Productivity Growth and Ownership Change in China: 1998-2007

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(Preliminary)

Abstract

This paper studies the industry productivity dynamics in China's manufacturing sector from 1998 to 2007, and in particular, explores to what extent the privatization of state-owned enterprises (SOEs) contributes to the aggregate productivity growth. Our results show that, though non-SOEs on average are more productive than SOEs, the average productivity growth among SOEs is greater than their counterparts. Industry concentration, taxation, and credit market all account for this difference in growth between SOEs and non-SOEs. We find that industry productivity growth is mainly attributed to the growth of non-SOEs, entry of non-SOE firms, and the exit of SOEs. However, non-SOE firms that are transformed directly from SOEs make a small and negative contribution to industry productivity growth.

Keyword: Productivity Growth, Industry Dynamics, Ownership Change, Reallocation

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1 Introduction

It is well documented that capital and labor misallocation across firms can be an important barrier to the aggregate productivity growth. Hsieh and Klenow (2009) measure the effects of misallocation by showing that, if the marginal products across firms are equalized, the aggregate industry Total Factor Productivity would be boosted by 30 to 50 percent in China relative to such gains in the U.S. There can be many factors contributing to misallocation, for instance the differential government policies between the state sector and the private sector, differential access to formal credit markets, barrier to entry, or the labor market distortions. In this paper, we extend Hsieh and Kelnow (2009) to study directly how the change of firm ownership has contributed to the aggregate productivity growth in China between 1998 and 2007. One such main change is the significantly shrunk share of state-owned enterprises (SOEs) in industry production during this period. In 1998, SOEs employ 49 percent of total workers. By 2007, only this dropped to 10 percent. SOEs are in general considered to display low labor efficiency while they enjoy the preferential government policy treatments (for example, formal credit is more accessible to SOEs than to non-SOEs). Switching from the state ownership to the private ownership presumably promotes the aggregate productivity growth.

Studying the impact of ownership change on productivity improves our understanding of the role of reallocation, which is particularly important for emerging economies where regulatory and policy distortions can be more severe than the developed economies. If reallocation (for example, through ownership changes) contributes significantly to the aggregate productivity growth, once this reallocation process in transition slows down or approaches to an end, the aggregate productivity growth will become slower if the rest of the economy keep the same pace of the growth.

To study the impact of SOE privatization, using the firm-level data on China's manufacturing during 1998-2007, we estimate the firm production function with the Olley-Pakes approach (Olley and Pakes (1996)), taking into account the ownership type in production. With the estimated firm-level TFP, we characterize the productivity dynamics of both SOEs and non-SOEs, and quantify to what extent the privatization of the state sector contributed to the aggregate productivity growth.

Our main findings are as follow. Not surprisingly, SOEs on average have lower estimated TFP than non-SOE firms between 1998 and 2007. SOEs had lower average labor productivity (ALP) than non-SOE firms before 2004, but higher since then. SOEs have higher growth rates in both TFP and ALP than non-SOEs. Further, we find that both employment size and market power contribute to the higher productivity growth of SOEs. High firm indebtedness can curtail productivity growth,

though its impact on SOEs and non-SOEs may not differ.

We find that industry productivity growth is mainly attributed to the entry of non-SOEs, the growth of non-SOEs and the exit of SOEs. Contribution from firms that are transformed from SOE to non-SOE type is small and negative. This seemingly counter-intuitive result may be interpreted in several ways. One is the selection problem, that is, the SOEs that did transform were less productive firms and they turned out to remain unproductive even after privatization. Our statistics suggest that this may form a partial explanation. It could also arise from the loss of policy favoring such as government subsidies, which offsets its expected growth from switching to be non-SOE.

There is a fast growing literature that studies the productivity growth in China and the role of reallocation in the process. Hsieh and Klenow (2009) showed that reducing misallocation can significantly improve the aggregate productivity Brandt et al. (2009) present the first comprehensive facts regarding productivity growth and they found that net entry accounts for most of productivity growth in China.

Our paper is the closest and complementary to Brandt et al. (2009). The difference is that here we focus on the role of firm ownership changes as a form of reallocation in the aggregate productivity growth, and in our model we explicitly take into account ownership types.

The rest of the paper is organized as follows. Section 2 provides the background of ownership type in China. Section 3 describes the firm data, followed by a simple model of ownership change and firm dynamics in Section 4. Then we estimate the productivity dynamics by taking into account the firm entry/exit and ownership changes in Section 5. The estimates and analysis on the contribution of ownership changes on productivity and on labor costs are given in Section 6. Implications on estimation results are given in Section 7. Finally, we conclude in Section 8.

2 Background of Ownership Type Change in China

Before China's economic reform in 1978, the majority of Chinese firms are SOEs located in big cities. In 1978, SOEs accounted for 78 percent of industrial output, 76 percent of employment and over 84 percent of physical investment (see statistics in Fifty Years (2000)). The rest of the firms are collectively-owned enterprises and they are run at a smaller economic scale by local government. These collectively-owned firms are mostly located in smaller cities, towns or rural areas, and they mainly focus on light industries and/or provides basic materials for agriculture use (Perkins et al. (1977)).

The economic reform, starting in 1978, led to an economy that is more open to free market as in Lau, Qian and Roland (2001) and Li (1997). The proportion of market-traded products, which reflect the supply and demand, increases from 0 percent in 1978 to 78 percent in 1995 as in OECD (2005). Meanwhile, new firms with various non-state ownership emerged and were permitted to enter industries which were previous exclusively occupied by SOEs. In particular, many government policies including taxes favored firms with foreign direct investment (FDI), and foreign investors were drawn to invest along the eastern coast areas of China. Many SOEs had to face rising competition from the emerging private firms. By 1995, SOEs' share of total industrial output had fallen from 77.6 percent in 1978 to 34 percent.

Since 1998, China's manufacturing industries have experienced substantial change in ownership type, as shown in Figure 1, which is characterized by SOE reconstruction and flourish of non-SOEs. It began with a government-initiated three-year plan in effort to reform the problematic SOEs. By 2000, 4,000 large- and medium-sized SOEs have been restructured; The number of poor-performed SOEs dropped from 6,599 in 1997 to 3,463. Meanwhile, 66.5 percent of SOEs turned profitable in 2000, with 140 percent increase in profit over the previous year. In addition to the extensive government intervention, these achievements are attributed to the 360 billion Renminbi directly injected into SOEs by government from 1997 to 2000, as well as expansive monetary and statutory policies such as interest cut, debt-equity swap, and debt write-off to reduce the SOEs' high debt[1]. Overall, the share of SOE in China's gross domestic product fell from 77.6 percent to less than 30 percent during this period, while SOEs still provided about 40 percent of urban employment.

By 2007, there were five types of ownerships (by order from left to right for each year): state-owned, private-owned, limited liability companies, non-domestic-owned (including foreign firms and firms from Hong Kong, Macau and Taiwan), collectively-owned, and shareholding corporations. Apparently, the portion of SOEs and collectively-owned firms has been decreasing across the time, and that of private firms and limited liability companies has been increasing since then. During 2000 and 2007, the fraction of SOEs declined from over 15 to 2 percent, and that of collective firms fell from 42 to 5 percent. It brings us attention to the rapid growth in the fraction of private firms within the manufacturing sector, rising from less than 10 percent in 2000 to over 40 percent by 2007. The fraction of limited liability companies rose from 12 to 27 percent, while the fraction of non-domestic-owned (including HMT & foreign) firms remains comparatively steady at around 15 percent.

[1]By some causal estimation, a series of interest rate cuts in those years reduced SOEs' financing costs by 260 billion RMB.

As in Figure 2, the total number of manufacturing firms more than doubled, rising from around 87,000 in 1998 to 213,000 in 2005. However, the total number of SOEs fell from over 24,000 in 1998 to 6,100 in 2007, almost one fourth of its previous size. In Figure 3 the fraction of SOEs fell from 28 percent in 1998 to 3 percent in 2007. Meanwhile, the average age of firms declined from 14.44 in 1998 to 9.72 in 2007, suggesting sizable non-SOEs were entering the manufacturing sector, that is, non-SOEs contributed to the growing population of firms.

Historically, there are deep-rooted differences between SOEs and non-SOEs. Their growth can not be assumed or supposed to follow the same trend[2]. So for the rest of this paper, we focus on one classification of ownership type: SOE and non-SOEs, and estimate the production function based on such type change between SOEs and non-SOEs.

It should be noted that the three years below mark the key points of great changes occurred.

- 2001: the year that China entered world trade organization (WTO)[3]. Exacerbated by its accession to the WTO, China experienced burgeoning exports since then.

- 2004: the year that China experienced an investment boom in infrastructure projects, which put great pressure on energy supply by rising demand for commodities and other raw materials. The fixed asset investment even accounted for 42 percent of China's gross domestic product. The high investment levels propelled China's economy to grow by 10.7 percent in the first nine months of 2004, raising concerns that the then world's fourth largest economy was overheating.

- 2005: Beijing imposed a series of temporary measures to cool China's overheating economy, including tightening credit market and restricting industrial land use[4].

Figure 4 further explores the fall of SOEs in manufacturing and presents the rate of SOE survival. Note that survival here refers to a firm remaining SOEs conditional on its stay in the sample. We find that if a SOE remains in the market, it is getting more likely to switch to non-SOE during this period. The rate of this possibility kept on rising from no more than 10 percent to around 20 percent, though after 2005, this trend disappeared.

[2]Before 1978, when China's economic reform started, private firms were not permitted in China's economy. Though private form of enterprises emerged after 1978, the debates on different ownership type, especially over the legitimacy of private-owned remain until the mid-1990s. It was until late 1990 private firms were widely encouraged and especially welcomed by the local government.

[3]See Lardy (2001) and World Trade Organization (2005).

[4]Note that in China, land is state-owned. It means that either new firms or continuing firms heavily rely on land use permission from government.

3 Manufacturing Data in China

3.1 The Sample

The sample we use comes from the annual survey conducted by the National Bureau of Statistics of China[5], and is firm-level data over the period 1998-2007 for all the industrial firms located in China[6] that are identified either as state-owned enterprises (SOEs), or non-state-owned "above-scale" firms (non-SOEs) with annual sales value above 5 million RMB. With one set of unified identity number for each firm within the economy[7], we are able to track firms across time. We keep as many observations as possible, but firms with broken history are excluded. Firms remained and tracked in our sample do not necessarily start or end their operation in the same years. During this period, China's manufacturing sector experienced an immense number of vigorous changes with entry and exit of firms. Finally, we obtain an unbalanced firm-level panel data between 1998 and 2007 with over 100,000 firms for each year. Besides, this sample provides a rich set of variables on firm heterogeneity as listed in Table 1.

3.2 Summary Statistics

Industry classification

The industry classification of a firm follows a 4-digit Chinese Industry Classification (CIC) system that resembles the old U.S. SIC system. Our sample covers 29 manufacturing industries (by taking first two digits of 4-digit CIC code), including food processing, textile, refinery, plastics, electronic equipment and so on. Further details on industries is available in Table 4. The setting of the classification system in the original data was revised in 2003 to incorporate more detail for some sectors, while some other sectors were merged. To make the industry code consistent over the period, we constructed a unified set of classification as did in Brandt, Biesebroeck and Zhang (2009).

Real output and industrial value added

We use China's Producer Price Index (PPI) at the CIC 2-digit level as the deflator to convert data from nominal to real terms. Not surprisingly, shown in Figure 6, the aggregate real output increased from 4,460 billion RMB in 1998 to 25,200 billion in 2007. And industrial value-added

[5]The official website of NBS China is at http://www.stats.gov.cn/english/.

[6]Industries in the original data include mining, manufacturing and public utilities. This paper focuses on only the manufacturing sector.

[7]Over this period there are sizable firms that experienced reconstructions, mergers and/or acquisitions and may change their identity numbers due to the change of ownership. We use information including firm name, address, telephone number, fax number, zip code to track a firm within the scope.

Table 1: Available Variables on Firm Heterogeneity

Variable	Definition
Output	real output of any manufacturing firm within the sample
Industrial value-added	real value added
Total employment	log(number of employees in a firm)
Wage	log (total compensation/(number of employees))
Capital stock	log of physical capital
Investment	investment in physical capital
Labor productivity	log (industrial value added/(number of employees))
TFP	log of total factor productivity from 4-digit industry-specific production function. We extend Olley-Pakes technique and include the change of ownership type
Credit constraints	the ratio of a firm's interest expenditures that is used as a proxy for its capability to borrow over its total debts
Tax	the ratio of the firm's income tax over its annual sales
Ownership Type:	
State-owned	if registration type is claimed to be state-owned, or be limited liability corporations or shareholding corporations with over 50% of the registered assets being state-owned[8]
Collective	if registration type is claimed to be collective, or be limited liability corporations or shareholding corporations with over 50% of the registered assets being from the collective source
Private	if registration type is claimed to be private, or be limited liability corporations or shareholding corporations with over 50% of the registered assets being private-owned
HMT	if registration type is claimed to be Hong-Kong, Macau and Taiwan
Foreign	if registration type is claimed to be other than Mainland China, Hong-Kong, Macau and Taiwan

[9]

increased from 1,210 billion RMB in 1998 to 6,640 in 2007. Both measures rose over fivefold over the past decade.

Ownership type

A firm claims its registration type annually. Using such information we classify the ownership of one firm into five basic groups: state-owned (SOEs), collectively-owned, private-owned, HMT (from Hong-Kong, Macau, and Taiwan) and foreign (from the rest of the world except mainland China and HMT). Meanwhile, additional information on the composition of a firm's registered capital is used to classify those firms that claim themselves as limited liability companies and shareholding corporations[10] to be state-owned, collective or private. In particular, one firm is termed as SOE if its registration type is claimed to be state-owned, or to be limited liability companies or shareholding corporations but with over 50 percent of its registered assets being owned by the state. Ownership change hereafter refers to the change in ownership type.

Capital

We follow Brandt etal (2009) and use the perpetual method to obtain the real value of capital stock.

Figure 14 and 15 show the smoothed firm size distribution measured using capital and employment, respectively. Relative to 1999, the firm size distribution shifted leftward, suggesting smaller average size due to the substantial entry during this period. The distribution of SOEs apparently displays larger dispersion and smaller skewness than that of non-SOEs as in Figure 18 and 19.

Capital investment exhibits significant lumpiness with at least half of the firms investment as low as 1 percent of capital, while the investment rate among the top 10 percentile of firms is as high as 40 percent. The coexistence of extremely low and extremely high investment rates has not changed during this period. On average, the investment rates of SOE firms are lower than Non-SOEs.

Table 2: Investment in 1999 and 2006

	1999			2006		
	All	SOE	non-SOE	All	SOE	Non-SOE
Mean	13.1%	8.2%	14.8%	16.5%	9.7%	16.7%
Median	1.6%	1.0%	2.2%	2.2%	1.0%	2.4%

[10]Mostly such firms are reconstructed from previous state-owned enterprises or collective firms. The changes in ownership type occur by means of management buy-out (MBO), previous management raising capital to form a new firm, shareholdings by previous employees, external finance such as getting public and/or private equity, and reporting bankrupt and turning private.

Employment and real wage

A firm reports its total annual employment and several components of employee compensation including total annual wages, total employee supplementary benefits, and total unemployment insurance[11]. Total wage here is termed as the sum of the above three classifications of compensations. The real term of firm-level average wage is calculated by dividing total deflated wage of one firm over its total number of employees within. Note that since our sample covers all the SOEs and those "above-scale" non-SOEs for the manufacturing sector, the deflator we use not only deflates across time but approximates the representative wage at the aggregate level[12]. As shown in Figure 6, employment of manufacturing sector keeps on rising, from less than 35 million workers in 1998 to over 46 million in 2004. This increase in manufacturing employment is mostly due to the rise of non-SOEs, both numerically and proportionally, as well as their increasing demand for labor force. We will further discuss this issues on section of change in ownership type. After 2004, the rising trend flats out and the total employment fell but remains over 20 million, which is also closely related to the growing pace of non-SOEs.

Productivity

Besides labor productivity, we also measure productivity in total factor productivity (TFP), which is derived from four-digit industry-specific production function. During 1998-2007, China's manufacturing industries experienced rapid growth both in output and total factor productivity: the firm-level total factor productivity growth has been as high as an average annual rate 9.5 percent while value added is used for estimation as in Brandt et al. (2009). If gross output production function is estimated, the average TFP growth in manufacturing sector is 2.6 percent. As is shown in Section 3, TFP is obtained by estimating the firm's production function, but we explicitly include the ownership type, and in particular, consider the privatization of SOEs.

4 Estimating TFP Through Dynamic Choices And By Ownership

The sweeping ownership change of Chinese manufacturing firms during 1998-2007 is hard to ignore. Heavy presence of SOEs in manufacturing is considered as a factor contributing to resource misallocation in existing studies, for example, Hsieh and Klenow (2009). Given this assumption, the rapid shrinking of SOEs in manufacturing sector is supposed to facilitate the aggregate productivity

[11]Most SOEs may further provide information on their expenditures/payment on employees' total housing subsidy, medical care and pension plan.

[12]From NBS website we obtain the average wage payment within the whole economy and this sampling deflator is calculated by dividing the average annual aggregate wage compensation in our sample over that in the whole economy.

Table 3: Summary Statistics

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
No. of firms	87,145	99,345	112,212	121,906	129,750	146,008	186,457	213,721	205,255	191,633
Firm Age	14.44	14.41	14.09	12.41	11.67	10.55	8.40	8.24	9.00	9.72
Capital Stock	2.57	3.53	3.90	4.13	4.19	4.55	5.15	6.10	6.45	6.79
Investment	981	439	462	464	571	701	1,040	1,122	1,190	691
Value Added	1.21	1.44	1.71	1.97	2.37	3.03	4.28	4.92	5.78	6.64
Output	4.46	5.24	6.34	7.33	8.67	11.3	11.5	18.5	21.8	25.2
Employment	34.5	36.1	37.2	37.6	38.5	41.7	46.1	52.6	52.3	51.7
No. of SOE	24,091	25,728	25,285	21,119	17,514	14,213	11,293	9,816	8,272	6,125
Percentage SOE	0.28	0.26	0.23	0.17	0.13	0.10	0.06	0.05	0.04	0.03
SOE Surv. Rat.		0.95	0.92	0.90	0.91	0.87	0.81	0.88	0.85	0.87
ALP (labor productivity)	3.15	3.26	3.41	3.46	3.60	3.74	4.15	3.98	4.18	4.33

Note: Employment is in the unit of million, capital stock, value-added and output are thousand billion renminbi (RMB), and investment is billion RMB.

growth. The main interest of this paper is to quantify the effect of ownership change on productivity and its growth pattern. This complements the study conducted by Hsieh and Klenow (2009) on misallocation. With the estimated productivity measures, we decompose the productivity growth so as to single out the contribution by ownership change. Meanwhile, as the process of ownership transformation completes or at least slows down, the productivity change due to reallocation of ownership will become smaller.

We first estimate the firm-level TFP by extending the Olley-Pakes approach to include the ownership change. Recent studies extended Olley and Pakes (1996) to improve the estimation, with Ackerberg, Caves and Frazer (2006) as the latest. To overcome the selection bias and simultaneity bias in estimating the production function, we first describe and model the firm's dynamic problem. Then the estimation equations are derived.

We assume that the ownership type change is exogenous. This assumption is necessary and sound based on the fact that changing in ownership type from private-owned to state-owned is rare in our data, while the privatization of SOEs prevails during this period. This process of SOE reconstruction owes more to the governmental policy than the firm's choice. Such ownership change may have two direct effects, both on productivity and on labor costs. In China, SOEs in general bear higher burden of labor costs for two reasons. First, besides wages SOEs generally provide benefits including housing subsidy, health care, and pension. Secondly, the wage setting might be distorted in state-owned firms. For example, wage depends more on tenure than on worker productivity. Switching to non-SOE type of ownership will reduce employment-related costs. Other than including an ownership type indicator in estimation, we do not explicitly model how the ownership change contributes to productivity growth.

4.1 Firm's Problem

The firm's production function has the Cobb-Douglas form,

$$Y_{it} = e^{\omega_{it} + \alpha_j j_{it} + \varepsilon_{it}} K_{it}^{\alpha_k} L_{it}^{\alpha_l}, \tag{1}$$

where Y_{it} is the value added of firm i in period t, j_{it} is the ownership type, ω_{it} denotes TFP, and ε_{it} is the measure error. Let the firm value function be $V(\omega_{it}, j_{it}, K_{it})$ for ownership type j in period t, where j could be SOE or non-SOE. The physical capital evolves as

$$K_{it} = (1 - \delta) K_{it-1} + I_{it-1}$$

. The capital adjustment cost is $C(I_{it})$ for firm i. To apply the original Olley-Pakes approach, adjustment cost is assumed to be convex, which appears inconsistent with the investment moments shown in earlier sections. In implementing the estimation we use the method by Ackerberg, Caves and Frazer (2006). Let $w(\omega_{it}, j_{it})$ be the compensation function per worker. We assume that the firm-level compensation is determined by three variables: market wage, ownership type, and firm productivity. We will estimate this function separately from the dynamic model. There is no labor adjustment cost, but ownership change may affect the labor cost. Hence, the labor choice is non-dynamic though it depends on ownership type.

We assume that the unobserved productivity ω_{it} follows the same Markov process for all types of firms, so it does not have j as a subscript, though the estimated productivity process is still affected by the presence of ownership type. In later sections we estimate the serial correlation and dispersion parameters for the productivity processes for SOEs and non-SOEs, respectively.

The continuation value of type j incumbent firms is given by

$$V^c(\omega_{it}, j_{it}, K_{it}) = \max_{\{L_{it}, I_{it}\}} Y(\omega_{it}, j_{it}, K_{it}, L_{it}) - C(I_{it}) - w(\omega_{it}, j_{it})L_{it} + \frac{1}{1+r_t} E_t V(\omega_{it+1}, j_{it+1}, K_{it+1}). \quad (2)$$

Let the firm exit value be $V^e(\omega_{it}, j_{it}, K_{it})$. The firm's value in period t is then

$$V(\omega_{it}, j_{it}, K_{it}) = \max(V^c, V^e).$$

The demand for investment in capital is

$$I_{it} = I(\omega_{it}, j_{it}, K_{it}). \quad (3)$$

Its inverse function

$$\omega_{it} = h(j_{it}, K_{it}, L_{it}) \quad (4)$$

is used to estimate the production function. Olley and Pakes (1996) show the conditions under which the inverse demand function exists. It requires that investment is a monotonic function of productivity. Here the extension to Olley-Pakes technique is the extra state variable of ownership type.

The firm's exit decision rule is given by

$$\chi_{it} = \begin{cases} 1, & \text{if } \omega_{it} \geq \overline{\omega}(j_{it}, K_{it}) \\ 0, & \text{otherwise.} \end{cases} \tag{5}$$

The inverse investment function and the exit rule are the two equations used to overcome the simultaneity and selection problems of estimation.

4.2 Production Function Estimation

The firm's dynamic optimal policy functions guide how ownership type enters the production function estimation. We apply the extended Olley-Pakes type of estimation to correct for the simultaneity bias, but not the selection bias arising from firm exit. Not correcting the selection bias is mainly due to the data limitation. The sample does not provide information on the true firm exit, because one firm exited from the sample may still exist[13]. In addition, the exit decision of one SOE may not arise from productivity shock, but rather closely relates to the government policy of encouraging the SOE reconstruction that leads to the wide-spread SOE privatization[14].

Half of the observations in our sample have investment rate equal to or lower than 1 percent, suggesting some degree of non-convexity in capital adjustment cost which invalidates the original Olley-Pakes approach. To overcome this problem, we adopt the Levinsohn-Petrin method and the method proposed by Ackerberg, Caves and Frazer (2006) (hereby ACF). We estimate the production function using value added as output for 28 industries. In the following analysis on productivity, the ACF estimation results are used. The difference between LP and ACF is that the latter identifies coefficient for labor in the second step of estimation. It turns out that when labor choice is made to be dynamic, the estimated coefficient for labor in production function is much larger in the ACF method than that in the LP method.

Table 4 gives the estimated parameters of the production function for each industry. The average share of labor in production is 0.35, and the average share of capital is 0.30. The share of labor in production is much lower than the similar estimates using the U.S. plant-level data, while the capital share is higher than that estimated using the U.S. data. This suggests that the production of Chinese firms are more labor intensive relative to that of the U.S. firms. The

[13] Due to the sampling rule of the original data that all the SOEs and "above-scale" non-SOEs are covered, one non-SOE firm that is no longer observed in the sample could be simply falling below the scale. However, the "above-scale" rule is not strictly imposed and we still observe sizable "below-scale" non-SOEs within our sample.

[14] We also estimate the production function after correcting the selection bias. The predicted probability of survival for most industries is close to one.

Table 4: Production function estimation

Industry	Labor		Capital		Ownership	
	OLS	ACF	OLS	ACF	OLS	ACF
Average	0.454	0.351	0.423	0.304	-0.942	-0.134
Diary products (13)	0.495	0.330	0.312	0.115	-1.048	-0.098
Food processing (14)	0.533	0.283	0.442	0.233	-1.369	-0.046
Beverage and soft drinks (15)	0.587	0.345	0.463	0.298	-0.964	-0.062
Tobacco (16)	0.465	0.185	0.899	0.326	-0.060	-0.150
Textile (17)	0.467	0.380	0.345	0.230	-0.822	-0.101
Apparel and foot wear (18)	0.568	0.379	0.261	0.218	-0.910	-0.269
Leather products (19)	0.468	0.390	0.329	0.095	-1.166	-0.312
Timber and wood products (20)	0.468	0.294	0.301	0.295	-1.076	-0.286
Furniture (21)	0.590	0.365	0.245	0.322	-1.320	-0.197
Paper (22)	0.428	0.350	0.402	0.348	-0.874	-0.117
Printing and publishing (23)	0.376	0.297	0.603	0.423	-0.841	-0.078
Recreation and sport products (24)	0.512	0.347	0.269	0.289	-0.996	-0.121
Refinery (25)	0.248	0.413	0.621	0.587	-0.496	-0.148
Chemical products (26)	0.335	0.336	0.467	0.339	-0.926	-0.123
Medicine (27)	0.430	0.376	0.550	0.451	-0.793	-0.155
Chemical fibre (28)	0.478	0.298	0.375	0.503	-0.880	-0.089
Rubber (29)	0.435	0.322	0.442	0.272	-0.833	0.006
Plastics (30)	0.419	0.364	0.368	0.395	-1.073	-0.170
Non-metallic mineral products (31)	0.382	0.342	0.384	0.279	-0.791	-0.066
Ferrous metals (32)	0.433	0.400	0.479	0.280	-0.778	-0.160
Metal products (34)	0.398	0.328	0.403	0.300	-0.975	-0.073
General machinery (35)	0.431	0.350	0.433	0.218	-1.027	-0.111
Special machinery (36)	0.488	0.390	0.410	0.188	-1.228	-0.160
Transport equipment (37)	0.555	0.438	0.452	0.340	-1.049	-0.105
Electrical machinery and equipment (39)	0.438	0.362	0.455	0.286	-0.935	-0.124
Communication and electronic equipment (40)	0.484	0.451	0.467	0.382	-1.049	-0.107
Measuring Instruments and office products (41)	0.384	0.361	0.392	0.238	-1.001	-0.095
Artworks (42)	0.427	0.339	0.281	0.269	-1.092	-0.225

estimated production function exhibits very different scale to returns across industries, with diary product industry (industry 13) being the lowest at 0.45 and refinery industry (25) being the largest at 0.99. Finally, a comparison with OLS estimation shows that the ACF estimation effectively corrects the downward bias of the capital share estimate.

SOEs are less productive than other firms, as suggested by the negative coefficient of ownership for SOEs. Except the chemical fiber industry (28), the estimated coefficients of the ownership type dummy for industries are all negative. The average estimate is -0.13, suggesting that SOEs are 13 percent less productive than other firms holding other variables the same across ownership types.

5 Productivity Growth

With the estimated production functions, we obtain the TFP measure for each firm. We assume that the firm's productivity shock follows AR(1) process, $\omega_{it} = \gamma x_t + \rho\omega_{it-1} + \varepsilon_{it}$, where x_t includes a constant and the year dummy. The average (over all industries) of the estimated serial correlation (ρ) is 0.75, and the standard deviation of ω_{it} is 1.30. The productivity shock is fairly persistent with the serial correlation ranging from 0.54 to 0.95, while the dispersion is large.

In this section, we examine the heterogeneity of productivity processes across industries, focusing on the differential between SOEs and other ownership types. The aggregate manufacturing TFP grows by 24 percent from 1998 to 2007. The average annual growth rate is close to 2.7 percent.

Table 5: Productivity differentials between SOEs and non-SOE firms

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
$\frac{\omega_{non-SOE}}{\omega_{SOE}}$	1.06	1.06	1.06	1.03	1.01	0.99	0.98	0.96	0.96	0.95
$\frac{ALP_{non-SOE}}{ALP_{SOE}}$	1.18	1.16	1.16	1.11	1.06	1.04	1.01	0.98	0.97	0.96

The estimated TFP ω_{it} differs significantly between SOEs and other firms, as shown in Table 5. The table shows the ratio of weighted average TFP values for SOEs and non-SOEs. Non-SOE firms are 6 percent more productive than SOEs between 1998 and 2000, and this positive gap narrows since then. By 2007, SOEs become more productive than other firms by 5 percent. This may reflect that the low productive SOEs either exited or were privatized between 1998 and 2007. The shrunken productivity gap between SOEs and other types are due to the faster productivity growth by SOEs during these years, on average catching up the non-SOEs, especially private ones. Figure 7 shows the TFP growth for SOEs and non-SOEs, normalized by the average SOEs TFP.

It should be noted that when calculating TFP for firms, we have already removed the negative contribution of SOE-type. The aggregate TFP changes with ownership even ownership type is already in production function. This is mainly because the estimated coefficient for the ownership dummy variable captures only the average partial difference between the two ownership type. Moreover, differences in trend by ownership is only captured in the estimated TFP.

The similar trend is observed when we use average labor productivity (ALP) to measure productivity. Moreover, the gap in ALP growth is even larger, as seen in Figure **?**. Similarly the plotted labor productivity values are already normalized by the average labor productivity of SOEs. In 1998, non-SOE firms are 18 percent more productive than SOEs, by 2007 the SOEs are 4 percent more productive than non-SOE firms. This differential productivity growth is attributable to mainly the deepening reform on SOEs including employee lay-offs (Yearbook (2006)) and capital restructuring (Jefferson et al. (1999)). This change also closely relates to government policies, which are to be in details discussed in later sections. The ownership change between SOE and other types plays a negative but minor role in the aggregate productivity growth.

6 Accounting For Productivity Growth

With the estimates on productivity, we next decompose productivity growth into components accounting for contributions from within the firm, between the firm, and reallocation terms (entry/exit and ownership change). In order to examine to what extent the privatization of SOE firms has contributed to the productivity growth, we also decompose the productivity growth by the ownership type.

Two important methods of decomposition are the one in Baily, Hulten and Campbell (1992) and its extension in Foster, Haltiwanger and Krizan (2002). Given our interest of quantifying the contribution from ownership changes, we extend the method by Foster, Haltiwanger and Krizan (2002) to allow ownership changes. Let P_t be the TFP or labor productivity measure of the entire manufacturing in period t, and p_{jt} be the productivity of firm j. The aggregated industry productivity is $P_t = \sum_j s_{jt} p_{jt}$, where s_{jt} is the share of employment of firm j. Let $\Delta p_{jt} = p_{jt} - p_{jt-1}$, let C_t^1 be firms that did not change ownership between period $t-1$ and t, C_t^2 be firms that did change ownership. Also let EN_t be the entrants in period t and EX_t be the firms exited in period $t-1$. The aggregate industry-level productivity is decomposed into three components: within

ownership, ownership change, and entry/exit, as follows[15],

$$\Delta P_t = \sum_{j \in C_t^1} (s_{jt} p_{jt} - s_{jt-1} p_{jt-1}) + \sum_{j \in C_t^2} (s_{jt} p_{jt} - s_{jt-1} p_{jt-1}) + \sum_{j \in EN_t} s_{jt} p_{jt} - \sum_{j \in EX_t} s_{jt-1} p_{jt-1}. \quad (6)$$

The first term is the productivity growth accounted by the firms that did not experience ownership changes. The second term captures the contribution through ownership change. The last two terms are respectively entry and exit. Within each component, we separate the contribution by SOEs from that by non-SOEs. Table 6 shows the decomposition for TFP.

The contribution from the SOE transforming to the non-SOE type contributed negatively to the total productivity growth. This is counter-intuitive, since the SOEs on average are less productive than non-SOEs, the transformation is expected to improve performance and promote productivity. However, we find that the private firms transformed from previous SOEs have lower productivity growth than the firms born as private.

The other contribution of SOE transformation is through the exit. The last two columns of Table 6 show that the exiting SOEs are in general less productive than exited non-SOEs, suggesting that the SOE exiting does help to improve the aggregate productivity.

Lastly, the net entry dominates all other components in the aggregate productivity growth, which confirms the findings by Brandt et al. (2009). The industry productivity is mainly driven by the entry of non-SOE firms.

We further decompose the TFP growth for C_t^1 firms into the within, between and cross terms, as in Foster, Haltiwanger and Krizan (2002) and given by

$$\Delta P_t = \sum_j s_{jt-1} \Delta p_{jt} + \sum_j p_{jt-1} \Delta s_{jt} + \sum_j \Delta s_{jt} \Delta p_{jt}. \quad (7)$$

Table 7 shows decomposition. For non-SOE firms both the firm growth and the reallocation between non-SOE firms are driving the productivity growth, but for SOEs the firm growth dominates. Similar to the previous studies, we find that the cross-firm effect of growth is small, relative to within effect and reallocation.

The decomposition of ALP displays a similar picture as delivered by the TFP decomposition, see Table 8. The main sources of labor productivity growth come from the growth of non-SOE firms, the entry of non-SOE firms, and the exit of SOEs. The net contribution of SOEs to labor

[15]Lentz and Mortensen (2008) also decompose productivity growth by firm types. They account the role of innovative firms in aggregate productivity growth, but in their data there is no switch of firm types.

Table 6: Manufacturing TFP Growth Decomposition, 1998-2007

		Within ownership		Cross ownership		Entry		Exit	
Year	Total Growth	Non-SOEs	SOEs	SOE→Non-SOE	Non-SOE→SOE	SOE	Non-SOE	SOE	Non-SOE
1999	-0.019	-0.081	-0.198	-0.009	0.004	0.059	0.176	0.000	0.000
2000	0.094	0.164	0.053	-0.006	0.002	0.026	0.163	0.066	0.104
2001	0.150	0.013	-0.144	-0.018	-0.002	0.037	0.310	0.064	0.137
2002	0.146	0.107	-0.081	-0.009	0.001	0.021	0.249	0.046	0.112
2003	0.152	0.066	-0.079	-0.011	0.000	0.022	0.324	0.045	0.112
2004	0.213	0.692	0.058	0.009	0.006	0.025	0.648	0.072	0.240
2005	-0.026	-0.920	-0.219	-0.028	-0.012	0.019	0.303	0.023	0.088
2006	0.124	-0.030	-0.034	-0.009	0.000	0.011	0.267	0.021	0.106
2007	0.194	0.499	0.037	0.005	0.005	0.000	0.000	0.015	0.117

Table 7: TFP growth decomposition within ownership type, 1998-2007

	Non-SOEs			SOEs		
Year	Within	Between	Cross	Within	Between	Cross
1999	-0.011	-0.060	-0.010	-0.013	-0.180	-0.005
2000	0.034	0.142	-0.011	0.024	0.037	-0.008
2001	0.023	0.005	-0.015	0.022	-0.153	-0.013
2002	0.056	0.056	-0.005	0.029	-0.105	-0.005
2003	0.077	-0.006	-0.005	0.022	-0.097	-0.004
2004	0.116	0.577	-0.001	0.021	0.040	-0.003
2005	0.037	-0.932	-0.024	0.007	-0.222	-0.004
2006	0.112	-0.133	-0.008	0.007	-0.040	-0.001
2007	0.127	0.371	0.002	0.011	0.026	0.000

productivity, through within effect, transforming, entry and exit, is negative. The decomposition within an ownership is shown in Table 9, which exhibits very similar results as the TFP case.

In summary, the growth of productivity at the industry level arises mostly from the expansion of non-SOEs and the exiting of SOE firms. Transforming an SOE firm to non-SOE firm does not increase the productivity.

7 Implications

7.1 Why Do SOEs outgrow non-SOEs?

The firm-level TFP summarizes all factors other than capital and employment in affecting production capacity of the firms. In this section, in addition to size, we examine three possible factors that can benefit the state-owned sector: competition, sales tax, and firm borrowing. These factors may arise from preferential policies toward the state-owned sector, such as market power, government subsidies, financing condition, etc.

Industry concentration

One hypothesis is that the market power of the state-owned firms may grow faster in TFP because of growing market power (See Sutton (1998) and Klepper and Graddy (1990)). We measure the market power with the industry concentration, that is, the Herfindahl index. The market power is calculated by summing up the squared market shares of top 10 percent firms. To measure the industry concentration due to the state-owned firms, we calculate the SOE Herfindahl index, measured as the sum of squared market shares of the state-owned firms among the top 10 percent

Table 8: Manufacturing Labor Productivity Growth Decomposition, 1998-2007

		Within ownership		Cross ownership		Entry		Exit	
Year	Total Growth	Non-SOEs	SOEs	SOE→Non-SOE	Non-SOE→SOE	SOE	Non-SOE	SOE	Non-SOE
1999	0.110	-0.026	-0.081	-0.003	0.003	0.052	0.165	0.000	0.000
2000	0.125	0.087	0.016	-0.004	0.002	0.031	0.158	0.062	0.103
2001	0.193	0.094	-0.041	-0.005	-0.001	0.043	0.298	0.067	0.129
2002	0.152	0.083	-0.043	-0.003	0.000	0.024	0.242	0.046	0.105
2003	0.179	0.064	-0.050	-0.005	-0.001	0.021	0.321	0.050	0.121
2004	0.237	0.565	0.056	0.013	0.005	0.001	0.011	0.108	0.306
2005	0.010	-0.752	-0.164	-0.020	-0.011	0.052	0.927	0.007	0.016
2006	0.150	-0.005	-0.024	-0.005	-0.001	0.012	0.271	0.021	0.078
2007	0.238	0.493	0.037	0.005	0.004	0.000	0.000	0.021	0.280

Table 9: Labor productivity growth decomposition within ownership, 1998-2007

	Non-SOEs			SOEs		
Year	Within	Between	Cross	Within	Between	Cross
1999	0.076	-0.034	-0.068	0.062	-0.107	-0.036
2000	0.071	0.077	-0.062	0.047	0.001	-0.031
2001	0.061	0.114	-0.082	0.061	-0.060	-0.042
2002	0.090	0.063	-0.070	0.042	-0.071	-0.014
2003	0.110	0.013	-0.059	0.031	-0.072	-0.010
2004	0.160	0.483	-0.078	0.036	0.031	-0.011
2005	0.058	-0.739	-0.071	0.012	-0.164	-0.011
2006	0.155	-0.094	-0.066	0.010	-0.029	-0.005
2007	0.179	0.348	-0.034	0.016	0.022	-0.002

firms. Figure 9 shows that on average the industry concentration in manufacturing decreases over time. The declining share of SOE firms in total sales is consistent with the shrinking number of state-owned firms and their falling role in the manufacturing sector.

Tax

Another potential candidate is tax, though its impact could be complicated. On the one hand, to promote the fast growth of SOEs, the government may subsidize these firms to make them more competitive. Meanwhile, as the fundamental form of China's economy, the SOEs have historically carried large share of government expenditures via corporate income tax (Wong and Shue (2007)). Figure 11 shows the tax per unit of firm income keeps increasing for the state-owned firms, which may negatively contribute to productivity growth.Thus the impact of tax depends on which side of effect dominates. The average tax ratios of both state-owned firms and other firms. Clearly, the non-SOEs have been paying much higher tax than SOEs. On average, between 1999-2007, the state-owned firms paid 25 percent less tax than the private firms per unit of sales (income). This gap narrowed only in 2007. The impact of such tax advantage on productivity growth of SOEs could be huge. If tax is taken into account, the state-owned firms would even be less productive than the private firms.

Debt

In China, the biggest eleven banks are all state-owned and their state-owned shares of assets are as high as 95.5%. These state-owned banks dominate the credit market. In 1999, the big-four

state-owned banks[16] accounted for over 77 percent of loans. By 2007, the 99 percent of mid-cap and small-cap non-SOEs took no more than 33 percent of bank loans. The state-owned firms have advantage in getting financed[17]. This potential credit misallocation strongly relates to government policy. It can be distortionary in that compared to SOEs, the private firms are in general smaller, and those small and median entrepreneurial firms are more likely to be credit constrained. Figure 12 shows two interesting things. First, the ratio of debt over asset for private firms is on average only half of that for state-owned firms, with slightly narrower gap in recent years. Secondly, the debt-asset ratio has been declining for both types of ownership. However, the lower debt-asset ratio for private firms does not suggest that the growth rate of productivity for private firms is lower than state-owned firms. Entry of private firms is significant and it's an important component of industry growth. The lower debt-asset ratio is more likely to be outcomes of limited access to credit. Such credit constraint[18] on small- and mid-cap private firms suggests that the government credit policy may hinder productivity growth of private firms.

Our estimation shows that state-owned firms are on average less productive than those non-SOE firms, though state-owned firms grow faster. The factors that may affect this outcome, however, remains unclear. To shed light on this, we conduct a regression of one firm's TFP growth on its firm size, industry concentration–Herfindahl index, indebtedness, and tax payment. Table 10 shows the regression results. It is a reduced-form regression, thus the causality effect will not be discussed.

First, we use employment to measure the firm size. The coefficients of firm size is negative at -.008 for non-SOEs, and positive at .03 for SOEs. That means, among non-SOEs, the larger firms have slightly lower productivity growth. For SOEs, the productivity growth increases with employment size.

Secondly, we look at the impact of competition. The coefficient for industry concentration index is negative at -9.045. The negative index suggests that, the more decentralized the industry is, the higher productivity growth is. The coefficient for SOE industry concentration is positive at 4.5, suggesting that if the state-owned firms have more market shares among the top 20 percent firms, the corresponding productivity growth is higher. This is consistent with the hypothesis that

[16]They refer to bank of China (BOC), Industrial and Commercial Bank of China (ICBC), China Construction Bank (CCB) and Agricultural Bank of China (ABC).

[17]Historically, SOEs have been contributing to majority of government tax revenue; meanwhile, state-owned banks used to subsidize SOEs heavily via the administrative methods. After economic reform in 1978, these administrative methods were gradually replaced by bank loans, which from many aspects inherit the similar tasks. The state-owned firms could obtain bank loans for some reasons, not necessarily because they are more productive.

[18]Until 2007, private firms are not allowed to issue corporate bonds to raise capital and finance their growth. This combined with the poorly-developed stock market in China makes financial options narrow to bank loans and internal fiance, though underground financing is getting common for many small and median private entrepreneurial firms (see Qi (1991)).

Table 10: Factors Affecting TFP growth

Variable	Coefficient	Std. Err.
SOE	-0.311	0.0142
Employment	-0.008	0.0011
Employment*SOE	0.038	0.0023
Herfindahl Index	-9.045	0.5324
SOE Herfindahl Index	4.500	0.8077
Tax/Sales	1.012	0.1059
Debt/Asset	-0.052	0.0079
Tax/Sales*SOE	-0.175	0.3240*
Debt/Asset*SOE	0.019	0.0176*

Note: Coefficients that are starred are statistically insignificant.

state-owned firms enjoy market power while they dominate the market.

Third, tax sales ratio may reflect potential differences of effective tax rates by ownership. The regression shows that firms that pay higher income tax per unit of sales have larger productivity growth than those with lower tax sales ratio. However, the state-owned firms paying higher tax per unit of sales grow even faster, though statistically insignificant. As we mentioned earlier, the impact of debt and tax on productivity growth may be causal. Due to the causality effect that SOEs on average have lower tax ratio than non-SOEs, this result only shows the cross term of SOE and tax ratio does not contribute in explaining the growth gap between SOEs and non-SOEs.

Fourth, for non-SOE firms, productivity growth is negatively correlated with the debt-asset ratio. A higher debt-asset ratio indicates slower growth. For SOEs a higher debt-asset ratio, however, indicates faster productivity growth. Given the available information, it remains unclear whether and via what channel debt-asset ratio affects the productivity growth. Without further and more structural analysis, it is difficult to speculate the underlining correlation between credit market and productivity growth.

In summary, faster productivity growth of SOEs relative to that of non-SOEs is positively correlated with size and industry concentration. Firms with higher indebtedness tend to grow slower, and this observation remains for both SOEs and non-SOEs.

7.2 Negative Growth in Productivity of SOE transformation

In decomposition, a counter-intuitive but interesting observation is that, the transformation from SOEs to non-SOEs contributes negatively to productivity growth in China. In order to

further understand the role of ownership type transformation, Table 11 shows the average growth of both TFP and ALP for SOEs before and after their transformation to non-SOEs. After becoming non-SOE, both TFP and ALP growth became slower.

On the one hand, it may be because the process of ownership change takes time to affect growth or it may disturb the production. On the other hand, in the process or privatization SOEs may survive either because they are highly productive or because the government prefers to maintain their market power in certain industries; the transformed SOEs could be simply poor-performed ones. This is consistent with the observation shown in Table 11 that the transformed SOEs had slower TFP growth than the industry average for all the SOEs before ownership change occurred, and not surprisingly, after transformation their TFP growth was slower than the average non-SOEs.

We find that those transformed firms are large in employment size. They are 6 percent larger than the average SOEs, with the ratio (in employment) being 1.06. After ownership change, these firms downsize by 78 percent in employment, though their employment is still twice the size of an average non-SOE firm. Apparently, employment downsizing did not make these firms grow faster. In addition, the firm's debt burden can potentially cause slower growth through financial constraint. We find that before the ownership change, the debt-asset ratio for transformed SOEs is only slightly lower than the average SOEs, while transformed SOEs are much less productive than industry average for SOEs. After the ownership change, their debt-asset ratio declines slightly but stays high, roughly twice the size of the average non-SOEs. It remains to be investigated on why the transformed SOE firms experience slower productivity growth, which is beyond this paper.

Table 11: Productivity growth before and after SOE becoming non-SOE

	TFP		ALP	
Year	Before	After	Before	After
1999	0.047	0.075	0.289	0.003
2000	0.060	-0.002	0.018	0.010
2001	0.017	-0.008	0.027	0.000
2002	0.020	0.000	-0.006	0.035
2003	0.023	-0.008	0.186	0.047
2004	0.015	0.031	0.079	0.052
2005	0.000	-0.009	0.001	-0.006
2006	0.004	0.012	0.006	0.002
2007	-	0.024	-	0.044
Average	0.023	0.013	0.075	0.021
Industry Average	SOE	non-SOE	SOE	non-SOE
	0.034	0.020	0.060	0.036

8 Concluding Remarks

In this paper, we have estimated the productivity of China's manufacturing firms and decomposed its growth in 1998-2007. We find that SOEs on average exhibit a lower level of productivity but higher productivity growth, relative to other ownership types. The exit of SOEs is one of the main sources of productivity growth at the industry level. Finally, the non-SOE firms transformed directly from the state-owned type have a small and negative contribution to the industry productivity growth.

Our findings contribute to the understanding of the role of reallocation in aggregate productivity. The ownership of SOE represents the unique feature of industry structure in emerging economies as China. Our findings shed lights on the consequences of more general government policies towards a particular group of firms through protection or preferential credit policy.

So far, our approach to quantifying the role of reallocation (more specifically ownership transformation) in the aggregate productivity growth is still reduced form. We did not identify the sources of misallocation and their quantitative importance. Further research is needed to quantify with more structural methods how the ownership transformation improved productivity. One such exploration could be to look into the labor adjustment in transition. Cooper et al. (2010) have demonstrated that labor reallocation and labor market frictions are important in better understanding the aggregate productivity growth. **More on contributions.**

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Appendices

A Production function estimation

Let the production function of firm i with ownership j be

$$Y_{it} = e^{\omega_{it}+\alpha_j j_{it}+\varepsilon_{it}} K_{it}^{\alpha_k} L_{it}^{\alpha_l}, \tag{8}$$

where Y_{it} is the value added of firm i in perdiod t, j_{it} is the ownership type, and ε_{it} is the measure error. The ownership type affects the firm's total factor productivity. Potentially, the ownership change may improve the efficiency of capital and labor, but it is difficult to identify this efficiency if we assume that the capital, labor and intermediate input shares in production is the same across different ownership types. Moreover, ownership can affect productivity that arises from competition. For example, the state-owned firms may be able to dominate a particular market designated by the government, switching to non-SOE ownership can lose such a market power.

We start with the well-known estimation procedures of Olley and Pakes (1996) and James Levinsohn and Amil Petrin (2003). Then we also discuss Ackerberg, Caves and Frazer (2006).[19]

In natural logarithm form, the firm's production function can be written as

$$y_{it} = \alpha_0 + \alpha_l l_{it} + \alpha_k k_{it} + \alpha_j j_{it} + \omega_{it} + \varepsilon_{it}. \tag{9}$$

Notice that ownership is now an input factor. The state variables in period t is capital stock k_{it}, ownership j_{it}, and productivity shock ω_{it}. Firm's ownership type j_{it} in period t is given, hence behaving as a state variable like the capital. Though the labor choice is partly determined by ownership, it is a static choice, hence labor is not a state variable.

Following Olley and Pakes (1996), the estimation can be done in three steps. In step one, inverse the investment demand function and estimate α_l with nonparametric function. In step two, we estimate α_k and α_j.

In the first step, we inverse the investment policy function, and plug the inverse function into production function as follows

$$y_{it} = \alpha_l l_{it} + \phi(j_{it}, i_{it}, k_{it}) + \varepsilon_{it}, \tag{10}$$

[19]See Doraszelski and Jaumandreu (2008) for endogenous productivity arising from R & D, and Amiti and Konings (2007) for applications to trade liberalization. See **?** for adjustment cost and production estimation.

where $\phi(j_{it}, i_{it}, k_{it}) = h(j_{it}, i_{it}, k_{it}) + \alpha_0 + \alpha_k k_{it} + \alpha_j j_{it}$, ϕ_t is a high-order polynomial in j_{it}, k_{it} and i_{it}.

The second step is to estimate α_k and α_j from the following

$$y_{it} - \alpha_l l_{it} = \alpha_0 + \alpha_k k_{it} + \alpha_j j_{it} + \omega_{it} + \varepsilon_{it}, \tag{11}$$

where α_l and ω_{it} are estimated in the first step. Note, in obtaining the estimated ω_{it}, its Markovian property is needed, so that we can write

$$\omega_{it} = g(\omega_{it-1}) + \xi_{it}$$

with $\omega_{it-1} = \phi_{it-1} - \alpha_0 - \alpha_k k_{it-1} - \alpha_j j_{it-1}$.

The second step estimation equation becomes

$$y_{it} - \alpha_l l_{it} = \alpha_k k_{it} + \alpha_j j_{it} + g(\omega_{it-1}) + \xi_{it} + \varepsilon_{it}, \tag{12}$$

We can estimate this equation with NLLS, using a high-order polynomial of $\phi_{it-1}, k_{it-1}, j_{it-1}$ for function $g(\cdot)$.

As Ackerberg, Caves and Frazer (2006) noted, the step one and step two can be estimated in one step with GMM. However, the firm exit decision is correlated with ξ_{it} in the step two equation. This is the selection bias, which needs to be corrected. Olley and Pakes use a probit model to estimate the conditional continuing probability P_{it} where the independent variables are 4th order polynomial in $j_{it-1}, i_{it-1}, k_{it-1}$. Then the step two estimation equation is given by

$$y_{it} - \alpha_l l_{it} = \alpha_k k_{it} + \alpha_j j_{it} + \tilde{g}(\phi_{it-1} - \alpha_0 - \alpha_k k_{it-1} - \alpha_j j_{it-1}, P_{it}) + \nu_{it} + \varepsilon_{it}. \tag{13}$$

In this equation, we use the estimated $\widehat{P_{it}}$, $\widehat{\phi_{it}}$, and $\widehat{\alpha_{it}}$ are obtained from step one. The above equation can be estimated with NLLS, by using a polynomial to approximate $\tilde{g}(\cdot)$.

James Levinsohn and Amil Petrin (2003) extends Olley-Pakes method by using intermediate inputs for a proxy for the choice variable that is monotonic in unobserved productivity shocks.

Ackerberg, Caves and Frazer (2006) further assume that labor choice can be a dynamic decision. Hence, step one does not identify α_l. All parameters are identified in step two and step three.

B Figures

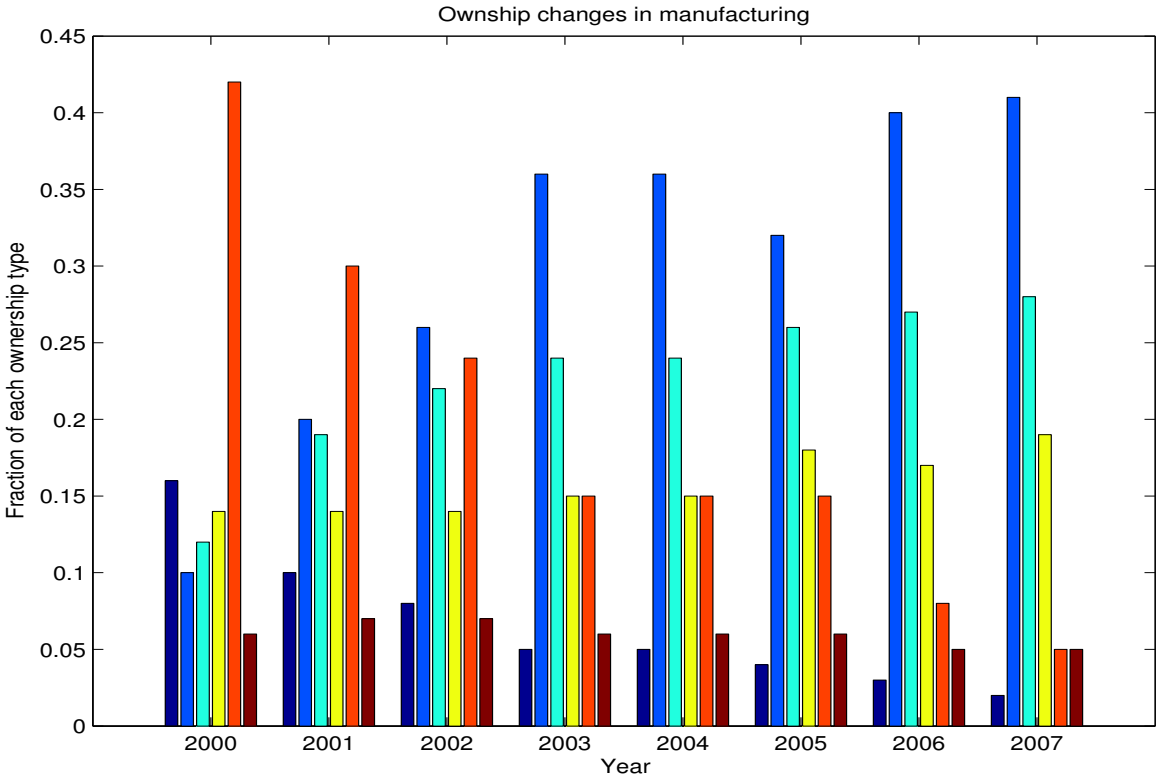

Figure 1: Ownership changes in China: from 2000 to 2007. In order from left to right for each year, ownership type of the bars is SOEs, private-owned, limited liability, HMT & foreign (including foreign firms and firms from Hong Kong, Macau and Taiwan), collectively-owned, and shareholding corporations.

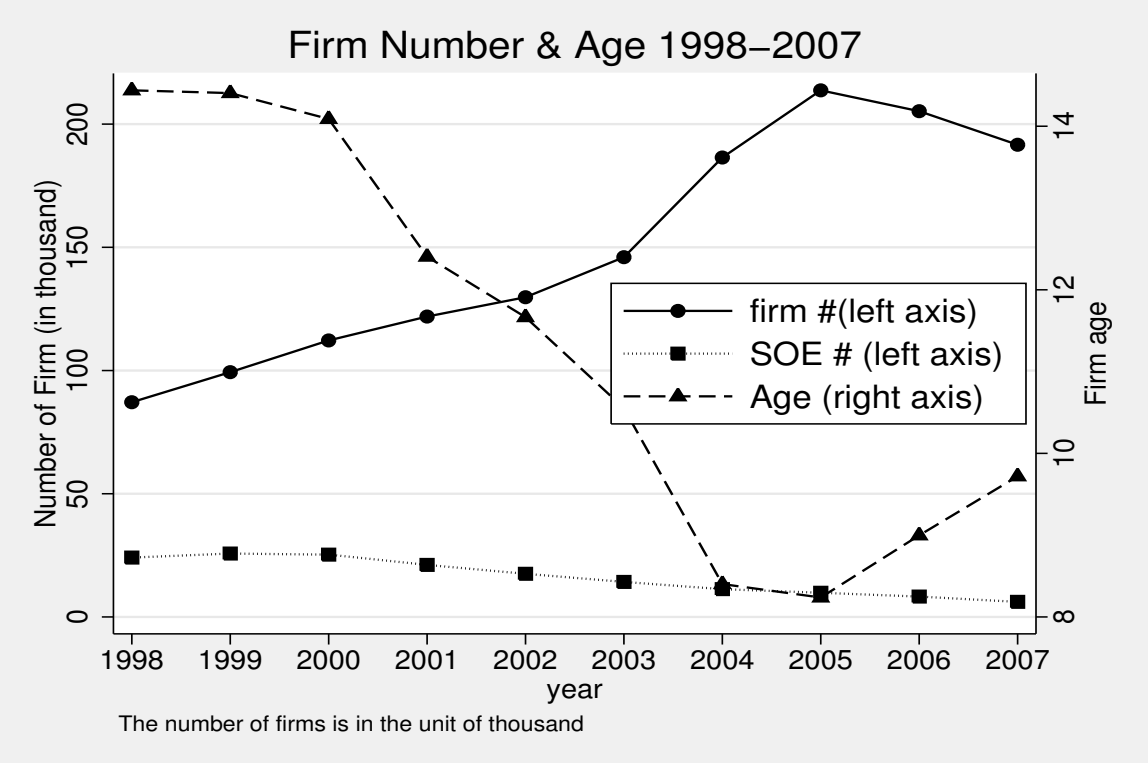

Figure 2: Number of firms, SOEs and firm age: 1998 to 2007.

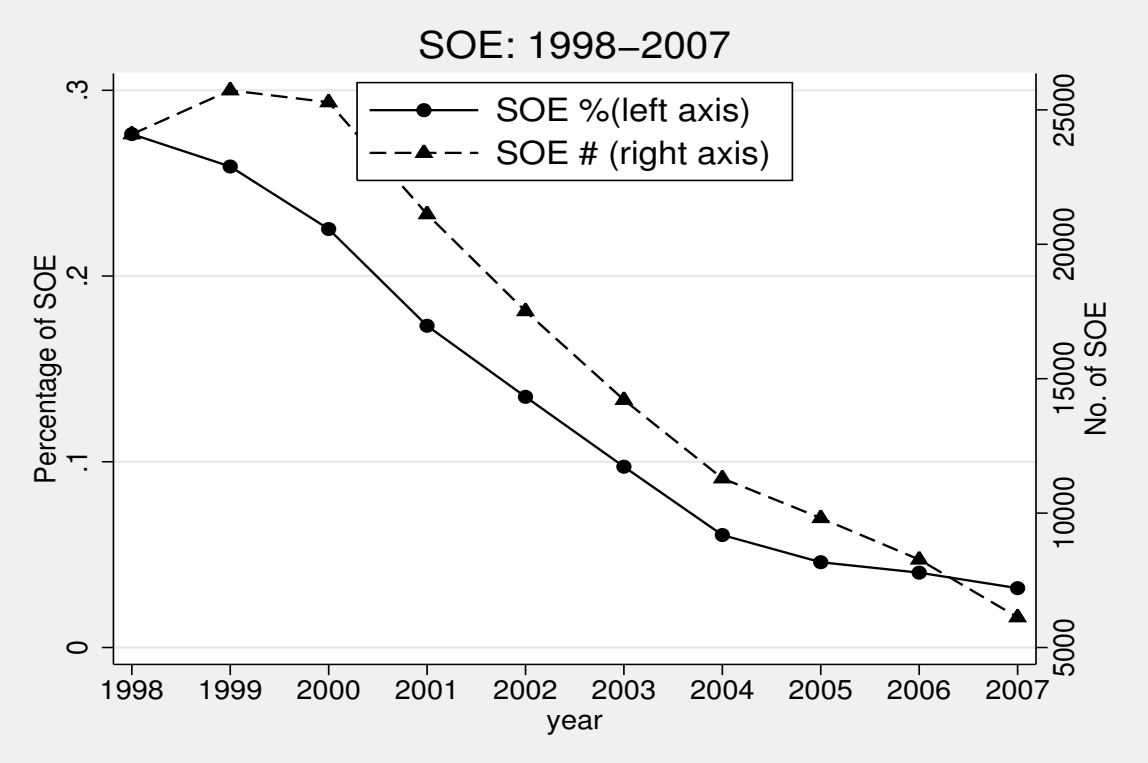

Figure 3: Number and percentage of SOEs: 1998 to 2007.

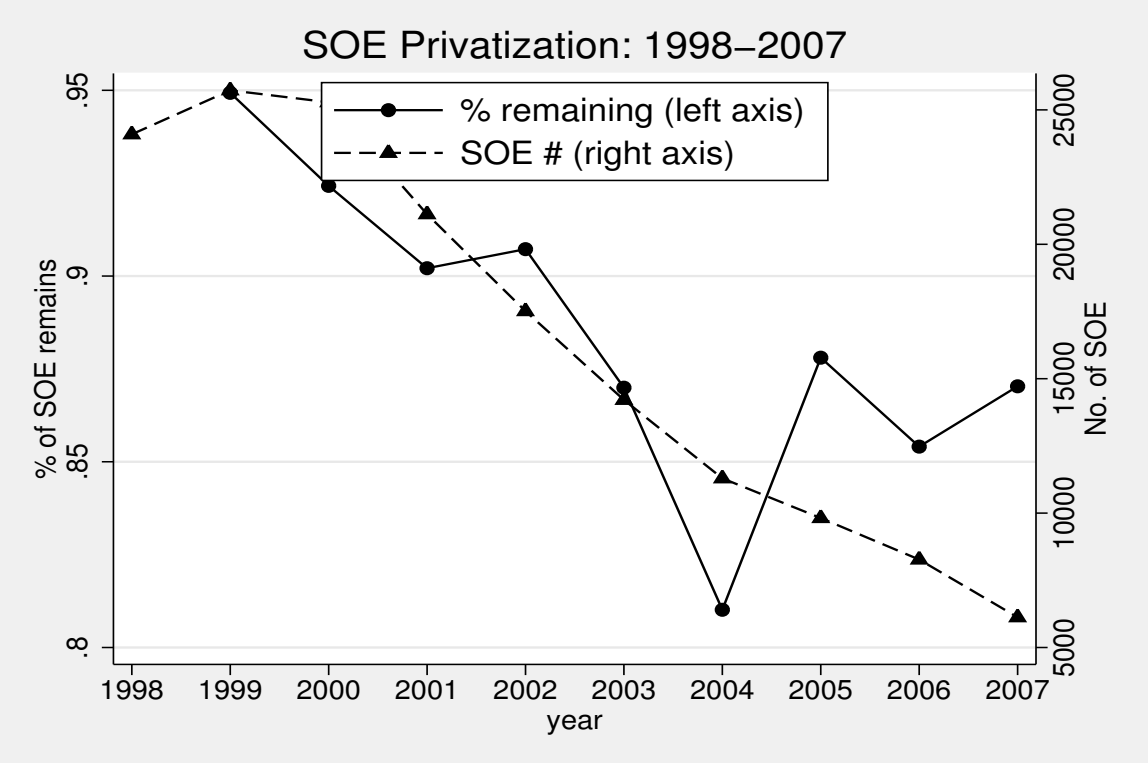

Figure 4: Number of SOEs and their survival rate: 1998 to 2007.

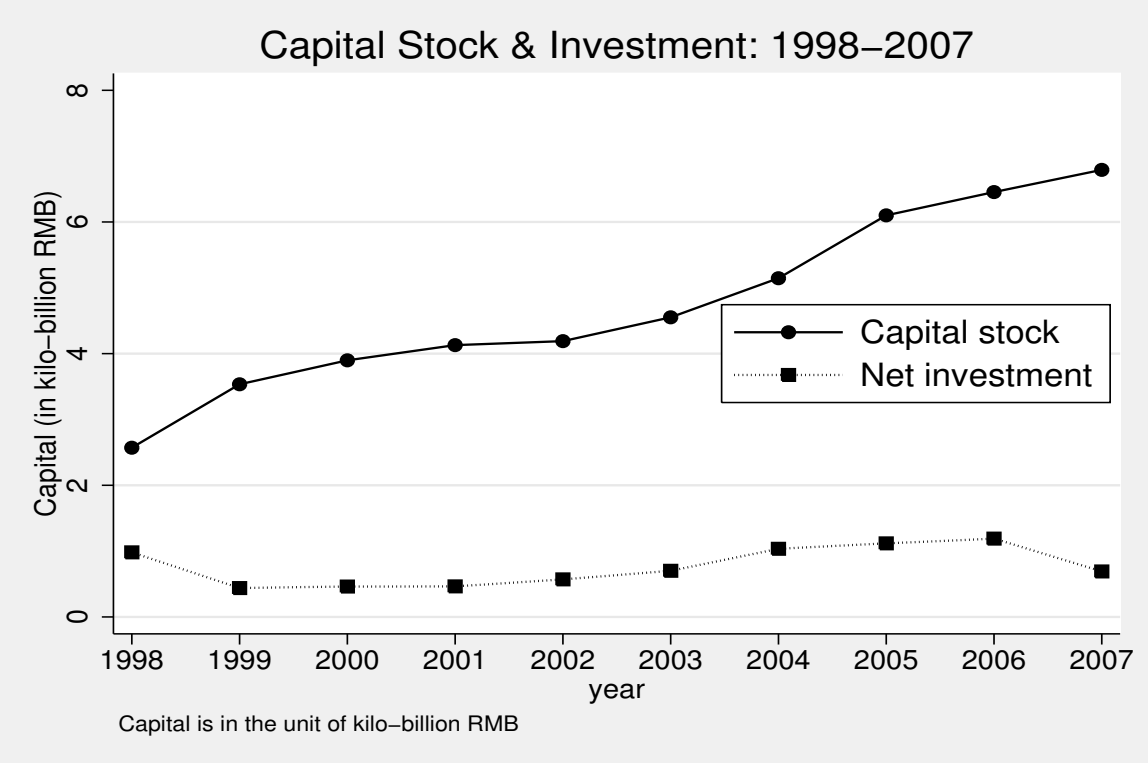

Figure 5: Aggregate Capital and Investment in Chinese Manufacturing: 1998 to 2007.

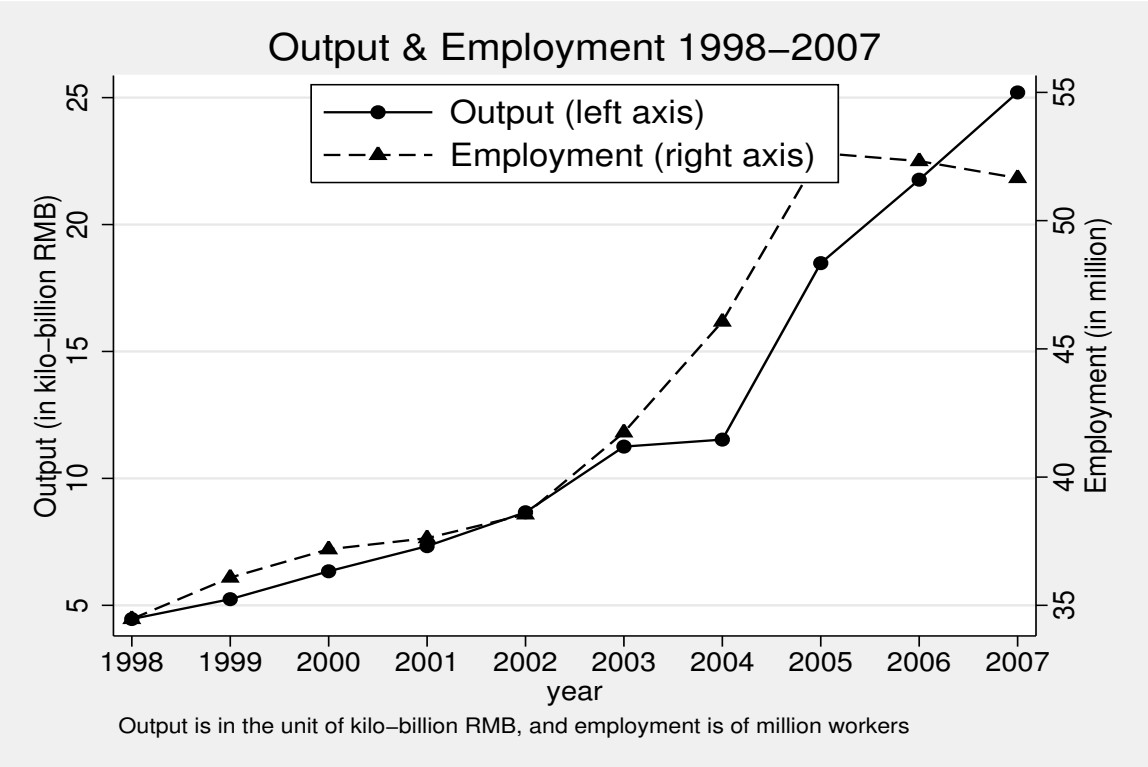

Figure 6: Aggregate Output and Employment in Chinese Manufacturing: 1998 to 2007.

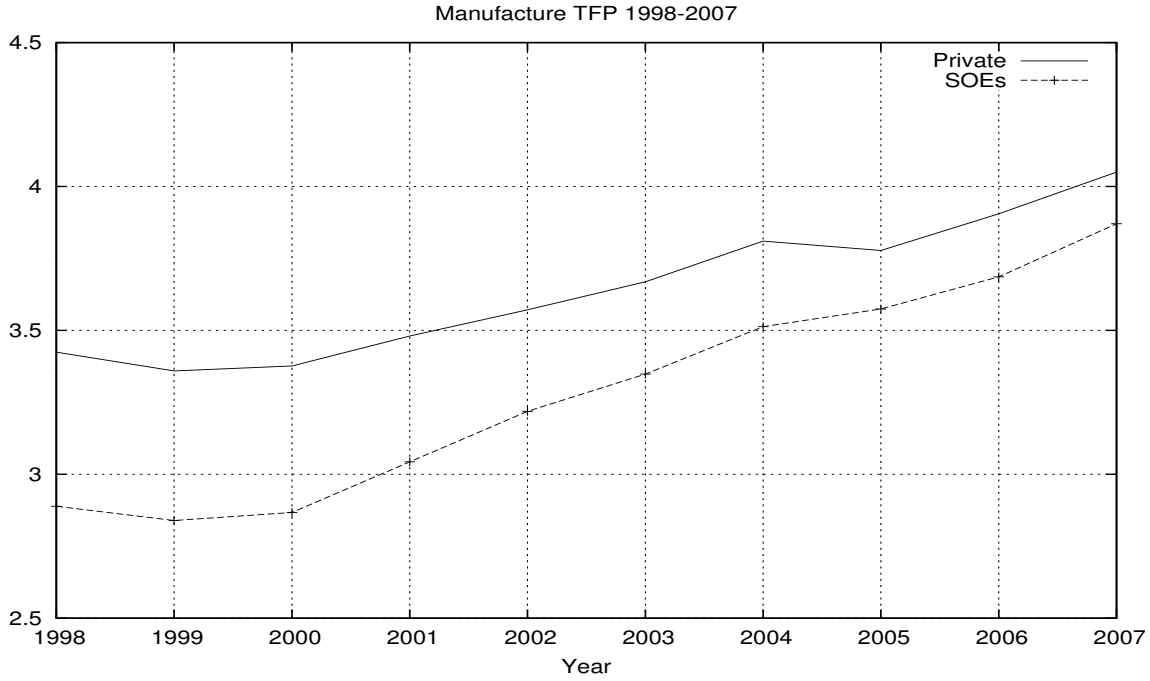

Figure 7: TFP 1998-2007.

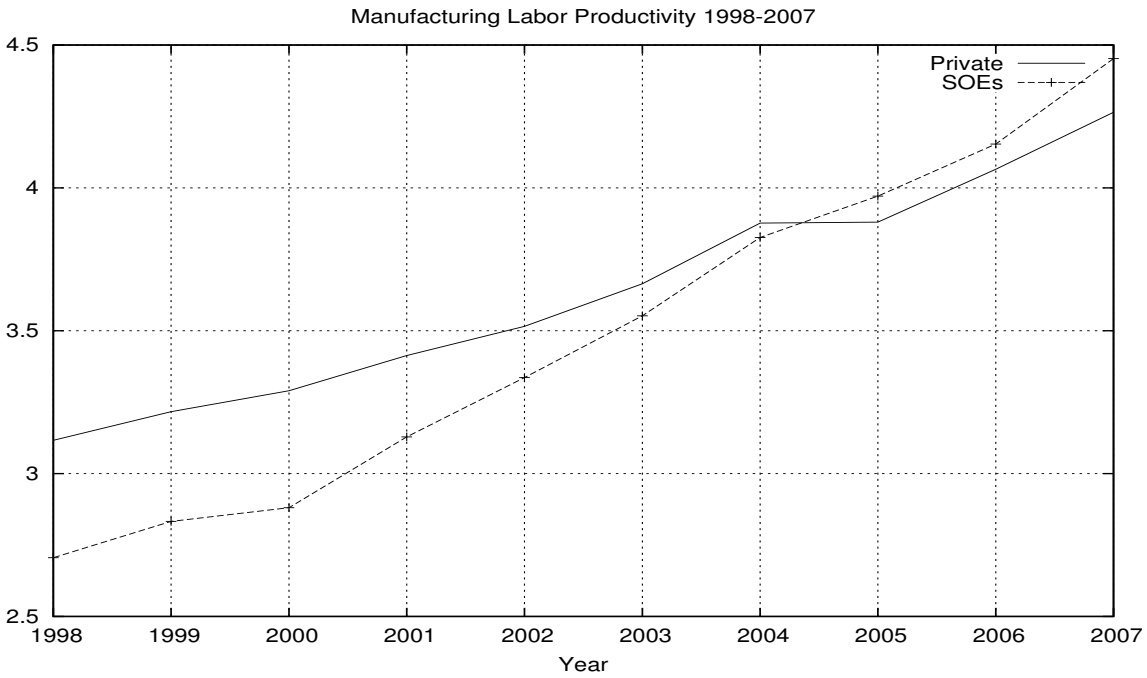

Figure 8: Labor Productivity 1998-2007.

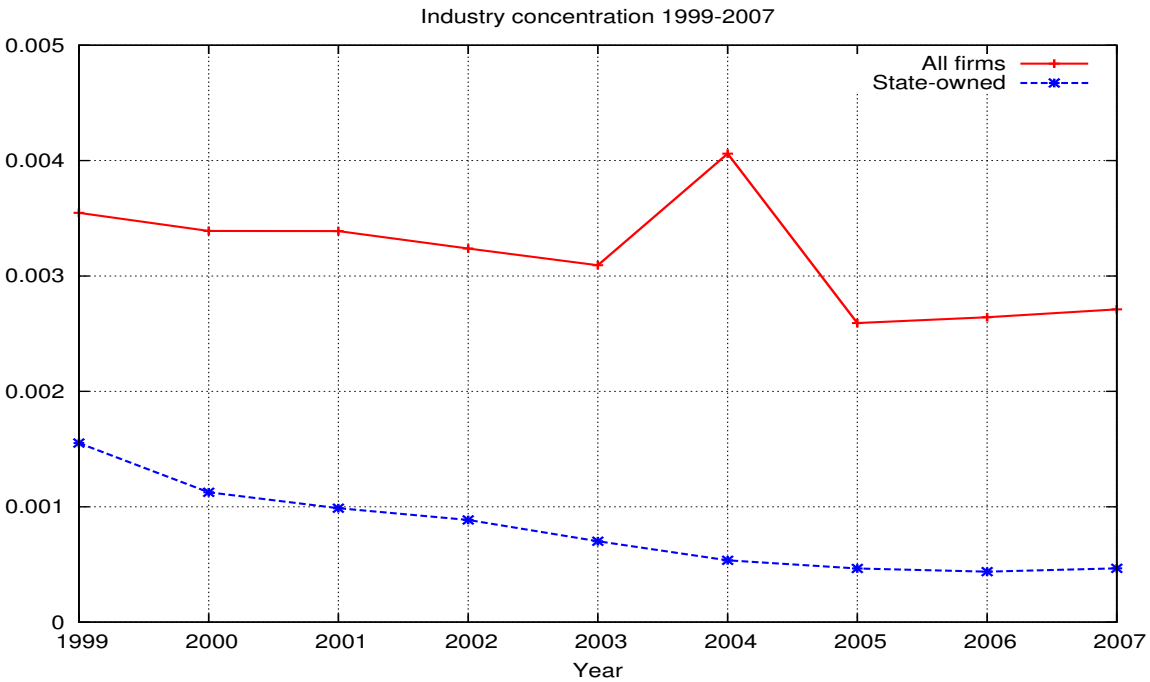

Figure 9: Average industry concentration 1999-2007.

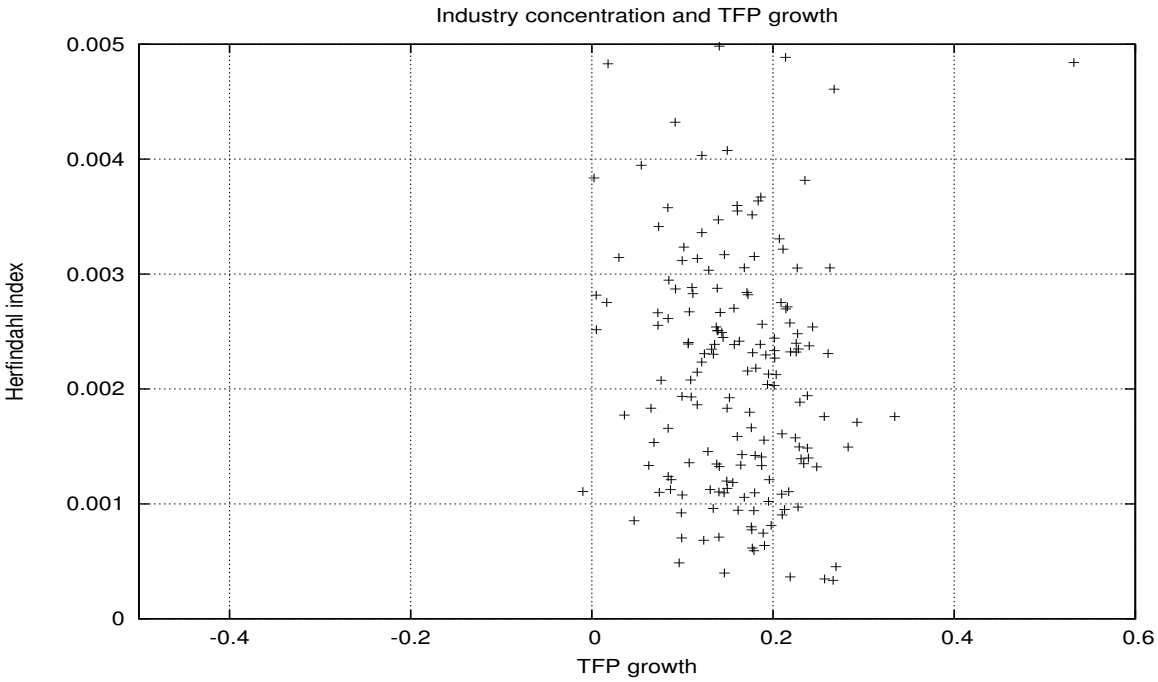

Figure 10: Average industry concentration 1999-2007.

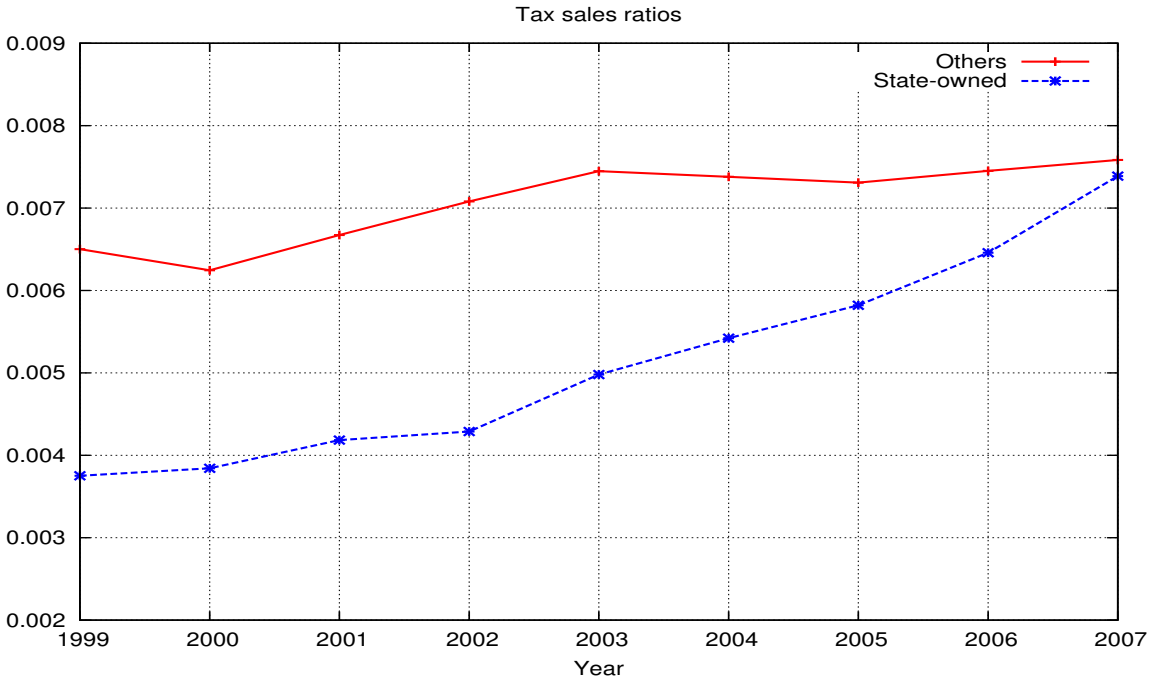

Figure 11: Average tax sales ratio.

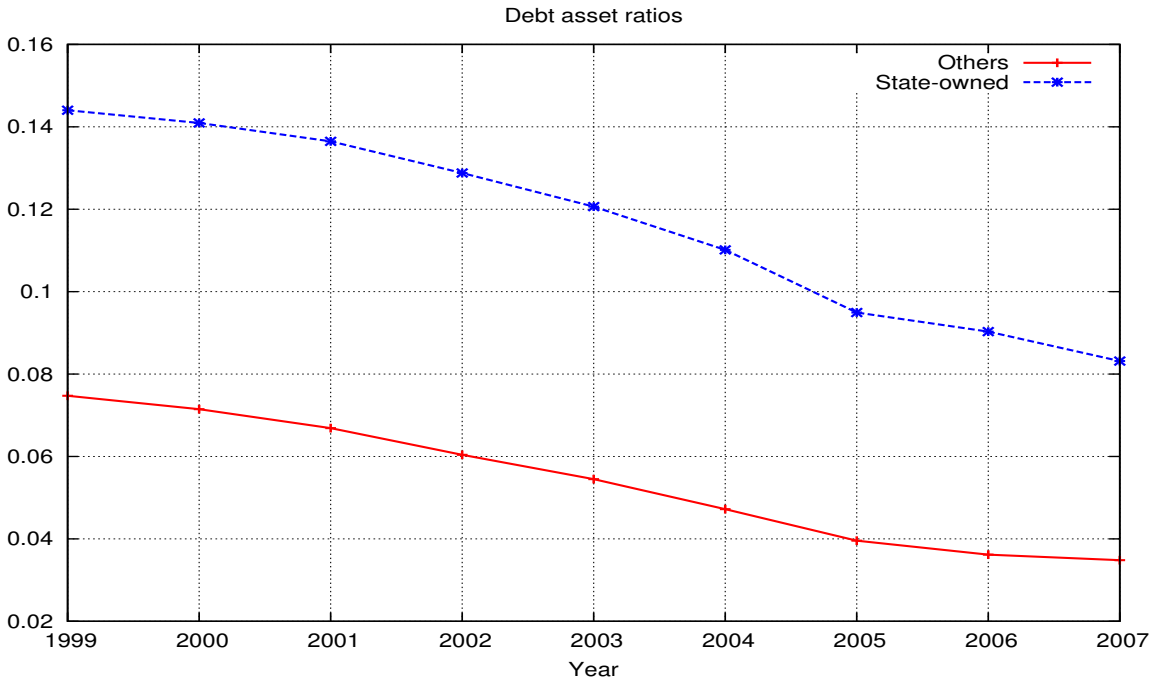

Figure 12: Average debt-asset ratio.

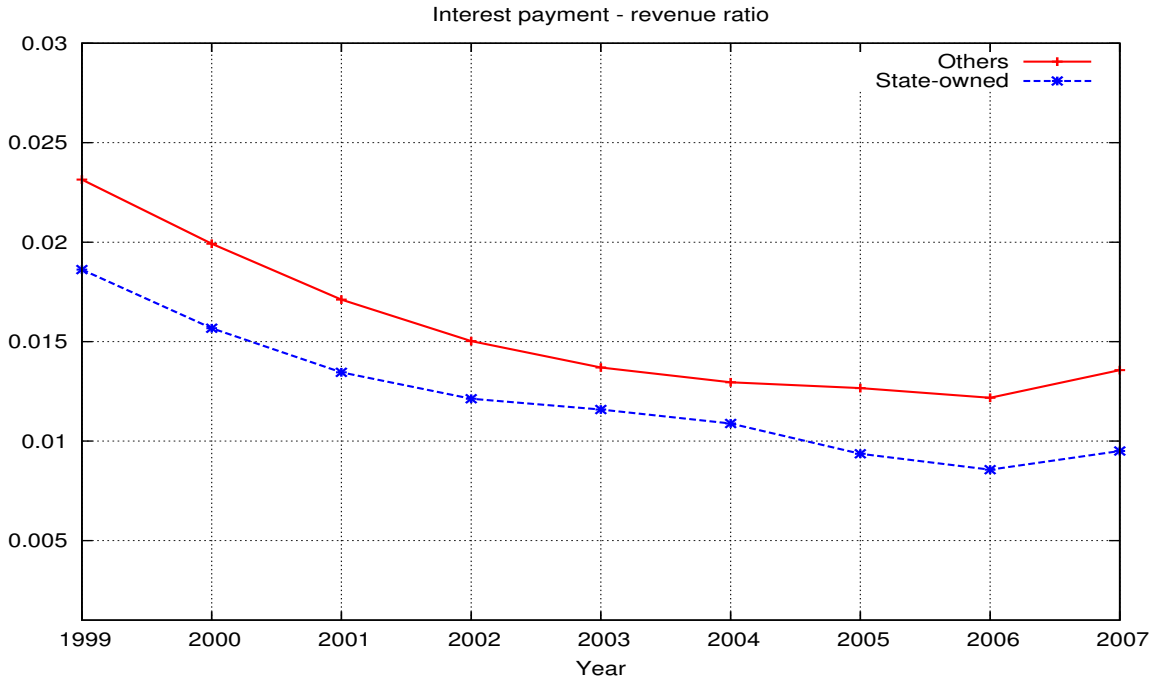

Figure 13: Average interest expediture asset ratio.

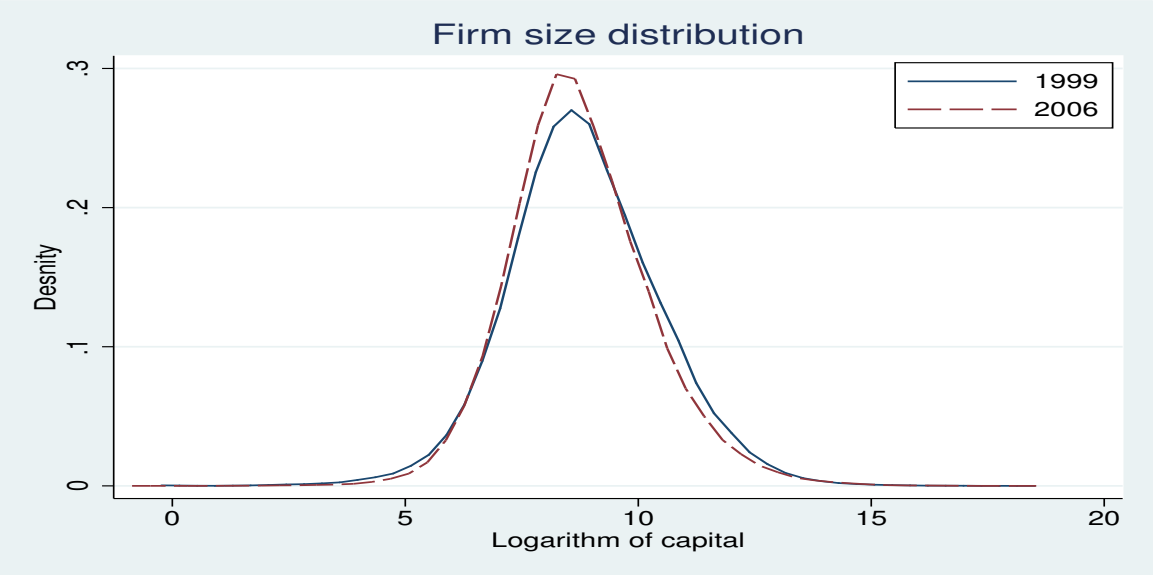

Figure 14: Firm Size Disitribution.

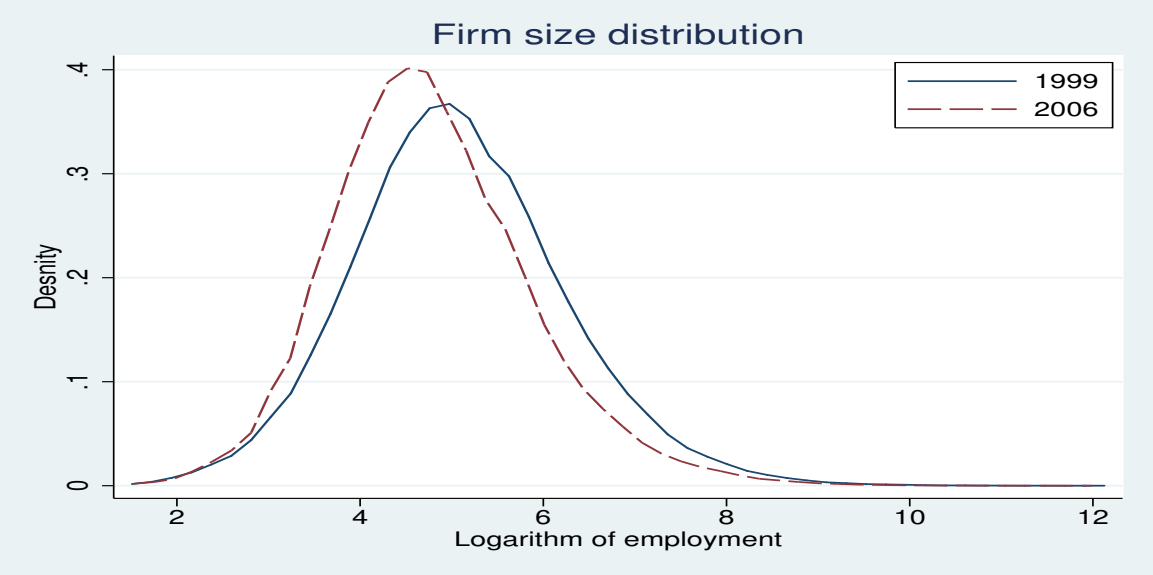

Figure 15: Firm Size Disitribution.

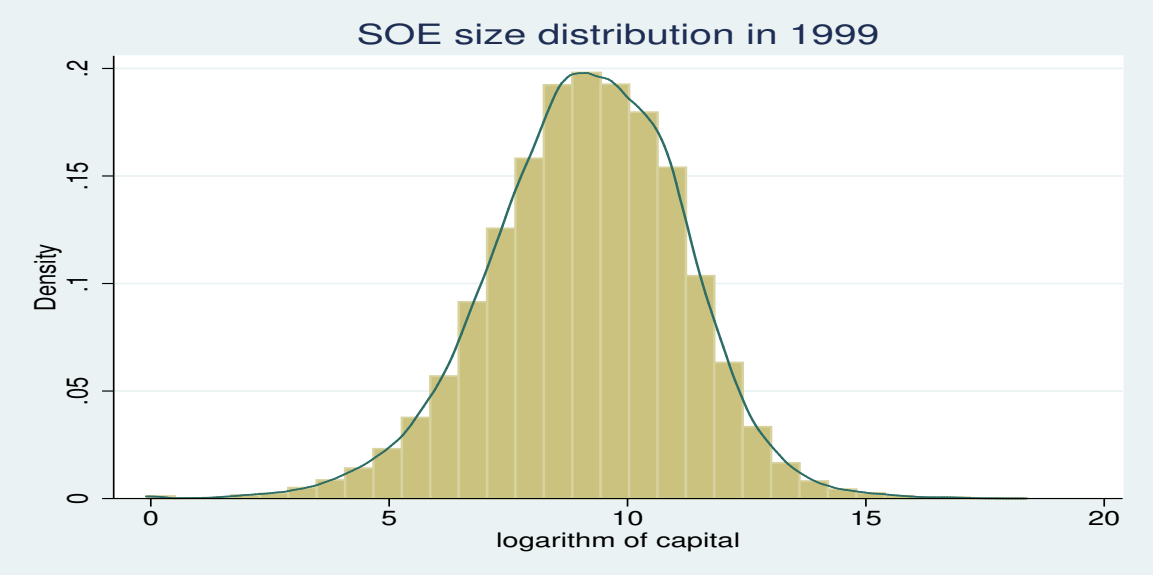

Figure 16: Firm Size Disitribution by Ownership Type

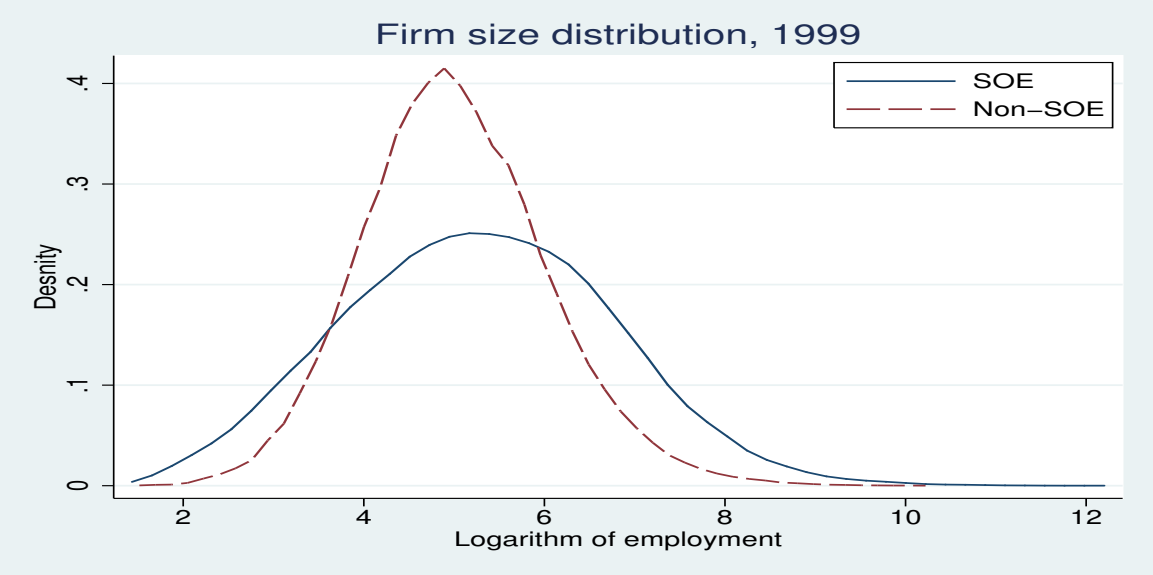

Figure 17: Firm Size Disitribution by Ownership Type

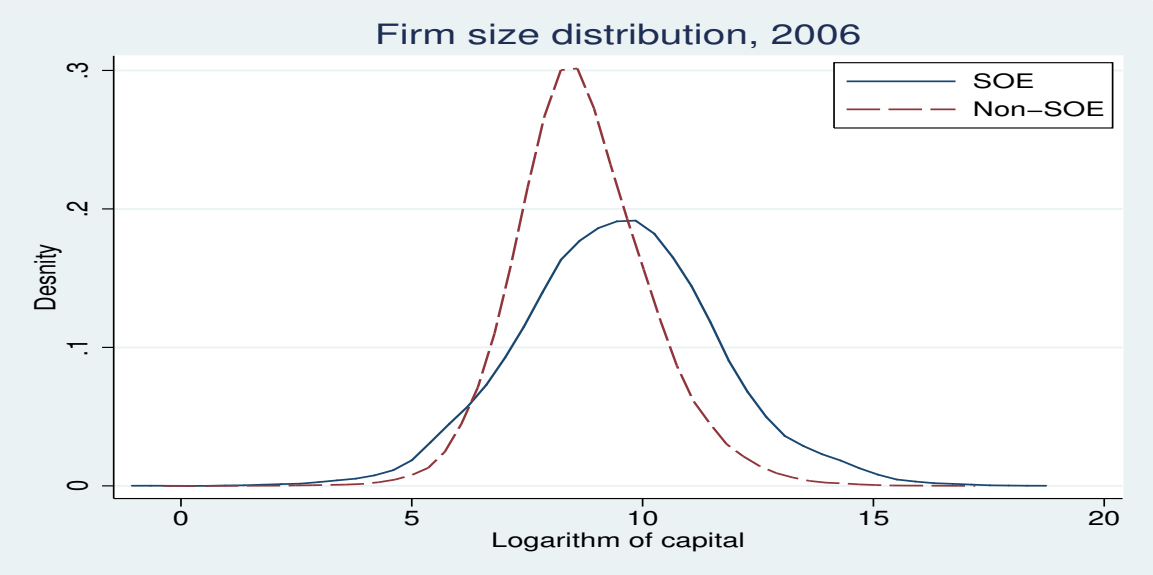

Figure 18: Firm Size Disitribution by Ownership Type

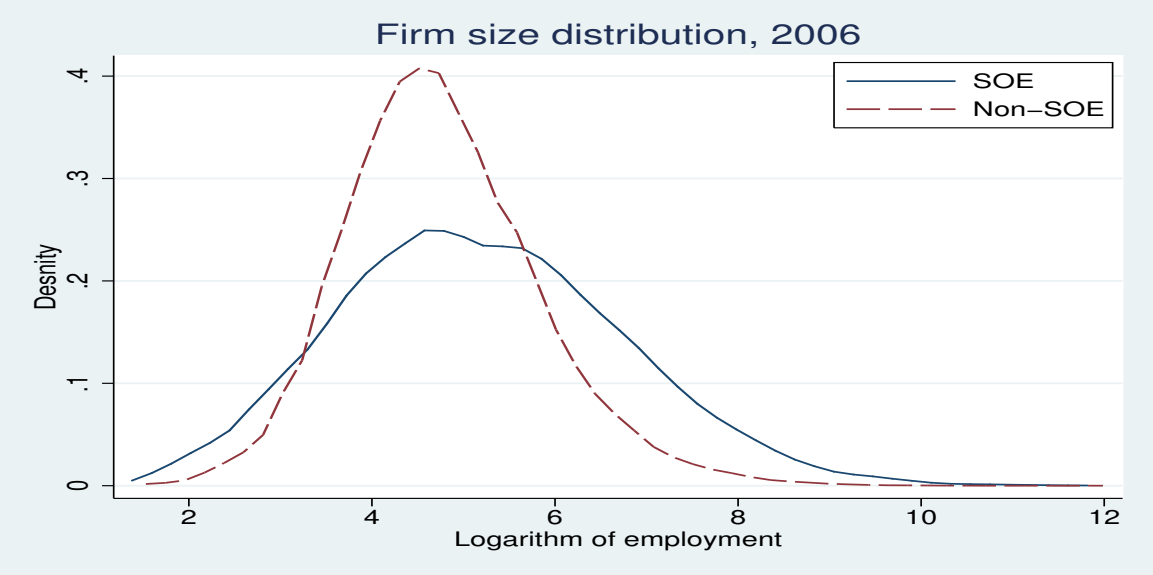

Figure 19: Firm Size Disitribution by Ownership Type