in equation 4.12.

2. Productivity is calculated as the Solow residual.

3. *** p<0.01, ** p<0.05, * p<0.1.

Table 4-9 Firm size, age, capital productivity and exporting share

VARIABLES	Log(K)	Age	Log(Sales/K)
0<Exporting intensity<=0.4	0.370***	0.771***	-0.160***
	(0.004)	(0.037)	(0.004)
0.4<Exporting intensity<=0.76	0.148***	-0.597***	-0.143***
	(0.005)	(0.052)	(0.005)
Exporting intensity>0.76	-0.250***	-1.485***	0.026***
	(0.004)	(0.025)	(0.004)
East	0.021***	-0.929***	0.331***
	(0.003)	(0.025)	(0.003)
Log(L)	0.968***	2.001***	
	(0.001)	(0.012)	
Industry dummy	Y	Y	Y
Year dummy	Y	Y	Y
Observations	1,229,821	1,236,309	1,230,106
R-squared	0.468	0.062	0.068

Notes: 1. Robust standard errors in parentheses.

2. *** p<0.01, ** p<0.05, * p<0.1.

Table 4-10 Other performance of exporters

VARIABLES	Log(K/L)	Log wages	Log sales	Profitability	Log R&D	Skill intensity
0<Exporting intensity<=0.4	0.344***	0.312***	0.362***	8.387***	0.408***	0.014***
	(0.004)	(0.004)	(0.003)	(0.471)	(0.017)	(0.001)
0.4<Exporting intensity<=0.76	0.126***	0.142***	0.132***	-0.359	0.058**	-0.003**
	(0.005)	(0.005)	(0.004)	(0.442)	(0.026)	(0.001)
Exporting intensity>0.76	-0.272***	-0.042***	-0.096***	-5.891***	-0.385***	-0.015***
	(0.004)	(0.004)	(0.003)	(0.363)	(0.024)	(0.001)
East	0.028***	0.048***	0.312***	5.600***	0.416***	-0.009***
	(0.003)	(0.003)	(0.002)	(0.247)	(0.015)	(0.001)
Log(L)		0.800***	0.780***		0.758***	
		(0.001)	(0.001)		(0.006)	
Industry dummy	Y	Y	Y	Y	Y	Y
Year dummy	Y	Y	Y	Y	Y	Y
Observations	1,229,821	1,059,875	1,236,492	1,236,492	87,064	248,893
R-squared	0.115	0.374	0.482	0.004	0.292	0.034

Notes: 1. Robust standard errors in parentheses.

2. *** p<0.01, ** p<0.05, * p<0.1.

3. R&D data only available in years 2005-2007.

4. Skill intensity is the ratio of labor force with college education and above, data only available in year 2004.

Table 4-11 LBE after spliting the sample

	0.4>=Exporting intensity>0			0.76>=Exporting intensity>0.4			Exporting intensity>0.76		
Industry	α_5	$s.e.(\alpha_5)$		α_6	$s.e.(\alpha_6)$		α_7	$s.e.(\alpha_7)$	
13	0.001	0.008		-0.050	0.013	***	-0.110	0.009	***
14	-0.015	0.012		-0.017	0.017		-0.054	0.015	***
15	0.034	0.014	***	0.008	0.031		-0.033	0.026	
16	-0.044	0.063		-0.084	0.226		-0.323	0.586	
17	-0.005	0.004		-0.028	0.005	***	-0.048	0.004	***
18	-0.023	0.009	***	-0.054	0.008	***	-0.081	0.005	***
19	0.023	0.012	*	-0.026	0.012	**	-0.115	0.007	***
20	0.037	0.013	***	-0.008	0.015		-0.060	0.010	***
21	-0.010	0.014		-0.078	0.016	***	-0.051	0.010	***
22	0.029	0.009	***	-0.016	0.016		-0.104	0.014	***
23	0.069	0.014	***	0.082	0.021	***	0.059	0.019	***
24	-0.029	0.014	**	-0.006	0.014		-0.065	0.009	***
26	0.025	0.005	***	0.012	0.008		-0.035	0.009	***
27	0.037	0.009	***	0.076	0.013	***	0.031	0.015	**
28	0.063	0.018	***	0.027	0.024		-0.083	0.044	*
29	0.015	0.012		-0.039	0.017	**	-0.080	0.012	***
30	-0.009	0.006		-0.027	0.007	***	-0.072	0.005	***
31	0.061	0.007	***	0.013	0.010		0.018	0.007	***
32	0.014	0.023		-0.006	0.023		-0.040	0.026	
34	-0.017	0.007	***	-0.049	0.007	***	-0.063	0.005	***
35	-0.018	0.004	***	-0.029	0.007	***	-0.044	0.006	***
36	-0.010	0.006		-0.021	0.011	***	-0.036	0.012	***
37	0.002	0.006		-0.017	0.009	*	-0.025	0.009	***
39	-0.035	0.006	***	-0.067	0.008	***	-0.111	0.006	***
40	-0.018	0.007	***	0.001	0.009		-0.048	0.007	***
41	-0.043	0.012	***	-0.038	0.016	***	-0.086	0.011	***
42	-0.039	0.014	***	-0.060	0.013	***	-0.103	0.008	***

Notes: 1. α_5, α_6 and α_7 represent the coefficient of T_1, T_2 and T_3 in equation 4.13.

2. Exporting intensity=export sales/total sales revenue.

3. *** p<0.01, ** p<0.05, * p<0.1.

Table 4-12 The LBE of FIE and Non-FIE

	FIE			Non-FIE		
Industry	α	$s.e.(\alpha)$		α	$s.e.(\alpha)$	
13	-0.101	0.019	***	-0.034	0.007	***
14	0.000	0.018		-0.028	0.010	***
15	-0.021	0.028		0.011	0.014	
17	-0.020	0.011	*	-0.028	0.003	***
18	-0.045	0.016	***	-0.066	0.005	***
19	-0.055	0.019	***	-0.076	0.007	***
20	-0.020	0.027		-0.010	0.008	
21	-0.047	0.025	*	-0.047	0.010	***
22	0.043	0.026		-0.023	0.009	***
23	0.045	0.032		0.059	0.012	***
24	-0.052	0.028	*	-0.051	0.009	***
26	0.002	0.011		0.009	0.005	*
27	0.011	0.022		0.062	0.011	***
28	0.142	0.059	***	0.022	0.016	
29	-0.075	0.030	***	-0.024	0.010	***
30	-0.040	0.012	***	-0.034	0.004	***
31	-0.013	0.012		0.046	0.006	***
32	0.016	0.029		-0.011	0.010	
34	-0.056	0.014	***	-0.048	0.004	***
35	-0.049	0.012	***	-0.033	0.004	***
36	0.001	0.013		-0.028	0.006	***
37	-0.017	0.013		-0.014	0.005	***
39	-0.066	0.014	***	-0.081	0.005	***
40	0.018	0.013		-0.045	0.007	***
41	-0.076	0.022	***	-0.071	0.010	***
42	-0.054	0.024	**	-0.096	0.009	***

Note:1. See Table 4-2.

2. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4-13 LBE and capital intensity

VARIABLES	LBE	LBE	LBE	LBE
L.Log(K/L)	0.014***		0.006***	
	(0.000)		(0.000)	
Log(K/L)		0.013***		0.005***
		(0.000)		(0.000)
FIE			0.003***	0.003***
			(0.000)	(0.000)
East			0.005***	0.006***
			(0.000)	(0.000)
Industry dummy	N	N	Y	Y
Year dummy	N	N	Y	Y
Observations	107,044	204,456	107,044	204,456
R-squared	0.157	0.132	0.652	0.640

Notes: 1. Robust standard errors in parentheses.
2. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4-14 LBE, income tax rate and subsidy ratio

VARIABLES	LBE	LBE	LBE	LBE	LBE	LBE
Income tax rate	0.104***				0.106***	
	(0.006)				(0.006)	
L.income tax rate		0.117***				0.120***
		(0.008)				(0.008)
Subsidy ratio			-0.024***		-0.026***	
			(0.008)		(0.009)	
L.subsidy ratio				-0.060***		-0.063***
				(0.010)		(0.011)
FIE	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
East	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Industry dummy	Y	Y	Y	Y	Y	Y
Year dummy	Y	Y	Y	Y	Y	Y
Observations	204,456	107,044	204,456	107,044	204,456	107,044
R-squared	0.627	0.633	0.627	0.632	0.627	0.633

Notes: 1. Robust standard errors in parentheses.

2. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

3. Income tax rate=Income tax/Sales revenue.

4. Subsidy ratio=Subsidy/Sales revenue.

Chapter 5

Summary

This thesis studies various topics of the productivity dynamics of Chinese manufacturing firms, including the evolution and distribution of productivity, the productivity of public infrastructure investment, and the dynamic learning by exporting effect. Total factor productivity growth is considered as the engine of long-run growth. In the early years, the large-scale firm-level data was not available. The TFP growth was usually calculated at the aggregate level. There may be conflicting findings about TFP growth with aggregate data, due to differences in choices of the deflator, the calculation of the aggregate variables and the method of calculating TFP. With the firm-level data, the aggregate level TFP growth can be the weighted average of the productivity growth of individual firms. However, there exists endogeneity problem between productivity and factor inputs when OLS is used to estimate the production function. In this thesis, the proxy method and the system GMM are employed to obtain a consistent estimation of the productivity.

Chapter 1 offers the motivation of this thesis. The research questions are proposed.

Chapter 2 investigates the productivity growth and the determinants of productivity of the Chinese manufacturing sector during 1998-2007. During that period, the manufacturing firms grew rapidly. We quantify the contribution of productivity growth. The source of productivity growth in the manufacturing sector can be within firms' productivity growth and resource reallocation as the result of the privatization process of SOEs and trade liberalization. With OLS, ACF and BB methods, the productivity of manufacturing firms is found to be always growing. The time trends of the productivity growth of these three methods are similar. The productivity growth rate is found be consistent with the findings in the literature. The contribution of resource reallocation to the productivity growth is significant only in the late 1990s and early 2000s. Firms' entry and exit contribute more than two-thirds of the productivity growth. The firms' characteristics are further linked to the productivity level. There are several robust findings regarding productivity level: firms in the eastern provinces enjoy the productivity advantage while firms in the western regions are least productive; FIEs have the highest productivity and SOEs still rank the last among all the ownerships; and a firm's age is negatively related with productivity. The role of exporting is found to be sensitive to the productivity estimation methods.

Chapter 3 estimates the productivity of public infrastructure investment. The quantity and quality of infrastructure affect the potential market size, the variety of intermediate inputs and the logistics cost, which relates to the unobserved productivity. The return rate of public infrastructure investment is a key question to rationalize the massive investment. Public infrastructure capital is usually treated as the input to the aggregate production function. There are several serious problems in that estimation, for example, the reverse causality between infrastructure investment and GDP growth. This chapter links public infrastructure investment to the firm's productivity. Those econometric problems are solved or avoided with our models. The return rate based on the revenue productivity is found to be 9.2%. This return rate is the sum of short-run Keynesian demand effect and long-run productivity effect. The return rate based on the quantity of productivity is found to be 2.5%. These two numbers are the most conservative return rates without considering the spillover effects. The return rates almost triple with spillover effects. We continue to compare those return rates to those of private investment in the literature. The return rate of private investment is lower than the return rate with spillover effects. These numbers indicate that the central government should encourage the province-level government to continue to invest in the infrastructure investment, if the return rate can be persistent. Currently, China is experienced enough to serve as the benchmark for other developing countries in investment in infrastructure. For developed countries, the quality and return of infrastructure may need to be improved after many years' stagnation.

Chapter 4 examines whether Chinese manufacturing firms really benefit from their exporting experience. As mentioned in chapter 2, trade liberalization improves the market competition, which will lead the less productive firms to exit. However, the less productive firms may choose to be processing exporters, which heavily depend on the international market and thus avoid the fierce domestic market competition. Previous literature mainly focuses on the productivity level of exporters. This chapter examines the dynamic learning by exporting effect in the Chinese manufacturing sector. We find that the learning by exporting effect is significantly positive in only a few industries, in contrast to the findings in the literature. Those heavily exporting firms have similar characteristics as the processing-trade firms. By engaging in the processing trade, firms have fewer connections with their customers or competitors, which results in lower productivity growth. The learning by exporting effect is found to be significantly and positively related with firms' capital intensity, which may indicate that capital-intensive industries can learn from their foreign customers and competitors more efficiently. The protection policies reduce the learning by exporting effect.

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