Small Privately-Owned and Large State-Owned Manufacturing Firms in Vietnam: A Productivity Comparison for 2000-2005*

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This paper uses data on individual manufacturing firms for 2000-2005 and estimates separate stochastic production frontiers for private and state firms in Vietnam. The primary objective is to compare these firms' productivity in terms of their production frontiers and technical efficiency.

The empirical results show that the average private firm has a production frontier that is 39% lower and technical efficiency that is 3% higher than the average state firm. Consequently, state firms are inferred to have considerably higher productivity than that of private firms. State firms have a higher production frontier because access to flexible state credit allows them to maintain the quality of their machinery and equipment. In addition, they have priority rights to utilize natural resources, only profitable firms were left after the restructuring and dissolution of state firms, and these firms are likely to have greater management ability or R&D investment.

These results imply that the Vietnamese government employed policies favoring state firms. To increase private firms' productivity, the state should give them rights similar to those granted to state firms. Otherwise, the manufacturing sector will not achieve its productivity potential; rather, it will face serious stagnation and impede Vietnam's development.

Keywords: Production frontier, Technical efficiency, Vietnamese manufacturing firms, Firm ownership, Firm size

Ⅰ. Introduction

In Vietnam's manufacturing sector, most privately-owned firms are substantially smaller than state-owned firms; however, they occupy a large share of the manufacturing sector. Data from the General Statistics Office (GSO) of Vietnam show that in 2008, private and state firms hired 4.7 and 1.6 million employees, respectively, and had turnovers of 2,973 and 1,349 trillion Vietnam dongs (VND), respectively. Thus, private firms had 2.9 and 2.2 times higher employment and turnover than state firms. With such large production shares, small private firms substantially contribute to the productivity level of Vietnam's manufacturing sector. Therefore, it is important to examine the productivity of private firms in comparison with that of state firms, a common research focus in socialist economies. Furthermore, it is important to explain why these firms have different productivity levels.

Firm ownership is a natural point of

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comparison between private and state firms' productivity. The literature commonly argues that private firms are more productive than state firms. In developing countries, this is likely the case partly because private firms are often managed by a family member working for a family firm. As the manager is the firm's only residual claimant, he or she puts a great deal of effort into its management to increase profits (Bottasso and Sembenelli, 2004). Furthermore, state firms are likely to be less productive partly because they are free of competitive pressure. They also lack a scheme for transferring residual claims, which reduces incentives for both managers and workers. Moreover, rather than pursuing higher productivity, state firms in the developing countries are expected to play a key role in stabilizing the economy.

Another point of comparison between Vietnam's private and state manufacturing firms is from firm size. This is because their sizes differ greatly and because productivity studies often address the relationship between firm size and productivity. Large firms are more efficient because of their greater product differentiation, their ability to access specialized resources (labor or capital), their greater market power, the cost advantages of scale economies, their higher prestige, and their perquisites to attract more competent managers and workers (Jovanovic, 1982; Ahuja and Majumdar, 1998). On the other hand, small firms might have higher production efficiency because their small size enables flexibility when responding to changes in the economic environment (e.g., instantaneous adjustments in labor) as well as lower supervision costs (Chapelle and Plain, 2005; Yang and Chen, 2009). Consequently, the two points of comparison might predict contrasting answers to the following question: are private or state firms more productive in the Vietnamese manufacturing sector?

An effective means of comparing private and state firms' productivity is by estimating their stochastic production frontiers (SPF).[1] SPF estimation allows us to examine the difference not only in their technology levels but also in their technical efficiency (TE), both of which are important components of productivity. Technology level represents the best production technology potentially available for all firms. On the other hand, TE represents how efficiently each firm actually produces outputs in comparison with the outputs that could be produced using the best technology.

Despite its importance, most studies that estimate SPF for different groups focus only on TE and not on production frontiers.[2] For Vietnamese manufacturing firms, no study presents SPF estimates for both private and state firms to compare their productivity levels. For example, Vu (2003) estimates SPF only for

state firms, while Tran, Grafton, and Kompas (2008) do so only for private firms. Nguyen, Giang, and Bach (2007) and Pham, Dao, and Reilly (2010) estimate SPF for the entire manufacturing sector, which differs only in the intercepts for private and state firms in the equation for TE. If we compare TE indexes of private and state firms assuming identical production technology, we might reach a misleading conclusion about their productivity differences.

This study utilizes data on individual manufacturing firms (Vietnamese Enterprise Survey) for 2000-2005 to estimate separate SPF for private and state firms. Specifically, we estimate the Cobb-Douglas SPF with a half-normal inefficiency term, which is assumed to be heteroskedastic to absorb factors that affect TE. To identify the more productive firms, we use the estimation results to compare production frontiers and TE indexes of private and state firms. Furthermore, to determine why they have different production frontiers and TE levels, we decompose the ratio of the predicted outputs (production frontiers) into the relevant factors and regress TE indexes on the selected variables.

The results indicate that private firms have a considerably lower production frontier than state firms do, whereas they tend to have slightly higher TE indexes. Combining these opposite effects on productivity, private firms are found to have much lower productivity due to their much lower production frontier. Important explanations for the difference between the production frontiers include policies that benefit only state firms in resource-based manufacturing industries and those that led to only profitable state firms remaining when state firms were restructured at the end of the 1990s.

Section II briefly describes the economic environment surrounding private manufacturing firms in Vietnam. Furthermore, it compares the variables appearing in production frontiers and those affecting the TE of private and state firms. Section III explains the specifications and estimation methods of the Cobb-Douglas SPF and compares production frontiers and the TE of private and state firms using the estimation results. In addition, it finds important factors to explain the productivity differences between private and state firms. Section IV concludes the paper.

Ⅱ. Characteristics of Private and State Firms in the Vietnamese Manufacturing Sector

1. Economic Environment Surrounding Private Firms

The seventh National Congress of the Communist Party of Vietnam legally approved the establishment of private firms

in 1991, five years after the 1986 Doimoi reforms began. Most of these private firms are small and have faced great difficulties, including restricted access to the formal financial system, shortages in the requisite supporting legal institutions and qualified human capital, and limited production technology (Friedman, 2004).

To alleviate these difficulties, the Vietnamese government promulgated the Enterprise Law in 1999, which abolished several administrative procedures and thus lowered various transaction costs, thereby improving the business environment and promoting the development of private firms (Tran, Grafton, and Kompas, 2008; Hansen, Rand, and Tarp, 2009). Since then, private firms have markedly developed and contributed to economic growth. The GSO data show that private firms attained a high growth rate of industrial outputs, 7% on average, during the period of our analysis. The data also show that private firms' employment share increased from 29% to 48% and that their long-run investment share increased from 8% to 21% over the six-year study period. In particular, the manufacturing sector led economic development and produced one-third of total turnover, resulting in 48% of total job creation and 32% of total long-run investment during the period. Although the overall economy was in an upturn, this period also experienced a drastic inflation hike: around 2003, the normal rate was 3%, but it increased to 7.8% and 8.3% in 2004 and 2005, respectively, leading to social instability. Such instability might have negatively influenced production in the leading manufacturing sector.

According to Hansen, Rand, and Tarp (2009), support programs for private firms in their start-up stage (e.g., obtaining licenses and permits, facilitating access to credit and business development services, and temporary tax exemptions) are likely to aid their growth. However, Tran, Grafton, and Kompas (2008) note that some support programs do not systematically improve the productivity of private firms. Furthermore, Nguyen and van Dijk (2012) show that under the present financial system, private firms might face credit constraints. For example, 71% and 37% of private firms are financed through formal and informal sources, respectively, although this is the case for 96% and 22% of state firms, respectively. Furthermore, private firms have access to formal credit for short-term purposes (e.g., day-to-day working capital or trading requirements) rather than for long-term purposes (e.g., capital investment). The subsequent sections investigate how these policies have produced different productivity levels for private and state firms.

2. Comparison of Selected Variables between Private and State Firms

This subsection introduces the main data for the subsequent analysis and provides a preliminary analysis. The main data are adapted from the Vietnamese Enterprise Survey (GSO) and span 2000-2005. We focus on domestic private and state firms in the manufacturing sector (ISIC15-ISIC37), both of which report positive turnover values, value added, labor compensation, and number of employees.[3] The manufacturing sector can be classified into four industrial groups of similar production technologies: resource-based, low-tech, medium-tech, and high-tech manufacturers (Ministry of Industry and Trade (MoIT) and United Nations Industrial Development Organization (UNIDO), 2011).[4] We can also classify Vietnam's 64 municipalities and provinces into six regions: Red River Delta, Northern Midlands and Mountain areas (henceforth Northern Mountains), North and South Central Coast (henceforth Central Coast), Central Highlands, South East, and Mekong River Delta.[5]

Table 1 shows the number of observations for private and state manufacturing firms by firm size for 2000-2005.[6] The number of observations for private firms is 54,644 (89%), while that for state firms is 6,597 (11%), and the shares among all firms are shown in parentheses. Furthermore, the number and share of private firms increased from 7,261 (85%) in 2000 to 14,024 (94%) in 2005, whereas that of state firms declined from 1,301 (15%) in 2000 to 885 (6%) in 2005. Among state firms, the number of small firms decreased much more rapidly than that of large firms over the six-year study period. Over the same period, among private firms, small firms increased from 6,300 to 11,109, and large firms also increased from 961 to 2,915.

Table 1. Number of Observations for Private and State Manufacturing Firms by Firm Size

Firm Ownership	Private			State			Total
Firm Size	Total	Small	Large	Total	Small	Large	
2000	7,261	6,300	961	1,301	542	759	8,562
2001	8,338	7,099	1,239	1,193	424	769	9,531
2002	7,337	5,848	1,489	1,200	376	824	8,537
2003	7,943	6,164	1,779	1,043	251	792	8,986
2004	9,741	7,478	2,263	975	185	790	10,716
2005	14,024	11,109	2,915	885	153	732	14,909
Total	54,644	43,998	10,646	6,597	1,931	4,666	61,241

Note: "Large" firms are defined as firms with turnover greater than the 75th centile of the turnover for all sample firms.

The total number of small firms was 45,929, 75% of the total sample. These observations reflect the overwhelming share of private firms in the manufacturing sector.

Now, we introduce the production function variables. We use value added Y for output because data for production materials are unavailable for some years. It is computed as the sum of total profit and labor compensation (including fringe benefits). Labor L is the number of total employees at the end of the survey year. Capital K is the value of fixed assets at the beginning of the survey year. The value added and capital are deflated by the distinct producer price indexes proposed by Javorcik (2004).

Table 2 reports the means of value added, labor, and capital. The means of

Table 2. Means of Variables Used for Empirical Analysis

Firm Ownership		Private		State	
Number of Observations		54,644		6,597	
Variables in production frontier					
Value-added	[mill.VND]	11.18	(46.72)	126.83	(398.21)
Labor	[person]	87.86	(290.14)	562.76	(900.29)
Capital	[mill.VND]	21.19	(98.94)	221.63	(842.91)
Regional dummies					
Red River delta		0.252	(0.434)	0.368	(0.482)
Northern Mountains		0.035	(0.183)	0.103	(0.304)
Central Coast		0.105	(0.307)	0.168	(0.374)
Central Highlands		0.017	(0.128)	0.031	(0.174)
South East		0.395	(0.489)	0.240	(0.427)
Mekong River delta		0.196	(0.397)	0.090	(0.286)
Industrial group dummies					
Resource-based		0.393	(0.488)	0.246	(0.431)
Low-tech		0.394	(0.489)	0.486	(0.500)
Medium-tech		0.203	(0.402)	0.251	(0.434)
High-tech		0.010	(0.098)	0.017	(0.128)
Variables to explain technical efficiency					
dsize		0.19	(0.40)	0.71	(0.46)
age		6.1	(7.5)	21.7	(13.4)
debt		0.34	(7.23)	0.65	(0.37)
percap_income	[mill.VND]	10.53	(12.18)	16.33	(19.10)
Herfindahl		0.0043	(0.0058)	0.0060	(0.0050)
spillover		0.3373	(0.1497)	0.3271	(0.1992)

Note: Standard deviations are shown in parentheses and units are shown in brackets. VND represents Vietnam dong, which is approximately equal to US 0.00007 dollar on average for 2000-2005. The variable *dsize* is included in both "variables in production frontier" and "variables to explain technical efficiency" in the empirical analysis.

L, K, and *Y* for private firms are 87.9, 21.2, and 11.2, respectively, whereas those of state firms are 562.8, 221.6, and 126.8, respectively. Therefore, state firms use 6.4 times more labor and 10.5 times more capital to produce 11.3 times more output. Furthermore, the capital/labor ratio *K/L* is 0.39 and 0.24 for state and private firms, respectively, implying that state firms adopt more capital-intensive technology. These results suggest that state firms are likely to have higher productivity. In such socialist developing countries as Vietnam, state firms can be more productive partly because they are designated as national economic stabilizers and can benefit from such policies as preferential investment policies, fund raising from state credit, and market protection (Friedman, 2004). We confirm the plausibility of this prediction by estimating separate SPFs for private and state firms.

Next, in view of the related literature, we introduce six variables (*dsize, age, debt, percap_income, Herfindhal,* and *spillover*), which potentially affect TE. The dummy variable takes the value 1 if the firm is classified as large scale, as defined in Table 1. The dummy variable can positively or negatively affect TE, as we examined in the Section I. The variable *age* is defined as the difference between the current year and the registration year.[7] It, too, can positively or negatively impact TE. Older firms may be technically more efficient due to their greater experience (Jovanovic, 1982), but they may be outdated in their organizational modes of thoughts and actions (Ahuja and Majumdar, 1998). The variable is defined as the ratio of total liabilities to total assets. Higher is expected to negatively influence TE. An increase in *debt* is associated with higher interest payments and an increase in the possibility of default (bankruptcy), which forces a greater input adjustment (Paul, Johnston, and Frengley, 2000). The variable *percap_income* is defined as total labor compensation divided by labor input, and it is expected to positively affect TE. Yang and Chen (2009) mention that higher incomes stimulate employees to increase effort, thereby increasing TE. Industrial concentration (or competition) is proxied by the index $Herfindahl_j = \sum_i S_{ji}^2$, where S_{ji} denotes the market share of firm i in industry j in terms of turnover. Sari (2003) finds a positive effect of the Herfindahl index on TE at two extremes of highly concentrated or highly competitive markets. Suyanto, Salim, and Bloch (2009) also interpret a negative effect of the Herfindahl index on TE as static competition and its positive effect as dynamic competition, depending on market conditions. Finally, the variable $spillover_j$ (j: industry name) is defined as the sum of the turnover of foreign firms in industry j divided by the sum of the turnover of all firms in the same

industry. It is expected to positively affect TE because domestic firms can imitate the better products of foreign firms and because they try to devote more effort to prevent falling behind these foreign firms (Caves, 1974; Javorcik, 2004).

Table 2 reports the means of the six variables. The mean of *dsize* shows that most private firms are classified as small scale, while most state firms are classified as large scale. The mean *age* for private firms is only 6.1, while that for state firms is 21.7. This large difference reflects Vietnam's social and economic background, which is examined in the Section 2.1. The mean of *debt* is 0.34 for private firms and 0.65 for state firms. Private firms' lower *debt* possibly implies that they do not finance from formal sources as state firms do. The mean of *percap_income* shows that private-firm employees are paid lower wages than state-firm employees are. The Herfindahl index, in terms of turnover, is smaller for private firms (0.0043) than for state firms (0.0060), implying that private firms face greater market competition. Both these values are small because there are many small firms in Vietnam's manufacturing sector. Finally, the means of *spillover* for private and state firms are similar, suggesting that both types of firms are similarly exposed to foreign products and technology.

Ⅲ. Empirical Analysis

1. Empirical Methods

To compare production frontiers of private and state firms, we specify and estimate two Cobb-Douglas SPFs separately for these firms. Specifically, the SPF has two inputs (labor L_{it} and capital K_{it}) and one output (value added Y_{it}) for firm i (= 1, ..., n) and year t (= 2000, ..., 2005):

$$\begin{aligned} lnY_{it} &= \beta_0+\beta_1 lnL_{it}+\beta_2 lnK_{it}+\beta_3 dsize_{it} \\ &\quad + \sum_s \beta_s dyear_s + \sum_{r\in R} \beta_r dregion_{ir} \\ &\quad + \sum_{g\in G} \beta_g dindustry_{ig} + v_{it} - u_{it}, \end{aligned} \quad (1)$$

where $dyear_s$ denotes time dummy variables for year s = 2001, ..., 2005, with 2000 chosen as the base year; $dregion_{ir}$ denotes regional dummy variables for firm i in region r with R denoting a regional set which includes five out of the six regions introduced in the Section II (Red River delta is chosen as the base group); $dindustry_{ig}$ denotes industrial dummy variables for firm i in industrial group g with G denoting an industrial set which includes three out of four industrial groups introduced in the Section II (medium-tech is chosen as the base group). Note that subscript j for industries is omitted from variables (except for $dindustry_{ig}$) to simplify notations, which means that their coefficients are common to all industries. We assume that v_{it} is a normal random variable with a mean zero and a constant variance σ_v^2 and that non-negative technical inefficiency u_{it}

follows a half normal distribution with variance σ_u^2.

The coefficients of labor and capital in the SPF (1) can be interpreted in two ways. On the one hand, higher coefficients of labor and capital can be regarded as higher quality or efforts related to these inputs because increases in the inputs make a higher contribution to output. On the other hand, a higher coefficient of labor, for example, can be regarded as a higher share or intensity of labor input because β_1 is equal to the ratio of wage payment to output under a competitive labor market.

Caudill, Ford, and Gropper (1995) emphasize that the heteroskedasticity of inefficiency u can substantially affect the estimated TE index. Recalling the six variables introduced in the Section II, we specify the variance σ_u^2 for firm i in industry j in year t as[8)]

$$ln\sigma_u^2 = \delta_0 + \sum_s \delta_s dyear_s + \delta_1 dsize_{it} + \delta_2 age_{it} + \delta_3 debt_{it} + \delta_4 percap\_income_{it} + \delta_5 Herfindahl_{jt} + \delta_6 spillover_{jt}. \quad (2)$$

We jointly estimate the SPF (1) and the variance function (2) using the maximum likelihood method. After separately estimating these functions for private and state firms, we follow Battese and Coelli (1988) to compute the TE index as

$$TE = \mathrm{E}[\exp(-u)\,|\,Y] = \{\Phi[(u^*/\sigma_*) - \sigma_*] / \Phi(u^*/\sigma_*)\} \exp[(\sigma_*^2/2) - u^*], \quad (3)$$

where $u^* = -(v-u)\sigma_u^2/\sigma^2$, $\sigma_*^2 = \sigma_u^2\sigma_v^2/\sigma^2$, and $\sigma^2 = \sigma_u^2 + \sigma_v^2$. Φ denotes the cumulative distribution function of the standard normal variable. If the TE indexes differ between private and state firms, we adopt a popular method to explain the difference by regressing the estimated TE indexes on the six variables and year dummies in equation (2).

To compare production frontiers for private and state firms, we compute an index of the predicted output in a manner similar to Kumbhakar, Tsionas, and Sipilainen (2009). Let $\hat{Y}_p$ and $\hat{Y}_s$ denote outputs predicted by using deterministic frontiers (the right hand side of equation (1) excluding the terms u and v) of private and state firms, respectively. It should be noted that each firm (private or state) has two predicted outputs $\hat{Y}_p$ and $\hat{Y}_s$ after substituting its actual value of labor, capital, and other dummy variables into the two deterministic frontiers. In other words, computing $\hat{Y}_p$ and $\hat{Y}_s$ for each firm allows us to compare the two production frontiers by controlling for the input levels.

If the production frontiers differ between private and state firms, we decompose the geometric means of $\hat{Y}_p$ and $\hat{Y}_s$ as follows to explain the difference. By their definition and equation (1), we can write $\hat{Y}_p$ and $\hat{Y}_s$ for (private or state) firm i as

$$\hat{Y}_{m,i} = \exp(\hat{\beta}_{0,m}) \Pi_{k=1}^{16} X_{k,i}^{\hat{\beta}_{k,m}} \quad (m = p, s) \quad (4)$$

where $X_{k,i}$ $(k = 1, \cdots, 16)$ denote L, K, exp $(dsize)$, exp $(dyear_s)$ $(s = 2001, \cdots, 2005)$, exp $(dregion_{ir})$ (r: index of the five regions), and exp $(dindustry_{ig})$ (g: index of

the three industrial groups). $\hat{\beta}_{0,m}$ and $\hat{\beta}_{k,m}$ ($m=p, s$) are maximum likelihood estimates of the parameters β_0 and β_k for type m (private or state) firms. Taking the geometric means $\hat{Y}_p$ and $\hat{Y}_s$ of $\hat{Y}_{p,i}$ and $\hat{Y}_{s,i}$ in equation (4) for all firms (including private and state firms), we obtain

$$\hat{Y}_p/\hat{Y}_s = \exp(\hat{\beta}_{0,p}-\hat{\beta}_{0,s})\Pi_{k=1}^{16}\tilde{X}_k^{\hat{\beta}_{k,p}-\hat{\beta}_{k,s}} \quad (5)$$

where $\tilde{X}_k$ ($k=1, \cdots, 16$) denote the geometric mean of $X_{k,i}$ for all firms. Equation (5) shows that the ratio $\hat{Y}_p/\hat{Y}_s$ is decomposed into the difference in the intercept of the production frontier, $\exp(\hat{\beta}_{0,p}-\hat{\beta}_{0,s})$, and the difference in the contribution of factor k ($=1, \cdots, 16$) to the production frontier, $\tilde{X}_k^{\hat{\beta}_{k,p}-\hat{\beta}_{k,s}}$. Each of these contributions is greater than 1 if $\hat{\beta}_{k,p} > \hat{\beta}_{k,s}$, lower than 1 if $\hat{\beta}_{k,p} < \hat{\beta}_{k,s}$, and equal to 1 if $\hat{\beta}_{k,p} = \hat{\beta}_{k,s}$.

2. Estimated Parameters

Table 3 presents estimated parameters of the SPF (1) and the variance function (2) for private and state firms. Most parameters are statistically significant at the 5% level. Production elasticity of labor is estimated at 0.90 for private firms and 0.83 for state firms. Production elasticity of capital is estimated at 0.04 for private firms and 0.09 for state firms. As explained in the previous section, the higher coefficient of labor for private firms shows that their workers seem to devote more efforts to producing output or that they use labor more intensively than capital. The lower coefficient of capital for private firms shows that they cannot maintain their machinery and equipment as well as state firms do or that they use capital less intensively than labor.

We are not aware of any Vietnamese studies suitable for comparison that use value added to estimate the Cobb-Douglas production function. However, Soderbom and Teal (2004) use value added to estimate production elasticities of labor and capital for manufacturing firms in Ghana. Their results are 0.89 and 0.18, respectively, and are consistent with ours in that the production elasticity of labor is very high in the manufacturing sector of the developing countries, in which most firms are small and use labor-intensive technology.[9)]

An examination of the coefficients of the regional dummy variables indicates that both private and state firms produce less in the Northern Mountains and more in the South East and the Mekong Delta than do firms in the Red River Delta. This result seems consistent with the actual economic situation in Vietnam. The Northern Mountains region is far less developed in terms of infrastructure and is not favorable for manufacturing production. On the other hand, the South East (including Ho Chi Minh City) and the Mekong River delta have been more exposed to the market economy for a long time because of their

experience in the pre-unification period and access to better market-supporting institutions (Vu, 2003; Pham, Dao, and Reilly, 2010). For the other two regions, we find statistically significant positive coefficients only for private firms, imply-

Table 3. Estimated Parameters of Stochastic Production Frontiers and Variance Functions

Firm Ownership	Private		State	
Number of Observations	54,644		6,597	
Production Frontier				
ln *L*	0.8997	(0.0027)***	0.8251	(0.0102)***
ln *K*	0.0365	(0.0010)***	0.0902	(0.0065)***
dsize	0.5993	(0.0100)***	0.6337	(0.0298)***
dyear2001	0.0243	(0.0143)*	0.0605	(0.0355)*
dyear2002	0.0817	(0.0145)***	0.1270	(0.0354)***
dyear2003	0.1656	(0.0141)***	0.2344	(0.0364)***
dyear2004	0.1063	(0.0135)***	0.2967	(0.0369)***
dyear2005	0.1029	(0.0126)***	0.4351	(0.0377)***
Northern Mountains	-0.0553	(0.0168)***	-0.1170	(0.0321)***
Central Coast	0.0339	(0.0103)***	-0.0507	(0.0261)*
Central Highlands	0.0957	(0.0221)***	-0.0500	(0.0520)
South East	0.2038	(0.0070)***	0.3349	(0.0205)***
Mekong River delta	0.3528	(0.0094)***	0.2329	(0.0310)***
Resource-based	-0.3182	(0.0083)***	-0.0965	(0.0262)***
Low-tech	-0.1970	(0.0074)***	-0.0002	(0.0205)
High-tech	0.0937	(0.0263)***	0.2109	(0.0588)***
constant	-1.8670	(0.0156)***	-1.5094	(0.0508)***
Variance Function				
dyear2001	0.1777	(0.0457)***	0.1395	(0.1170)
dyear2002	0.3299	(0.0504)***	0.3907	(0.1197)***
dyear2003	0.5214	(0.0514)***	0.8385	(0.1268)***
dyear2004	0.6488	(0.0503)***	1.2927	(0.1333)***
dyear2005	0.8514	(0.0470)***	2.0132	(0.1459)***
dsize	1.0683	(0.0419)***	0.6721	(0.0848)***
age	-0.0145	(0.0014)***	0.0008	(0.0021)
debt	0.0003	(0.0009)	0.6680	(0.0772)***
percap_income	-0.4089	(0.0053)***	-0.2629	(0.0080)***
Herfindahl	1.0723	(2.4982)	-32.2211	(8.4160)***
spillover	0.7252	(0.0883)***	0.6103	(0.2124)***
constant	1.3618	(0.0444)***	0.8639	(0.1384)***
σ_v	0.5107	(0.0024)***	0.5078	(0.0063)***
log-likelihood	-50748.16		-6292.58	

Note: Standard errors are shown in parentheses. *, **, and *** represent the statistical significance at 10%, 5%, and 1% levels, respectively.

ing that local authorities support and/or contribute to the development of the region's private sector.

The positive coefficients of the year dummy variables show that both types of firms experience technological progress (i.e., upward shifts in the production frontiers) throughout 2000-2005. Specifically, private firms' production frontier steadily shifted upward since 2000 to record 10% growth over the six-year study period, after reaching the peak growth rate at 17% in 2003. State firms recorded considerably faster growth, particularly in the last two years. State firms' faster growth since 2004 can be attributed to various policies for intensified restructuring and dissolution of state firms at the end of the 1990s, which led to the dissolution or privatization of incapable firms (especially local firms), leaving only capable firms as completely or partially state-owned ones. As a result, restructured state firms are considered key in stabilizing the economy, and hence can benefit more from governmental support to fulfill their socioeconomic role.

The estimated coefficients of the industrial group dummies are plausible for both private and state firms because the production frontiers of the low-tech (although insignificant for the low-tech manufacturing state firms) and the resource-based manufacturers are lower, while the production frontiers of the high-tech manufacturers are higher than those of the medium-tech manufacturers (the base group). The low-tech and resource-based manufacturers utilize relatively simple technologies and low-skilled labor and are more labor- or resource-intensive (MoIT and UNIDO, 2011), which suggests their lower production frontiers. On the other hand, the medium- and high-tech manufacturing require much more sophisticated technologies, a skilled workforce, investment in and development of new products (MoIT and UNIDO, 2011), which suggests their higher production frontiers.

Table 3 also presents the estimated parameters of the variance function (2). Most parameters are statistically significant at the 5% level. Because these coefficients are more easily interpreted using the related partial effects, this topic will be further discussed in the Section 3.4.

3. Comparison of Production Frontiers

The estimated production frontiers of private and state firms are compared in two ways. First, we use a Wald test to compare the parameters of these firms' production frontiers. When only the production elasticities of labor and capital are compared, the test statistic has a chi-square distribution with two degrees of freedom and is computed as 72.99 (0.00), with the p-value in parentheses. When all the parameters in the production frontier

are compared, the test statistic has a chi-square distribution with seventeen degrees of freedom and is computed as 398.48 (0.00). Both these tests reject the equivalence of the parameters between private and state firms at the 1% statistical significance level. Therefore, their production frontiers are found to be different, which justifies our assumption in estimating the two SPFs separately.

Second, we compute the predicted outputs (or the deterministic frontiers) $\hat{Y}_p$ and $\hat{Y}_s$ using the estimated production frontiers of both private and state firms. The means of these outputs are shown in Table 4, with the measurement unit in million VND. Between 2000 and 2005, private firms' production frontier was always lower than that of state firms. The means of $\hat{Y}_p$ and $\hat{Y}_s$ are 22.0 and 36.2 during this period, implying that the private firms have a 39% lower frontier on average. More specifically, the production frontier $\hat{Y}_p$ of private firms increased from 18.2 in 2000 to 28.5 and then decreased after 2003 to 18.8 in 2005. The production frontier $\hat{Y}_s$ of state firms increased from 25.7 to 43.7 and then decreased to 37.8 for the same years. Because the decrease in $\hat{Y}_p$ was faster (15% and 23% for private firms compared to 3% and 10% for state firms for the last two periods), the difference between $\hat{Y}_p$ and $\hat{Y}_s$ widened over the whole study period.

Why is the production frontier of private firms much lower than that of state firms? To determine this, we decompose the ratio $\hat{Y}_p/\hat{Y}_s$ of the geometric means of the predicted outputs $\hat{Y}_p$ and $\hat{Y}_s$ using equation (5). Table 4 presents results of the decomposition as well as the geometric means of the predicted outputs. The ratio $\hat{Y}_p/\hat{Y}_s$ of the geometric means over the six years, 0.63, confirms that private firms had a 37% lower production frontier than did state firms, which is quite close to their predicted output difference (39%) in terms of the arithmetic mean. Furthermore, it confirms that the difference in the production frontiers widened from 27% in 2000 to 48% in 2005.

We can explain the difference in their production frontiers by investigating the contributions to the ratio. Labor input L is the only marked contribution that increases the ratio $\hat{Y}_p/\hat{Y}_s$. Labor's positive contribution comes from the higher coefficient of labor in the SPF for private firms, as explained in the Section 3.3.

On the other hand, capital K contributes negatively because state firms can use state credits for regular maintenance of their production lines and sustain the superior quality of their machinery and equipment, as expressed by the higher coefficient of capital in the SPF for state firms. The resource-based manufacture dummy negatively affects the ratio $\hat{Y}_p/\hat{Y}_s$ probably because private firms in this industrial group (e.g., food and beverages from agricultural products and

Table 4. Predicted Outputs Based on Production Technologies of Private and State Firms and Their Decomposition into Contributions

	2000	2001	2002	2003	2004	2005	Total
$\bar{\hat{Y}}_p$	18.2	18.9	25.3	28.5	24.3	18.8	22.0
$\bar{\hat{Y}}_s$	25.7	27.6	37.8	43.7	42.2	37.8	36.2
$\tilde{\hat{Y}}_p$	3.55	3.82	5.52	6.09	5.18	3.97	4.54
$\tilde{\hat{Y}}_s$	4.87	5.38	8.11	9.24	8.81	7.67	7.23
$\tilde{\hat{Y}}_p/\tilde{\hat{Y}}_s$	0.73	0.71	0.68	0.66	0.59	0.52	0.63
Contributions to $\tilde{\hat{Y}}_p/\tilde{\hat{Y}}_s$							
L	1.29	1.29	1.32	1.32	1.31	1.29	1.30
K	0.96	0.97	0.94	0.92	0.94	0.97	0.95
dsize	0.99	0.99	0.99	0.99	0.99	0.99	0.99
dyear2001		0.96					0.99
dyear2002			0.96				0.99
dyear2003				0.93			0.99
dyear2004					0.83		0.97
dyear2005						0.72	0.92
Northern Mountains	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Central Coast	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Central Highlands	1.00	1.00	1.00	1.00	1.00	1.00	1.00
South East	0.96	0.96	0.95	0.95	0.95	0.95	0.95
Mekong River delta	1.04	1.03	1.02	1.02	1.02	1.02	1.02
Resource-based	0.90	0.91	0.92	0.92	0.93	0.93	0.92
Low-tech	0.93	0.93	0.92	0.92	0.92	0.92	0.92
High-tech	1.00	1.00	1.00	1.00	1.00	1.00	1.00
constant	0.70	0.70	0.70	0.70	0.70	0.70	0.70

Note: $\bar{\hat{Y}}_m$ and $\tilde{\hat{Y}}_m$ ($m=p, s$) respectively denote arithmetic and geometric means of output $\hat{Y}_m$ which are predicted using production technologies of type m (private or state) firms. Unit of the predicted output is million VND. Decomposition of the ratio $\tilde{\hat{Y}}_p/\tilde{\hat{Y}}_s$ to its contributions is done for each year from 2000 to 2005, where the explanatory variables are also averaged for each year. Note that the product of all the contributions is equal to $\tilde{\hat{Y}}_p/\tilde{\hat{Y}}_s$.

petroleum refining) have limited rights to utilize natural resources in comparison with state firms in the same group. For the low-tech manufacture dummy, it is impossible to discuss further due to its statistically insignificant estimated coefficient in the SPF for state firms, although its negative contribution is marked. The year dummies for 2004 and 2005 contribute the most in these years. After the intensified restructuring and dissolution of state firms at the end of the 1990s, profitable state firms remained in operation, but unprofitable ones (particularly local ones) were dissolved or privatized. The negative contributions of the year dummies seem to reflect the gradual improvement of production technology of remaining state firms in comparison with that of private firms after

the restructuring and dissolution. Furthermore, the negative contribution of the constant term implies that state firms have greater management ability or R&D investment, which is unobserved or unavailable in our analysis.

Finally, firm size (*dsize*) has negligible effects on the difference (just 1%) between private and state firms' production frontiers. Although *dsize* actually has large effects on private and state firms' production frontiers, the effects are similar for each type of firms, as seen from the negligible difference between the estimated coefficients of *dsize* in Table 3. In other words, large private firms have an approximately similar production frontier to large state firms, with other things being equal, although the share of large firms is much lower for private firms.

4. Comparison of Technical Efficiency

Next, we examine the difference in the TE indexes between private and state firms. On the basis of their own production frontiers, the TE indexes are computed using equation (3), and their means are shown in Table 5. The average TE is 0.67 for private firms and 0.64 for state firms. Therefore, private firms have a slightly higher TE index during 2000-2005. More specifically, state firms' TE index increased slowly from 0.62 in 2000 to 0.66 in 2005, while that of private firms increased more rapidly and in fact improved from 0.60 in 2000 to 0.72 in 2005. These estimates seem plausible compared with other studies that estimate the TE index for the Vietnamese manufacturing sector. Nguyen, Giang, and Bach (2007) adopt the SPF method to estimate the index at 0.58 for 2000 and 0.52 for 2003, and they cannot find a significant difference between private and state firms. Furthermore, Matsunaga and Vixathep (2012) employ data envelopment analysis to estimate garment firms' TE index at 0.52 for state firms and 0.63 for private firms in Ho Chi Minh City in 2006.

The difference in the TE index (3% on average) is much smaller than the difference in the production frontier (39% on average) between private and state firms. Therefore, we briefly examine why private firms improved their TE more rapidly. For this purpose, we regress the estimated TE index on the variables introduced in the Section 3.1. Table 6 presents the estimation results by the ordinary least squares method. As discussed in the Section 2.2, *percap_income* positively in-

Table 5. Estimated Technical Efficiency Index of Private and State Firms

	2000	2001	2002	2003	2004	2005	Total
Private Firms	0.60	0.62	0.66	0.69	0.70	0.72	0.67
State Firms	0.62	0.63	0.63	0.64	0.64	0.66	0.64

fluences the TE index and *dsbt* negatively affects the TE index for state firms. Only *spillover* has an unexpected sign, which implies that private and state firms seem discouraged by the entry of foreign firms in the domestic market. The variable *age* positively affects the TE index for both private and state firms, which supports the hypothesis that the greater experience of the older firms enhances TE. Firm size (*dsize*) positively influences the TE index for both types of firms because larger firms have such advantages as greater product differentiation, as examined in the Section 2.2. The Herfindahl index has a significantly positive effect, implying that firms still required compensation (e.g., the agglomeration effects associated with concentrated rights) under a competitive market. Sari (2003) also finds a positive effect of the Herfindahl index on TE in a market where the Herfindahl index is as low as 0.26. Finally, the estimated coefficients of the year dummies show that, after controlling for the other variables, there still exist factors that increased private firms' TE over the six-year study period.

Regarding the size of these effects, most are small when sample means of these variables in Table 2 are taken into account.[10] The *dsize* (for state firms) and the year dummies (for private firms) seem to have moderate effects on the TE index. Furthermore, the *dsize* has a greater effect of increasing state firms' TE. Consequently, private firms improved their TE slightly faster than did state firms, although the former's production frontier shifted much more slowly than that of state firms during the period.

Table 6. Ordinary Least Squares Regression of TE index on Selected Variables

Firm Ownership	Private		State	
Number of Observations	54,644		6,597	
dyear2001	0.0057	(0.0032)*	0.0084	(0.0077)
dyear2002	0.0378	(0.0033)***	0.0069	(0.0077)
dyear2003	0.0483	(0.0032)***	-0.0025	(0.0081)
dyear2004	0.0555	(0.0031)***	-0.0123	(0.0083)
dyear2005	0.0623	(0.0029)***	-0.0227	(0.0086)***
dsize	0.0085	(0.0022)***	0.0499	(0.0055)***
age	0.0003	(0.0001)**	0.0008	(0.0002)***
debt	-0.0002	(0.0001)	-0.1671	(0.0066)***
percap_income	0.0085	(0.0001)***	0.0049	(0.0001)***
Herfindahl	1.1521	(0.1590) ***	10.9470	(0.5070)***
spillover	-0.0426	(0.0061)***	-0.2298	(0.0129)***
constant	0.5508	(0.0031)***	0.6230	(0.0090)***
Adjusted R^2	0.5508		0.5508	

Note: Standard errors are shown in parentheses. *, **, and *** represent the statistical significance at 10%, 5%, and 1% levels, respectively.

5. Robustness of the Results

Our empirical analysis above has shown that state firms have higher productivity than private firms mainly because the former have slightly lower TE but have a considerably higher production frontier. We have found these results by assuming that state firms have a different production frontier from pri-

Table 7. Estimated Parameters of Stochastic Production Frontiers and Variance Functions

Industries	Resource-based		Low-tech		Medium-tech		High-tech	
Number of Observations	23,088		24,744		12,767		642	
Production Frontier								
ln *L*	0.87	(188.80)	0.90	(244.43)	0.98	(147.70)	0.94	(32.63)
ln *K*	0.05	(22.59)	0.04	(24.71)	0.03	(17.00)	0.05	(5.26)
private	-0.40	(14.78)	-0.50	(30.15)	-0.07	(2.75)	-0.21	(1.97)
dsize	0.73	(43.55)	0.50	(34.99)	0.53	(25.83)	0.84	(9.16)
dyear2001	0.03	(1.24)	-0.01	(0.33)	0.11	(3.57)	0.12	(0.86)
dyear2002	0.04	(2.20)	0.08	(3.85)	0.17	(5.81)	0.23	(1.74)
dyear2003	0.12	(5.37)	0.21	(10.00)	0.25	(8.53)	0.22	(1.70)
dyear2004	-0.00	(0.04)	0.18	(9.15)	0.24	(8.57)	0.19	(1.53)
dyear2005	0.05	(2.44)	0.16	(8.77)	0.21	(8.15)	0.22	(1.91)
Northern Mountains	-0.02	(0.89)	-0.10	(4.53)	-0.04	(1.24)	-0.39	(2.22)
Central Coast	0.04	(2.60)	0.02	(1.47)	0.02	(0.86)	-0.07	(0.63)
Central Highlands	0.09	(2.95)	0.08	(2.15)	0.07	(1.45)	n.a.	
South East	0.22	(15.82)	0.21	(22.55)	0.23	(18.61)	0.26	(4.69)
Mekong River delta	0.34	(23.47)	0.25	(13.83)	0.26	(10.54)	0.04	(0.07)
constant	-1.75	(46.52)	-1.55	(57.46)	-2.05	(49.21)	-1.66	(9.37)
Variance Function								
dyear2001	0.27	(4.05)	0.06	(0.94)	0.12	(1.19)	0.22	(0.46)
dyear2002	0.22	(2.83)	0.32	(4.48)	0.34	(3.23)	0.73	(1.58)
dyear2003	0.47	(5.85)	0.55	(7.37)	0.69	(6.52)	0.37	(0.74)
dyear2004	0.34	(4.22)	0.84	(11.55)	0.86	(8.30)	0.91	(2.17)
dyear2005	0.86	(11.08)	0.95	(13.85)	0.82	(8.34)	0.56	(1.35)
private	-1.20	(11.81)	-1.38	(19.99)	-0.59	(5.20)	-0.69	(1.43)
dsize	1.28	(19.95)	0.79	(13.19)	1.19	(14.04)	1.43	(4.07)
age	-0.01	(2.78)	-0.01	(8.13)	-0.01	(3.45)	-0.02	(1.19)
debt	0.33	(5.28)	0.00	(0.31)	0.10	(1.15)	0.53	(1.71)
percap_income	-0.45	(45.01)	-0.38	(54.55)	-0.34	(42.72)	-0.26	(10.52)
Herfindahl	12.43	(1.07)	-3.65	(0.77)	3.03	(0.24)	-14.29	(2.16)
spillover	-3.56	(4.58)	0.73	(7.14)	-0.81	(1.62)	12.47	(2.75)
constant	3.50	(13.84)	2.64	(27.18)	2.48	(12.06)	-7.56	(2.13)
σ_v	0.56	(139.80)	0.49	(143.36)	0.48	(109.27)	0.44	(22.68)
log-likelihood	-23037.36		-22120.88		-11089.40		-553.76	

Note: Absolute values of t-statistic are shown in parentheses. "n.a." means the value is not available.

vate firms, while state (or private) firms in the different industries share a common production frontier except for the intercept. This section verifies the robustness of the main results by estimating the SPFs separately for each of the four industries (resource-based, low-tech, medium-tech, and high-tech industries), assuming that state and private firms share a common production frontier except for the intercept. Specifically, we estimate the SPF (6) separately for these industries:

$$lnY_{it}=\beta_0+\beta_1 lnL_{it}+\beta_2 lnK_{it}+\beta_3 private_{it}+\beta_4 dsize_{it}+\sum_s \beta_s dyear_s+\sum_{r\in R}\beta_r dregion_{ir}+v_{it}-u_{it}, \quad (6)$$

Note that the subscript j for industries is omitted from variables to simplify the notations and that the SPF for each industry is estimated using the data for both private and state firms.

Table 7 presents the estimated parameters of the SPF and the variance function. Similarly to the results in Table 3, the coefficient of labor is very high (between 0.87 and 0.98) and that of capital is very low (between 0.03 and 0.05) for all the industries. The year and regional dummies have similar coefficients to those for private firms in Table 3 because the number of these firms is much larger than that of state firms in all the industries.

The coefficients of firm size dummy vary with industries, but they are estimated between 0.50 and 0.84, which includes the estimates 0.60 and 0.63 in Table 3. Finally, the dummy variable for private firms has a statistically negative coefficient for all industries, which implies higher production frontiers for state firms in all the industries.

Table 8 presents the predicted production frontiers and TE index, which are comparable to Table 4. The predicted outputs show that the production frontier of state firms is much higher than that of private firms in the four industries. In particular, it is substantially higher in the resource-based and low-tech industries. The growth rate of the predicted output also changes very similarly in all the industries: it increases from 2000 to 2002 or 2003 and decreases after then. Furthermore, the TE index is slightly lower for state firms in three out of the four industries. Although it is higher for state firms in the medium-tech industry, the percentage difference in TE (5%) is still lower than that in the predicted output (7%). Finally, the TE index tends to increase over the study period for both state and private firms in all the industries, which is similar to the results in Table 4.

The results seem to show that our results obtained in the previous subsections are robust to the different specification examined in this subsection.

Table 8. Means of Predicted Outputs and of Estimated Technical Efficiency of Private and State Firms Compared with the Results for Pooled Sample

	2000	2001	2002	2003	2004	2005	Total
Predicted Outputs							
Pooled sample							
Private Firms	18.2	18.9	25.3	28.5	24.3	18.8	22.0
State Firms	25.7	27.6	37.8	43.8	42.2	37.8	36.2
Resource-Based							
Private Firms	9.6	11.1	16.4	17.5	15.5	13.5	13.7
State Firms	14.4	16.5	24.5	26.1	23.1	20.1	20.4
Low-Tech							
Private Firms	27.4	25.7	32.5	38.8	32.8	24.4	29.8
State Firms	45.2	42.3	53.5	63.9	54.0	40.1	49.1
Medium-Tech							
Private Firms	20.7	21.0	25.7	27.9	25.1	18.9	22.8
State Firms	22.1	22.4	27.4	29.8	26.8	20.2	24.4
High-Tech							
Private Firms	37.2	46.3	50.8	46.6	36.4	23.0	37.3
State Firms	46.0	57.4	62.9	57.6	45.0	28.4	46.2
Estimated Technical Efficiency							
Pooled sample							
Private Firms	0.60	0.62	0.66	0.69	0.70	0.72	0.67
State Firms	0.62	0.63	0.63	0.64	0.64	0.66	0.64
Resource-Based							
Private Firms	0.63	0.62	0.68	0.68	0.72	0.72	0.68
State Firms	0.57	0.58	0.60	0.63	0.68	0.75	0.63
Low-Tech							
Private Firms	0.59	0.62	0.66	0.69	0.69	0.70	0.67
State Firms	0.59	0.61	0.63	0.67	0.71	0.77	0.66
Medium-Tech							
Private Firms	0.59	0.63	0.66	0.66	0.68	0.71	0.67
State Firms	0.65	0.69	0.71	0.73	0.76	0.84	0.72
High-Tech							
Private Firms	0.59	0.61	0.60	0.69	0.62	0.69	0.65
State Firms	0.61	0.66	0.59	0.67	0.62	0.73	0.64

Note: Unit of the predicted output is million VND. The predicted outputs of private and state firms in the four industries are evaluated with respect to the based Hong River delta in all cases and additionally with respect to the based year 2000 for the total case.

Ⅳ. Concluding Remarks

This paper used data on individual manufacturing firms (Vietnamese Enterprise Survey by GSO) for 2000-2005 and estimated two separate SPFs for private and state firms in Vietnam. The primary objective was to compare the productivity of the two types of firms in terms of their production frontiers and TE.

The empirical results show that the average private firm has a 39% lower production frontier (the maximum predicted output based on their production technology) and a 3% higher TE than the average state firm. Consequently, state firms are inferred to have a much higher productivity than private firms in the Vietnamese manufacturing sector. It is worth noting that the higher production frontier of state firms is not due to a considerably higher share of large firms in this sector. Instead, large private firms have a production frontier similar to that of large state firms, with other things being equal. Therefore, large state firms have a further higher production frontier than small private firms. This is because they can use flexible state credit to maintain their machinery and equipment and because they have priority rights to utilize natural resources, advantages that private firms lack. Furthermore, only the profitable state firms remained in operation after the restructuring and dissolution of some of these firms, implying that they are likely to have had greater management ability or R&D investment.

These results imply that the Vietnamese government employed policies favoring state firms. It also introduced several policies to encourage private firms to enter the market; consequently, the number of private firms has increased. However, these policies were insufficient for increasing these firms' productivity (particularly through production technology), as pointed out by Tran, Grafton, and Kompas (2008) and Nguyen and van Dijk (2012). To increase the productivity of private firms in the manufacturing sector, the government should give them similar rights and privileges to those of state firms, including rights to utilize natural resources or more access to credit for long-term capital investment. Otherwise, the manufacturing sector, which is largely occupied by small private firms, will face serious stagnation and will not achieve the productivity needed to facilitate Vietnam's further economic development.

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Notes

1) SPF method not only captures random noise but also allows hypothesis tests, which cannot be handled by DEA method (Coelli et al., 2005).
2) Exceptions include Kumbhakar, Tsionas, and Sipilainen (2009).
3) Many private firms do not report fringe benefits that are included in total labor compensation defined in this study. We replace missing values of fringe benefits with zero for private firms because most of them are unlikely to pay fringe benefits. Furthermore, some private firms report fixed assets to be zero. For these firms, fixed assets are replaced with one tenth of the smallest positive value of fixed assets to estimate a Cobb-Douglas production frontier.
4) Resource-based manufactures include food products and beverages (15), tobacco products (16), wood and wood products (20), paper and paper products (21), and coke, refined petroleum products and nuclear fuel (23), where the numbers in parentheses are ISIC codes. Low-tech manufactures include textiles (17), wearing apparel, dressing and dyeing of fur (18), tanning and dressing of leather (19), publishing, printing and reproduction of recorded media (22), rubber and plastic products (25), other non-metallic mineral products (26), basic metals (27), furniture and other products not classified elsewhere (36), and recycling (37). Medium-tech manufactures include chemicals and chemical products (24), fabricated metal products (28), machinery and equipment (29), electrical machinery and apparatus (31), motor vehicles, trailers and semi-trailers (34), and other transport equipment (35). High-tech manufactures include office, accounting and computing machinery (30), radio, television and communication equipment (32), and medical, precision and optical instruments (33).
5) Observations for the "non-province" regions are dropped because they have no administrative status in reality.
6) Firms of "large scale" are defined as those with turnover greater than the 75th centile of turnover for all sample firms. Although it might be natural to define them as those with turnover greater than the median, this definition results in too small number of state firms of "small scale".
7) We dropped from our sample firms which report the registration year to be zero, smaller than 1945, or larger than the current year.
8) Note that *Herfindahl* and *spillover* are industry-level variables.
9) If we test constant returns to scale using a likelihood ratio statistic, which has a chi-square distribution with one degree of freedom, the test statistic is 632.46 (0.00) for private firms and 101.92 (0.00) for state firms, where p-values are shown in parentheses. Therefore, the hypothesis of constant returns to scale is rejected for both types of firms.
10) Other studies computing partial effects of continuous variables on TE also show that these effects are generally small (e.g., Lundvall and Battese, 2000; Bhandari and Maiti, 2007).

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