Technical Efficiency of Vietnamese Manufacturing Firms and Its Determinants: A Preliminary Analysis

ABSTRACT: This paper estimates stochastic production frontiers separately for foreign-invested, state-owned and private firms of the Vietnamese manufacturing industries during the period 2000-2009. The result shows that private firms’ technical efficiency is, on average, the highest of the three groups of firms in most years. If we look at determinants of their technical efficiency, private firms are found to benefit from production activities of foreign-invested firms until 2008, while state-owned firms are not. This implies that those private manufacturing firms in Vietnam have been able to imitate/absorb new production technologies from foreign firms. In 2009, however, the private firms also start losing their market power to the foreign firms as the state-owned firms have experienced. Moreover, there is environmental spillover effect on technical efficiency of the domestic private firms in most of years, and of the foreign firms and state-owned firms in some certain years.

KEYWORDS: technical efficiency, production frontier, Vietnamese manufacturing industries, spillover effects

1. Introduction

Vietnam - a young emerging country has been on its reform process to complete its economic system targeting at a sustainable development since late 1980s. Looking at the structure of the economy via data on the homepage of the General Statistics Office of Vietnam (GSO), the secondary industry (including Manufacturing industries) has been increasing its share in GDP (almost twofold) while the first industry (Agriculture, Forestry and Fishery) is decreasing its GDP share in these 20 years since 1990. In details, the GDP shares of the three sectors of Agriculture, Forestry and Fishery; Industry and Construction; and Services for every five years are as follows: 31.8 - 25.2 - 43.0% in 1990; 26.2 – 29.9 – 43.8% in 1995; 23.3 – 35.4 – 41.3% in 2000; 19.6 – 40.2 – 40.3% in 2005; and 17.1 – 41.6 – 41.4% in 2009. In terms of ownership, the GDP shares of the foreign-invested firms sector, state-owned firms sector, and private firms sector also experience changes from 12.1 – 40.7 – 47.3% in 2005 to 13.4 – 37.8 – 48.8% in 2009, respectively.

Our sample of Enterprise Survey provides the following findings during the period 2000-2009: manufacturing industries as a wholes increase almost twofold in turnover with respect to an increase from 10,399 to 43,937 firms; total sales respectively increase with a factor of approximately 2, 5 and 4 for foreign-invested firms sector, state-owned firms sector and private firms sector; number of foreign firms and private firms has increased by a factor of approximately 5, respectively from 647 to 3,185 firms, and from 7,361 to 34,837 firms; while, state-owned sector, in general, experiences a decrease in number of firms by almost a half; labor productivity of the three sectors are from 294 – 291 - 478; from 132 – 279 - 569, and from 94 – 179 - 439 million VND for each period.
of five years from 2000 – 2005 - 2009, respectively. We can confirm that foreign and private firms sectors have been developing quite remarkably and playing a more important role in the economy of Vietnam, especially since the mid-2000s. This should be the performance of the Vietnamese government’s efforts in inducing foreign direct investment and domestic private businesses through its legislation system including the Law on Foreign Direct Investment (promulgated in late 1987 with the latest revision in 2006), Enterprise Law (promulgated in 1999 with the latest revision in 2005), and so on. Changes with more foreign firms could impact, maybe differently, on productivity of the three economic ownership sectors in the Vietnamese manufacturing industries.

There is a large body of literature focusing on productivity growth of firms through “knowledge spillover effects” with respect to foreign firms’ presence (technological spillover effects) and R&D investment (R&D spillover effects). In studies about technological spillover effects from foreign investment, conventionally, researchers consider productivity growth as residuals from estimating production function, and explain factors determining this productivity growth with respect to a proxy variable for spillovers from foreign investment (or foreign presence) in the host industries. Regarding the interpretation of spillover variable, if the coefficient is positive and significant, it can be concluded that host industries could increase their productivity through imitation of foreign firms’ products and/or technology, or through their efforts to produce more efficiently in order not to fall behind foreign competitors within the industry (Caves (1974), Kokko (1994, 1996), Wei and Liu (2006)). On the contrary, negative coefficient is attributed to the so called “market stealing” effects. That is, if domestic firms in the host country cannot compete with foreign enterprises, they will lose their market share to foreign enterprises due to an increase in fixed costs as well as a reduction in production (Aitken and Harrison (1999)).

In some studies about environmental spillover effects, investment on the application of environmental technologies is considered as one kind of R&D investment. Thus, spillovers from this application can be interchangeably considered as R&D spillover effects on firms’ productivity and efficiency improvement. Investment in environmental practices contributes to the development of valuable capabilities which can then lead to firm productivity through both cost reduction and product differentiation (Shrivastava (1995)). Environmental techniques application may reduce environmental externalities as well as derive the typical R&D spillover effects. Those are known as a “double externality”. Consider spillover as a type of firm’s input of knowledge production process (hence an input of firm’s production function), spillover effects are linked to the transfer of environmental knowledge, which is facilitated by firms operating in the same industry and in the same geographical region (Galdeano-Gomez and Cespedes-Lorente (2008), hereinafter called GC (2008)).

Still, to our best knowledge, there are very few studies applying the method of stochastic frontier analysis in the field of knowledge spillover effects on productivity growth, except for a recent research by Suyanto, Salim, and Bloch (2009) (hereinafter called SSB (2009)). They provide evidence supporting positive effects of foreign presence on productivity growth of Indonesian chemical and pharmaceutical firms. This study uses cross-sectional firm-level data of the Vietnamese manufacturing industries during the period 2000 through 2009 and estimates a Cobb-Douglas stochastic production frontier (SPF) separately for foreign-invested firms, state-owned firms, and private firms sectors. Further, we examine determinants of firms’ technical efficiency including the presence of foreign firms, firm’s stock of knowledge capital, the
proximity of firms’ investment in environmental practices, and industrial concentration level.

The empirical result shows that private firms’ technical efficiency is, on average, the highest of the three groups of firms in most years. If we look at the determinants of those firms’ technical efficiency, private firms are beneficiaries of production activities of foreign-invested firms until 2008, while state-owned firms are not. Each firm’s stock of knowledge capital affects the firm’s technical efficiency in the opposite way in comparison as that of its production in most of cases. However, the investment in environmental practices of the proximity of firms spills over its effects on technical efficiency of the private firms in most of years and that of the foreign firms and state-owned firms in some certain years. Moreover, the variable of industrial concentration level is found to positively and significantly affect all firms’ technical efficiency.

Section 2 introduces our SPF empirical model and its estimation method. Section 3 describes data and variables in the empirical analysis. The estimation result is provided in Section 4. The analysis summary and concluding remarks come in Section 5.

2. Empirical Method

We specify a Cobb-Douglas SPF of two factor inputs (labor input $L_i$, physical capital input $K_i^P$), a function of knowledge capital expressed as $K_i^K$, and a series of regional dummy variables, $dregion$, as equation (1).

$$\ln Y_i = \beta_0 + \beta_1 \ln L_i + \beta_2 \ln K_i^P + K_i^K + \sum_{r=1}^{7} \beta_r dregion_r + v_i - u_i$$

$Y_i$ is production output of firm $i$ ($i = 1, ..., n$). Regional dummy variables ($r = 1, ..., 7$), $dregion$, will control for differences in the locations of firms which could affect firms’ production. We assume that $v_i$ is a normal random variable with mean zero and constant variance $\sigma_v^2$ and that $u_i \geq 0$ representing a firm’s technical inefficiency follows a truncated (at zero) normal distribution with mean $\mu$ and variance $\sigma_u^2$.

Suppose that a firm’s application of environmental practices is influenced by its own environmental management and the environmental investment of its geographical proximity of firms. To the end, the externality of environment spillovers can result in the firm’s efficiency and productivity. Following the method in Chen and Yang (2005) (hereinafter called CY (2005)) and in GC (2008), we specify the functional form of knowledge capital $K_i^K$ in the Generalized Leontief Linear form as equation (2) including two variables, $environment_i$ and $envt_spillover_i$.

$$K_i^K = \gamma_1 \sqrt{environment_i} + \gamma_2 \sqrt{envt}$$

Substituting equation (2) into equation (1), we have the estimation SPF model as equation (3).

$$\ln Y_i = \beta_0 + \beta_1 \ln L_i + \beta_2 \ln K_i^P + \gamma_1 \sqrt{environment_i} + \gamma_2 \sqrt{envt_spillover_i} + \sum_{r=1}^{7} \beta_r dregion_r + v_i - u_i$$

Following previous literature (CY (2005), GC (2008), and SSB (2009)) on discussing determinants of productivity growth, we assume that variables in the
conditional mean $\mu$ function as equation (4) explain a firm’s technical inefficiency.

$$
\mu = \delta_1 \sqrt{\text{environment}_i} + \delta_2 \sqrt{\varepsilon_i} + \delta_3 \text{spillover}_i + \delta_4 i
$$

(4)

$\varepsilon_i$ is the unobserved statistical noise.

Here Herfindahl known as Herfindahl index represents the level of industrial concentration (or market competition). Spillover is a proxy variable for the presence of foreign firms in each two digit level manufacturing industry. Environment is stock of a firm’s knowledge capital, which is represented by firm’s investment in environmental practices. Env_t_spillover is the environmental practices spillover from other firms within an industry in the same region. We expect to get negative and significant coefficient of spillover. That is, increased production activities of foreign firms help reduce technical inefficiency of the Vietnamese manufacturing industries. Similarly, negative and significant coefficient of env_t_spillover is expected. If it is the case, we can conclude that there is relationship between firms’ productivity and efficiency improvement and environmental practices through environmental spillovers (GC (2008)).

If a firm’s investment in environmental practices is suitable and of success, it helps increase the firm’s production, hence links to increase in its productivity and technical efficiency. However, if the application of environmental techniques is not suitable to the firm’s production technology, such investment can depress production and efficiency of the firm (Klassen and Whybark (1999). Therefore, the expected sign of the coefficient of environment is still in debate.

The argument on Herfindahl is two ways. A higher value of Herfindahl implies greater concentration (i.e., lower competition in the market) among firms in the industry. The coefficient may be positive or negative. Higher concentration can protect inefficient firms as an inverse measure of static competition, but increasing competition will remove those inefficient firms from the industry as a result of dynamic competition among firms of differential efficiencies (SSB (2009)).

Applying the method of SPF, as Driffield and Munday (2001) discuss, we do not explain total factor productivity (TFP) growth in terms of foreign presence as the conventional way, but we allow TFP to be determined from the production function in terms of the efficient frontier. Given the model specifications in equations (1) and (4), we estimate our SPF model by the maximum likelihood method separately for three groups of firm ownership: foreign-invested firms, state-owned firms, and private firms, and explain determinants of the industrial technical inefficiency based on coefficients of variables in equation (4). Then, $i$ firm’s technical efficiency $TE_i$, given $\mu \neq 0$, is calculated following Kumbhakar and Lovell (2000) as equation (5) below.

$$
TE_i = E [\exp(-\mu_i)(v_i - u_i)]
$$

$$
= \frac{1 - \Phi[\sigma_{\phi} - (\hat{\mu}_i / \sigma_i)]}{1 - \Phi(-\hat{\mu}_i / \sigma_i)} \times \exp(-\hat{\mu}_i + 0.5 \sigma_i^2)
$$

(5)

where $\hat{\mu}_i = [-\sigma_i^2 (v_i - u_i) + \mu \sigma_i^2] / \sigma^2$.

$\sigma_i^2 = \sigma_{\phi}^2 \sigma_v^2 / \sigma^2$. $\Phi$ denotes the cumulative distribution function of the standard normal variable.

3. Data and Variables

The empirical analysis uses annual Vietnamese enterprise survey data conducted by GSO during the
period 2000-2009. The survey collects firm data for all sectors in the national economy with a variety of information including total turnover, total profit before taxes, labors, fixed assets, firm ownership, labor compensation, type of firm’s production activities, firm location, expenditure on environmental protection activities and investment in environmental facilities, and so on. In this paper, we focus on two-digit level manufacturing industries ranging from ISIC15-ISIC37.

We separate firms into three groups based on their ownership status. They are foreign-invested firms, state-owned firms, and private firms. Firms in each singular year are examined for which data on relevant variables are not missing and satisfy the following conditions: 1) the computed value added are positive; 2) zero values of labor and zero values of total labor compensation are dropped; 3) negative fixed assets are considered as missing values, and zero values of fixed assets are rescaled at one tenth of the minimum value of all positive fixed assets; 4) missing values of expenditure on environmental protection and investment in environmental facilities are set to zero, due to the fact that firms without these expenditure and investment tend to leave blank to the related surveyed questions. We classify 64 provinces and governmentally administered cities of Vietnam as location of firms into six administrational regions, including: (1) the Red River Delta; (2) the Northern Midlands and Mountain Areas; (3) the North Central Coast and South Central Coast; (4) the Central Highlands; (5) the South East; (6) the Mekong River Delta, and another so-called “non-province” region. Then we generate a series of seven regional dummy variables, \( d_{region} \).

Due to the unavailability of relevant production materials data, we decide to estimate the SPF with dependent variables \( Y \) as \( \text{value\_added} \). \( \text{Value\_added} \) is calculated as the sum of firm’s total profit and total labor compensation which is the sum of labor salary and all other 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.

\( Environment \) is proxy for a firm’s stock of knowledge capital indexed by environmental practices. It is measured as the total money value of expenditure on environmental protection and investment in environmental facilities of the firm. \( Env_{t} \) is proxy for spillover effects of environmental practices taken by neighboring firms on a certain firm’s productivity within the industry. It is computed as total sum of environment practices implemented by all firms within \( j (j=1, \ldots, 23) \) industry in the same \( r \) region other than firm \( i \) as follows,

\[
envt_{spillover,i} = \sum_{r=1}^{7} \sum_{j=1}^{23} envrhomne_{rj} - envrhomne_{ri}
\]

(6)

\( Spillover \) is proxy for the presence of foreign-invested firms in each industry. It is measured as the share of foreign-invested firms’ turnover in total turnover of each corresponding industry as follows,

\[
spillover_{i} = \frac{\sum_{i=1}^{n} foreign\_turnover_{i}}{\sum_{i=1}^{n} industry\_turnover_{i}}
\]

(7)

\( Herfindahl \) index is a proxy for the concentration (or competition) level of each industry and is computed as the sum of each firm’s squared market share in terms of turnover as follows,

\[
Herfindahl_{i} = \sum_{i=1}^{n} S_{i}^{2}
\]

(8)

To save space, we briefly describe changes in the data of the three firms groups without table reporting the descriptive statistics. During 10 years, value added...
respectively increase by a factor of 2.4 (from 15,672 to 37,233 million VND); 4.6 (from 9,642 to 44,187 million VND); and 3.7 (from 690 to 2,553 million VND) in the three sectors of foreign firms, state-owned firms, and private firms. Labors increase in foreign firms and state-owned firms while decrease in private firms. On the contrary, capital (as fixed assets) changes show an increasing trend with large differences in magnitude. State-owned sector increases its fixed assets scale most greatly by a factor of 10, from 15 billion to 155 billion VND (the Vietnamese currency – Vietnam Dong). Foreign firms, on average, increase their fixed assets the least among the three groups from 60 billion to 72 billion VND. The magnitude of fixed assets in private firms sector itself is the smallest, and it has increased from around 1 billion to 5 billion VND after 10 years. Private firms’ knowledge capital stock ($environment$) and environmental spillover are, on average, the smallest. $Environment$ value of foreign firms is smaller than that of state-owned firms in most of years (except for 2001 and 2005). Meanwhile, value of $envt\_spillover$ of these foreign and state-owned sectors are in contrast with larger value for foreign firms in most of years (except for 2002 and 2008). $Spillover$ ranges within 42% and 49% for foreign firms sector and within 31% and 38% for the state-owned firms and private firms. $Herfindahl$ index is the slowest, respectively within 1.4–2.9%, 2.2-3.6%, and 2.2-3.6% for the private, the state-owned, and the foreign sectors.

4. Empirical Results

The SPF modeled in equations (1) and (4) is estimated separately for three groups of foreign-invested firms, state-owned firms, and private firms. For foreign-invested firms sector in 2001 and 2003, because the estimation of truncated normal distribution technical inefficiency error term $u_i$ could not reach convergence, we, instead, estimate the model with the assumption of $u_i$ following half-normal distribution and heteroskedasticity. Due to the unavailability of data in 2000 and 2003, two variables, $environment$ and $envt\_spillover$, are not included in the estimations. Labor elasticity and capital elasticity are all estimated to be significantly positive at 1% level. However, the magnitudes of those coefficients are different. For foreign firms sector, production elasticities of capital are among 15-25% while those of labor are among 59-73% of production output. This is approximately comparable to the study on the UK industrial production frontier by Driffield and Munday (2001) in which capital elasticity is 28% and labor elasticity is 63%. Meanwhile, the labor elasticities are at the lowest level of 82% for state-owned firms and of 92% for private firms. On the contrary, capital elasticities for the private firms sector are the lowest among the three sectors which is around 4-10%. This can be referred to Haddad and Harrison (1993) in the study of Moroccan productivity growth when they estimated capital elasticity at 11% and labor elasticity at 77% for non-FDI firms. It is noteworthy that our paper as well as Driffield and Munday (2001) and Haddad and Harrison (1993) measures output in the production function as value added which is different from other studies of gross output on labor, capital, and materials input. That means, in the latter case, production elasticity of materials should act a role which instead would balance with the labor elasticity. For example, Vu (2003) in his study about technical efficiency of Vietnamese state-owned firms in 1997-1998 presents a Cobb-Douglas SPF with elasticities of labor, capital, and materials input at 49, 15, and 47%, respectively. Thus, it could be reasonable with such high production elasticity of labor in our paper. After estimating the SPF, we predict firms’ average technical efficiency TE levels following equation (5) and their deterministic frontiers. However, due to the fact that the variable of $environment$ has too many zero value, maximum possible production based on the
estimated frontiers are extremely large in some years. Therefore, in addition to the average TEs, we also present their medians and plot these medians of TEs for three firms sectors in Figure 1.

On average, our estimated TEs are a little low. Among the three firms groups, the annual average and median TEs for the private firms sector is the highest throughout the sample period. Meanwhile TEs for the foreign firms sector is the lowest except for 2008 which is higher than that for the state-owned firms sector. First, for the state-owned firms sector, compared with Vu (2003) who reports average TEs for local-level and central-level state owned firms at 73% and 83% respectively, our estimated TEs are among 49–62%.

However, our result, for example of 59% in 2006, is close to Matsunaga and Vixathep (2012) in applying Data Envelopment Analysis method in calculating TEs of the Vietnamese garment enterprises in Ho Chi Minh city at 52% in 2006 if we look at the case of 10% capital depreciation. Then, Matsunaga and Vixathep (2012) report the average TEs in 2006 for those foreign garment firms and private firms (the average of private firms, private limited liability firms, and joint stock firms) respectively at 64% and 63% in comparison with 50% and 59% in our paper. Just comparing our paper’s average TEs in 2006 for all manufacturing industries with Matsunaga and Vixathep (2012) for the garment industry only, the order of TEs levels among the three firms sectors (foreign–state–private) are mine (49 – 59 – 59%) versus theirs (64 – 52 – 63%) whose difference is more slight in comparison with those in Vu (2003). Second, for the private firms sector, our estimated average TEs are still lower than what Tran et al. (2008) report in their study about small and medium sized private firms in some Vietnamese manufacturing industries including food processing; chemicals; manufactured goods classified chiefly by material; machinery and transport equipment; and miscellaneous manufactured articles7.

Finally, we examine the determinants of technical inefficiencies of firms. The estimation results in Table 1 for the foreign firms in 2001 and 2003 are from the estimation step 2 with the dependent variable as the estimated technical efficiency. Therefore, the expected sign of variables, especially the two variables of the hypothesized spillover effects should be opposite to all other estimation results.

The coefficients of Herfindahl for the domestic firms sector are all statistically significant at 1% level with negative sign. That is, high concentration (i.e., low market competition) among firms decreases the inefficiencies of firms. In the other words, moderate competition in the market makes Vietnamese private manufacturing firms use their existing production technologies more efficiently. This result is the same with GC (2008). In another way, it can be interpreted that less degree of competition in the market implies less firm efficiency. Thus, the factor of this low competition pressure would be one reason for low technical efficiency levels of firms in our sample. The same result appears in the groups of foreign firms and state-owned firms in most of years.

Turning to technological spillovers, private firms are found to benefit from production activities of foreign firms within each manufacturing industry throughout 9 years until 2008. This is shown in negative coefficients at 1% significant level of the spillover variable. The coefficient, however, changes to positive but insignificant in 2009. On the contrary, increased presence or production activities of those foreign firms increase the inefficiency levels of the state-owned firms throughout the sample. Our estimation result of spillover is consistent in part with the body of previous literature which focuses on the intra-industry spillover effects of foreign presence on productivity growth. Because, different in further separating domestic firms into state-owned firms and private firms, we find evidence supporting our hypothesis only for private
firms, while SSB (2009) gives conclusion for domestic firms as a whole. This result can be interpreted that higher foreign share in the industry triggers domestic private firms in more efficient utilization of resources and existing production technologies, which then leads to gains in firms’ productivity.

Evidence of environmental spillover appears in private firms sector in seven out of eight years with available environmental-related investment data (no evidence in 2001 only), in the foreign firms sector in 2001, 2004, 2005, 2006 and 2009, and in state-owned firms in 2002 and 2004 only. However, the magnitude of the coefficient is small. Thus, for these cases, we can follow GC (2008) in the conclusion that the moderation effect of environmental spillover effect has more impact on technical efficiency of each individual domestic private firm and foreign firm.

However, a firm’s own stock of knowledge capital in terms of investment in environmental practices is proved to positively influence the firm’s productivity at 1% significance level in its direct way, but this investment does not show its impact on the increase of the firm’s technical efficiency. This can be confirmed when we examine the estimated coefficients of environment in the deterministic frontier and in the technical inefficiency function separately. This result is consistent with CY (2005) and GC (2008) only in part due to the differences in the objective analyzed industry and country. Our result can be interpreted that manufacturing firms devoting more to the application of environmental practices can produce more output, but it does not result in a more efficient exploitation of resources and production technology.

5. Summary and Concluding Remarks

This paper uses Vietnamese Enterprises Survey data from 2000 to 2009 to estimate industrial production frontiers for three manufacturing firms sectors including foreign-invested firms, state-owned firms, and private firms separately. Then, we compute technical efficiency levels of those firms, and investigate determinants of their technical efficiencies. The estimation result shows that the private firms sector is the most technically efficient, while the foreign-invested firms have the lowest technical efficiencies among the three firms sectors in Vietnam. Our factor analysis of firms’ technical inefficiencies finds that only moderate competition among firms in an industry acts to increase the level of their technical efficiencies regardless of the type of firms. On the other hand, the determinant of foreign spillover only has positive effect on technical efficiencies of the private firms sector, while it derives no effect on the efficiencies of the state-owned firms. Thus, we conclude that production activities of foreign-invested firms result in technical efficiencies of domestic private firms when those private firms try hard to make use of their production technologies and resources in a more efficient way, which, to the end, leads to their productivity growth. If investment and application of environmental practices help to increase the production output of all types of firms, the spillover effects from such kind of investment, even small in magnitude, result in technical efficiency increase of the domestic private firms in most of years, of foreign firms and state-owned firms only in some certain years.

Implications of these results are that it is necessary to induce more competition in the industries in order to increase firms’ technical efficiency, which then would result in higher productivity in the Vietnamese manufacturing sector. Moreover, the Vietnamese domestic private manufacturing firms sector which even has higher technical efficiencies than the foreign-invested and the state-owned firms sectors for these 10 years is still in a small production scale. Therefore, the government should promote the development of this economic sector more aggressively and make them act their true role in the
Vietnamese economy. To make these implications more reliable, future study should make use of the availability of the data as an application of panel data as well as find other more explainable determinants of changes in firms’ technical efficiency and productivity.

Notes
1 In Shrivastava (1995), environmental technologies are defined as production equipment, methods and procedures, product designs, and product delivery mechanisms that conserve energy and natural resources, minimize environmental load of human activities, and protect the natural environment. Environmental technologies evolve both as set of techniques and as management orientation.
2 According to the classification by GSO, foreign-invested firms sector includes 100% foreign owned firms and joint venture firms; state-owned firms sector includes central-level and local-level state-owned firms, non-state-owned sector includes cooperatives, private firms, cooperative name firms, private limited liability firms, and joint stock firms. In this study, we make up the three sectors by summing up all component types of firms in each GSO-defined sector.
3 Because investment in environment techniques (one kind of R&D investment) is frequently zero, this specification for knowledge capital avoids the problem of taking logarithms of R&D investment. For private firms sector, there are too many firms with missing values of fringe benefits. Therefore, we consider those missing values as zero fringe benefits. All other negative fringe benefits for foreign firms sector and state-owned firms sector are considered as missing values.
4 We tried computing following MV (2012). However, the computation result is not reasonable with too big share of production materials. That is, there must be other unobserved cost factors besides the reported total cost in the data sample.
5 To save space, we do not present the estimated parameters of the SPF. The estimated coefficients of technical inefficiency determinants, means and medians of TEs are presented in Table 1 at the end of the paper.
6 Our paper is different from Tran et al. (2008) in the classification of manufacturing industries. That is, we follow the ISIC (International Standard Industrial Classification) as what is determined in the data sample by GSO while they follow the SITC (standard international trade classification).

Acknowledgements
This research was supported by the Grant-in-Aid for Asian CORE Program “Manufacturing and Environmental Management in East Asia” of Japan Society for the Promotion of Science (JSPS). The data-cleaning process and empirical analysis in the paper are instructed by Professor Tadashi SONODA in Graduate School of Economics, Nagoya University.

I am grateful to Professor Yuko ARAYAMA, my Academic Professor for his valuable comments. All errors remain the author’s own.

References
Wei, Y. and X. Liu (2006), “Productivity spillovers from R&D, export and FDI in China’s manufacturing sector”.


textograph
Figure 1: Estimated Medians of Technical Efficiency for Three Groups of Firms

Source: The author’s calculation
Table 1: Means, Medians and Determinants of Technical Inefficiency for Three Groups of Firms

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<td>Sample size</td>
<td>647</td>
<td>848</td>
<td>1,103</td>
<td>1,375</td>
<td>1,595</td>
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<td>0.490</td>
<td>0.503</td>
<td>0.431</td>
<td>0.524</td>
<td>0.501</td>
<td>0.489</td>
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<tr>
<td>Median(TE)</td>
<td>0.513</td>
<td>0.504</td>
<td>0.530</td>
<td>0.438</td>
<td>0.557</td>
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<tr>
<td>S.D.(TE)</td>
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<td>(0.150)</td>
<td>(0.203)</td>
<td>(0.023)</td>
<td>(0.032)</td>
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<td>0.0561</td>
<td>-2.854</td>
<td>-0.609</td>
<td>-0.457</td>
<td>-4.165</td>
<td>-4.767</td>
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<td>spillover</td>
<td>(0.43)</td>
<td>(5.32)</td>
<td>(-1.43)</td>
<td>(1.79)</td>
<td>(-1.64)</td>
<td>(-0.89)</td>
<td>(-0.69)</td>
<td>(-2.13)</td>
<td>(-2.70)</td>
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<tr>
<td>Sample size</td>
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<td>0.610</td>
<td>0.620</td>
<td>0.562</td>
<td>0.596</td>
<td>0.598</td>
<td>0.591</td>
<td>0.576</td>
<td>0.492</td>
<td>0.492</td>
</tr>
<tr>
<td>Median(TE)</td>
<td>0.578</td>
<td>0.631</td>
<td>0.643</td>
<td>0.576</td>
<td>0.625</td>
<td>0.617</td>
<td>0.615</td>
<td>0.590</td>
<td>0.504</td>
<td>0.505</td>
</tr>
<tr>
<td>S.D.(TE)</td>
<td>(0.150)</td>
<td>(0.154)</td>
<td>(0.164)</td>
<td>(0.167)</td>
<td>(0.174)</td>
<td>(0.151)</td>
<td>(0.131)</td>
<td>(0.137)</td>
<td>(0.159)</td>
<td>(0.172)</td>
</tr>
<tr>
<td>Herfindahl</td>
<td>-19.2755</td>
<td>-14.8933</td>
<td>-50.7259</td>
<td>-41.4567</td>
<td>-41.0005</td>
<td>-29.4287</td>
<td>-0.8031</td>
<td>-3.0290</td>
<td>-0.8544</td>
<td>-5.8514</td>
</tr>
<tr>
<td>spillover</td>
<td>(6.82)</td>
<td>(2.56)</td>
<td>(5.18)</td>
<td>(4.66)</td>
<td>(7.36)</td>
<td>(2.21)</td>
<td>(3.84)</td>
<td>(2.00)</td>
<td>(2.79)</td>
<td>(5.37)</td>
</tr>
<tr>
<td>Private</td>
<td>2000</td>
<td>2001</td>
<td>2002</td>
<td>2003</td>
<td>2004</td>
<td>2005</td>
<td>2006</td>
<td>2007</td>
<td>2008</td>
<td>2009</td>
</tr>
<tr>
<td>Sample size</td>
<td>7,361</td>
<td>8,523</td>
<td>9,568</td>
<td>11,501</td>
<td>14,104</td>
<td>17,271</td>
<td>19,192</td>
<td>22,791</td>
<td>29,367</td>
<td>34,837</td>
</tr>
<tr>
<td>Mean (TE)</td>
<td>0.592</td>
<td>0.589</td>
<td>0.634</td>
<td>0.598</td>
<td>0.640</td>
<td>0.620</td>
<td>0.594</td>
<td>0.642</td>
<td>0.700</td>
<td>0.668</td>
</tr>
<tr>
<td>Median(TE)</td>
<td>0.626</td>
<td>0.622</td>
<td>0.659</td>
<td>0.628</td>
<td>0.668</td>
<td>0.648</td>
<td>0.628</td>
<td>0.665</td>
<td>0.726</td>
<td>0.688</td>
</tr>
<tr>
<td>S.D.(TE)</td>
<td>(0.159)</td>
<td>(0.160)</td>
<td>(0.133)</td>
<td>(0.155)</td>
<td>(0.142)</td>
<td>(0.151)</td>
<td>(0.157)</td>
<td>(0.141)</td>
<td>(0.135)</td>
<td>(0.118)</td>
</tr>
<tr>
<td>spillover</td>
<td>(-4.20)</td>
<td>(-3.86)</td>
<td>(-3.33)</td>
<td>(-3.21)</td>
<td>(-4.53)</td>
<td>(-5.08)</td>
<td>(-3.17)</td>
<td>(-4.52)</td>
<td>(-4.94)</td>
<td>(0.61)</td>
</tr>
</tbody>
</table>

Notes: Absolute values of the t statistics are shown in parentheses. Estimations in 2000 and 2003 do not include the two environmental-related variables due to the unavailability of the relevant data.

a) The estimated results are from the estimation step when we perform the regression of the predicted TE's on their determinant variables and the series of regional dummy variables. To save space, the estimated results of the SPF are not shown.