ISO 9000 certification and technical efficiency of foreign-financed manufacturing firms in southern China

A stochastic frontier approach

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Abstract

Purpose – Based on a sample of foreign-financed manufacturing firms in southern China, the purpose of this paper is to study the effects of ISO certification on productivity.

Design/methodology/approach – The paper employs the stochastic frontier approach to estimate frontier efficiency scores at firm level.

Findings – The empirical results suggest that the implementation of ISO was able to improve firms’ productivity in the form of a wholly disembodied shift of the production frontier. The results further show that there was a mildly positive embodied shift of the production frontier due to the effects of ISO on the marginal product of labor. However, the embodied effects of ISO on the marginal product of capital were not significant.

Research limitations/implications – The sample size is small and the data were collected from southern China. A generalization of results to other parts of China should be interpreted with caution. Despite the limited degree of generalization, firms with ISO certifications are suggested to be aware of certain flexibility in the implementation of the ISO documented procedures.

Practical implications – The findings of the paper should be of general interest to firms seeking or adopting ISO system or other international standards.

Originality/value – The originality of the paper resides in the fact that the empirical work investigates the embodied effects of ISO certification on the marginal product of labor and capital.

Keywords: Process efficiency, ISO 9000 series, Manufacturing industries, China

Paper type: Research paper

JEL classification – D24, O40

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1. Introduction
The proliferation of international standards, in particular the ISO 9000, is one of the phenomena in the increasingly competitive global economy. The rapid adoption of ISO 9000 certification by manufacturing firms in developed and developing countries could be partially due to a widespread belief in the market about the business benefits of ISO 9000 certification, or the demand for a “quality label” from the market (Martínez-Costa and Martínez-Lorente, 2003). However, there could be cases that some firms truly comply with the ISO 9000 standards with great efforts while others may only do the necessary minimum in order to get through the audit requirements (Yeung and Mok, 2005).

There are many scholarly works reporting the relationship between ISO 9000 certification and firm’s financial performance (see the next section). While the ISO 9000 certification emphasizes on the documented quality system in the process of production and delivery of goods and services, none of the existing literature examines the effect of ISO 9000 certification on the production process in terms of utilization of inputs (e.g. labor and capital). That is, in the use of resources in production, does ISO 9000 certification matter?

Based on a sample of foreign-financed manufacturing firms in Guangzhou (the municipal city of Guangdong province) spanning the period 1999-2001, this paper fills the literature gap by examining the effects of ISO 9000 certification on firms’ technical efficiency in southern China. Given the significant role of foreign-financed firms in China’s economic performance, the findings of this paper add to the growing literature on the growing popularity of adherence to ISO certifications and the subsequent effects on firm efficiency. To improve the validity of findings, this paper adopts frontier efficiency scores to evaluate firm performance. When compared with the conventional measures of performance, the method of frontier efficiency measurement offers relative scores such that a comparison with the best practice firms is directly taken into consideration. Both of the disembodied and embodied shifts in the effects of ISO certification on output in the sample firms are examined to determine the extent of compliance to ISO 9000 certification on firm performance.

The literature review and the research hypotheses will be outlined in the next section, before a description of the dataset and the methodology of this paper. The empirical data will be analyzed and the hypotheses on the relationship between the impositions of ISO 9000 certification and productivity will be tested in section 4. The empirical results are interpreted in section 5 and conclusions are given in section 5.

2. Background and literature review
2.1 Background of ISO 9000 certification
In quality management, one milestone was the establishment of the international standards for quality by the International Organization for Standardization (ISO) in 1987. The ISO issued a series of international standards, which are usually implemented inside a firm for the purposes of external quality assurances. ISO 9000 is mainly concerned with the Quality Management System (QMS), i.e. whether the firm has done everything to ensure that its products conform to the customer’s requirements (ISO, 2003a)[1]. Generally, the reasons for firms to adopt ISO 9000 certification are partly to fulfill their customers’ requirements and partly to improve their own quality control processes. The main purpose of the ISO 9000 standards is to ensure that certified firms follow the quality management system in order to meet the
pre-determined quality standards relating to the production and delivering processes of goods and services. The systematic documentation of ISO 9000 helps the firms to meet the purpose. For instance, in manufacturing firms, each batch of products is documented or electronically tagged. Any faulty products picked up by quality control staff can result in the whole batch being double-checked before leaving the factory. The quality control staff can trace the production date(s) and identify the possible reasons for the faults in the manufactured products back down the production line. As this leads to fewer faulty products, these documentation procedures may also improve procedural productivity. Firms have to document their production practices relating to the quality management of their products so that the procedures have to be delivered consistently in order to gain and maintain ISO 9000 certification.

ISO 9000 certification will only be granted upon satisfactory report from an independent ISO audit. After the initial certification, regular independent audits will be undertaken (every six months) to maintain the continuous status of certification. If there is an unsatisfactory audit, de-registration could be imposed with subsequent registration to be contingent upon fulfillment of certification requirement. In addition to the fees payable for auditors and consultants for the certification, this is one of the reasons why the process to maintain the status of ISO 9000 certification can be costly.

2.2 Literature review

However, an equally impressive list of scholar has argued that ISO 9000 certification does not have a positive effect on firm performance. To name a few typical examples, Beattie and Sohal (1999) showed that a mere four percent of the 50 Australian firms reported an improvement in their profitability after the ISO certification. Shams-ur (2001) also found insignificant differences in self-rated performance between small- and medium-sized firms with and without ISO 9000 certification in Australia. Wayhan et al. (2002) showed that ISO 9000 certification failed to improve financial growth or profitability. Yet, they found a positive association between ISO 9000 certification and return on assets. Martinez-Costa and Martinez-Lorente (2003) did not find clear evidence to support that ISO 9000 certification could be positively valued by the market. Based on a sample of more than 2,700 US firms in the electronics industry, Morris (2006) argued that there is no link between ISO 9000 certification and financial performance.

Methodological differences, especially on the working definition of performance, can partially reconcile the mixed findings among the empirical studies into the relationship between ISO 9000 certification and financial performance. For instance, one commonly used indicator is financial ratios. However, the limitations on the use of various financial ratios have been well noted. For instance, the use of return on equity usually suffers from the effects of differential asset valuations and the bias by the debt-to-equity ratios, which are often high for firms in some developing economies (Nachum, 2004). In addition, Graham (2005, p. 66) argued that “most earnings management is achieved ... [when managers] take real economic actions such as delaying maintenance ... to meet short-term earnings benchmarks”. This kind of behavior to burn economic value to meet financial reporting goals may undermine the reliability of profit earnings data used to estimate various financial ratios.

Although many scholars reported an improvement in quality control, productivity and customer satisfaction, they also pointed to the high costs of implementation, and of providing the documentation required by the ISO (Quazi and Padibjo, 1998; Juran, 1999, p. 30). Some firms experienced difficulties in conducting internal quality audits and, subsequently, in taking the required corrective actions (Ebrahimipour et al., 1997). Sun and Cheng (2002) and Thomas and Webb (2003) even questioned the cost-effectiveness and feasibility of implementing ISO 9000 in small-to-medium size enterprises in the manufacturing sector. Some even question the motivation in pursuing ISO 9000 mainly a result of customer pressure (Terziovski et al., 2003; Martinez-Costa and Martinez-Lorente, 2003). From the above, it can be concluded that the implementation of ISO 9000 may improve procedural productivity and quality control over products, but may not lead to an expansion of market share nor an improvement in cost efficiency (Terziovski et al., 2003, p. 584).

2.3 Theory development and hypotheses
The literature review on the ISO 9000 delineates two popular explanations for firms to comply with ISO 9000 certification: to implement TQM (Najmi and Kehoe, 2000; Pheng and Alfelor, 2000) or to give firms a competitive advantage (Terziovski et al., 2003; Simmons and White, 1999; Sharma, 2005; Corbett et al., 2005). ISO 9000 certification produces a signal to the market about quality assurance. The systematic documentation of ISO 9000 helps firms to maintain the quality of their products. Firms complying with ISO 9000 certification are expected to enjoy benefits of a QMS.
The conventional wisdom is that QMS is able to translate the benefits into higher performance at the firm, demonstrated by an improvement in productivity caused by less rework, decrease in costs such as less in scraps and wastage, and/or an increase in customer satisfaction resulting in higher sales revenues. The above argument leads to the following hypothesis:

\[ H. \] Firms with ISO 9000 certification have higher levels of productivity than their counterparts without ISO 9000 certification.

To consider the effects of ISO certification on the production processes, such as the expectation on a better use of resources, i.e. labor and capital, through the compliance with a QMS in production and delivery of products, firms with ISO 9000 certification are expected to have a higher marginal product of production resources. This argument lend to the following sub-hypotheses:

\[ Ha. \] Firms with ISO 9000 certification have a higher marginal product of labor compared with their counterparts without ISO 9000 certification.

\[ Hb. \] Firms with ISO 9000 certification have a higher marginal product of capital compared with their counterparts without ISO 9000 certification.

Export-orientedness as a control variable. As foreign-financed firms in southern China are normally export-oriented, it may affect output for given capital and labor inputs and thus has to be controlled to accurately estimate the effects of ISO 9000 certification on firm performance. To cater for the effect of export-orientation on performance, a control variable of export-orientedness, measured by the ratio of exports to gross output, is included in the model[2]. Export-oriented industrialization and a firm’s resulting exposure to international competition are identified as one of the major causes of the rapid economic growth in East Asian countries (World Bank, 1993). Theoretically, firms with a higher proportion of exports are likely to be more efficient because of their exposure to competitive international markets (Hikino and Amsden, 1994; Yin and Yin, 2005). Hence, it is logical to expect that firms that export a greater portion of their output are likely to be more productive than firms that export less.

3. The model

While many previous studies on the productivity of firms directed their attention towards average rather than best-practice production processes, a stochastic production frontier model that is more consistent with the theoretical ideal of a production function is employed in this paper[3]:

\[
Q_{it} = f(X_{it}, \alpha)e^{\varepsilon_{it}},
\]

where:

\[ Q_{it} = \] the output in real terms of the \( i \)th sample firm at time \( t \).

\[ X_{it} = \] a vector of inputs for the \( i \)th sample firm at time \( t \).

\[ \alpha = \] a vector of unknown parameters to be estimated.

\[ \varepsilon_{it} = \] a random disturbance term.
Following Aigner et al. (1977), and Meeusen and Van Den Broeck (1977), the random disturbance term is split into two error terms:

\[ \varepsilon_{it} = v_{it} - u_{it} \]

\( v_{it} \) is assumed to be normally and identically distributed (NID), with a zero mean and a variance of \( \sigma^2_v \), which captures the effects of random shocks and statistical noise. \( u_{it} \) is assumed to consist of independent and identically distributed non-negative truncations of the \( \text{N}[\mu, \sigma^2_u] \), and to be independent of \( v_{it} \). \( u_{it} \) is the measurement of inefficiency. In this paper, the distribution of \( u_{it} \) is assumed to follow the error component model, the formulation of which traces back to the works of Battese and Coelli (1992):

\[ u_{it} = \left\{ \exp[-\eta(t - T_i)] \right\} u_i \quad (2) \]

\( i = 1, \ldots, n; t = 1, \ldots, T, \)

where \( \eta \) is an unknown parameter. The level of technical efficiency of firm \( i \) in period \( t \) is defined as its actual output as a proportion of its corresponding frontier output when the firm utilizes its level of inputs most efficiently:

\[ TE_{it} = \exp(-u_{it}) \quad (3) \]

In equation (2), the exponential function, \( \exp[-\eta(t - T_i)] \), has a value of 1 when \( t = T \). Then, the random variable \( u_{it} \) is the technical inefficiency effect for firm \( i \) in the last period of the panel. In cases where \( t < T \), firm \( i \)'s technical inefficiencies in production are the product of its technical inefficiency in the last period and the value of the exponential function, which is a function of \( \eta \) and \( t \). When \( t \) increases, \( u_{it} \) decreases, remains constant, or increases if \( \eta > 0 \), \( \eta = 0 \) or \( \eta < 0 \), respectively. When \( \eta \) is positive, the model then suggests that the technical efficiencies of the firms are improving over time. Conversely, when \( \eta \) is negative, their technical efficiencies are decreasing. The specification of equation (2) is a rigid parameterization in that the variation in the effects of the technical inefficiency of all firms is monotone throughout the period of observation. However, the main advantage of the specification is that the changes in technical inefficiency over time can be separated from the technical changes, which can be detected by adding a time trend in the regressor vector.

On the estimation of the stochastic frontier production function, the method of maximum likelihood (ML) is used to estimate its parameters. To simplify the search for a suitable starting value in the iterative process of maximization, Battese and Corra (1977) replaced \( \sigma^2_v \) and \( \sigma^2_u \) with \( \sigma^2 = \sigma^2_v + \sigma^2_u / (\sigma^2_v + \sigma^2_u) \), respectively. With this form of parameterization, the value of \( \gamma \) falls into the range of zero and one. This provides a convenient method for performing a test of the hypothesis to determine whether the mean response production function model is an adequate representation for the sample data, given the assumptions of the stochastic frontier model that are defined. If no technical inefficiency has been measured, i.e. \( \sigma^2_u = 0 \), then \( \gamma \) is zero, and it follows that the estimation of the mean response production function by ordinary least squares (OLS), where the estimated residuals have an expected value of zero, will be an appropriate model for analysis. On the other hand, if \( \gamma \) is large, this implies that the inefficiency term is a significant component in the estimation of the production function by the stochastic frontier approach, as compared to the mean response.
production function approach. A number of special cases for the particular model
delineated above will be obtained with the imposition of one or more restrictions. For
instance, setting $\mu = 0$ reduces the model to a half-normal truncation, while restricting
$\eta$ to zero provides the time-invariant model explained in Battese et al. (1989).

In the computation of $TE_{it}$ in equation (3), Battese and Coelli (1993) decomposed $u_{it}$
from the estimated residuals, $\varepsilon_{it}$, in equation (1). The decomposition can be obtained by
taking the conditional expectation of equation (3), conditional upon $\varepsilon_{it}$. The
formulation of the conditional expectation is as follows:

$$E[\exp(-u_{it}|\varepsilon_{it})] = \left\{ \frac{1 - \phi[\eta_i \sigma_i^* - (\mu_i^*/\sigma_i^*)]}{1 - \phi(-\mu_i^*/\sigma_i^*)} \right\} \exp[ -\eta_i \mu_i^* + \frac{1}{2} \eta_i^2 \sigma_i^*2 ]$$

where

$$u_i^* = \frac{\mu \sigma_v^2 - \eta_i \varepsilon_i \sigma_i^2}{\sigma_v^2 + \eta_i \eta_i \sigma_i^2}$$

and

$$\sigma_i^*2 = \frac{\sigma_v^2 \sigma_i^2}{\sigma_v^2 + \eta_i \eta_i \sigma_i^2}$$

where $\eta_i$ represents a $(T_i \times 1)$ vector of $\eta_{it}$ associated with the time period observed for
firm $i$, and $\phi(\bullet)$ stands for the distribution function for the standard normal variables.

4. Data and empirical estimations
4.1 The data sample
A set of panel data collected in Guangzhou in southern China is used to estimate the
parameters of the stochastic frontier production function described above. In March
2002, with the assistance of the Foreign Economic Relations and Trade Office in
Guangzhou, a questionnaire survey on various data relating to the output, capital,
labor, exports, and ISO information of foreign-financed manufacturing firms was
conducted. Based on an internal list containing 550 foreign-financed manufacturing
firms in the Foreign Economic Relations and Trade Office, questionnaires were sent to
80 firms randomly selected from the list. After two rounds of follow-up enquiries,
including telephone calls, 57 questionnaires were returned, for a return rate of 71
percent. Observations with missing data were deleted, leaving a sample of 47 firms
covering the period 1999-2001, with 141 observations in an unbalanced panel dataset.
Of these firms, 13 are certified with ISO 9000, accounting for 28 percent of the sample.
At the time the data were collected, these 13 firms had a rather short history of ISO
9000 adoption of only four years or less. Although the absolute size of the sample is
small, the dataset covering various firm-specific attributes permitted us to construct
measures of key variables that are close to theoretical ideals. For example, the export
data are collected to depict the effects of exports on the productivity of firms, while the
data on firms with ISO 9000 certification allow us to examine the embodied and
disembodied shifts of the production frontier, due to the effect of the ISO on the
marginal products of inputs (see below). Table I sets out a description and summary
statistics of the variables. All variables with monetary figures are measured in units of
The large diversity in size among the sample firms is indicated by the values of the standard deviations of the variables for output and capital, which are more than double their respective means. Furthermore, the standard deviations of the two variables for labor and export ratio are of magnitudes comparable with their means. To complement the findings of the questionnaire survey, the authors conducted semi-structured interviews with eight firms in Guangdong and one firm in Hong Kong between March and June 2003.

The manufacturing industry in Guangzhou was chosen for this study for three main reasons. First, undertaking empirical studies on data at the firm level in China is often contingent on being able to gain access to organizations. The local government unit has good access to firms, which made the collection of data more feasible. Second, since China introduced its economic reforms in 1979, Guangdong has been given a higher level of economic freedom than other provinces. It is one of the provinces that has attracted the largest amount of FDI in China. Third, most other studies have tended to use data at the national level to study the effects of selected firm-specific attributes on productivity, e.g. Young (2000), Jefferson et al. (2000), and so forth. However, in view of the vast extent of China’s industry, certain firm-specific attributes may have produced positive effects in some provinces but not in others. Thus, this paper, based on the manufacturing industry in Guangdong, seeks to determine whether certain selected firm-specific attributes have brought about significant changes to firms’ efficiency at the provincial level.

As regards the sources of funding of the sample firms, the sample consists of 25 firms owned by investors originating in Hong Kong, 16 firms from Taiwan, two from Thailand, and the remainder from Japan, Germany and France. The sample firms represent three modes of investment: equity joint ventures (14 cases), contractual joint ventures (11 cases), and wholly owned foreign ventures (22 cases). All were located in Guangzhou. In terms of the industrial sectors represented, 13 firms were in electronics, five in paper and printing, four in metal products, five in textiles and clothing, three in food and beverages and six in plastic products.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description of variable</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V$</td>
<td>Value added at constant 2000 prices.</td>
<td>1,587</td>
<td>3,640</td>
</tr>
<tr>
<td>$K$</td>
<td>Net value of fixed assets deflated by a capital price index with a base year of 2000 (10,000 yuan)</td>
<td>1,212</td>
<td>2,448</td>
</tr>
<tr>
<td>$L$</td>
<td>Total number of employees</td>
<td>226</td>
<td>223</td>
</tr>
<tr>
<td>EXPORT</td>
<td>Ratio of exports to gross output</td>
<td>0.50</td>
<td>0.44</td>
</tr>
<tr>
<td>ISO</td>
<td>A dummy variable takes the value of 1 for firms that have adopted ISO 9000 and 0 for firms that have not</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISO_K</td>
<td>The variable capturing the embodied ISO 9000 effects on the marginal product of capital</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISO_L</td>
<td>The variable capturing the embodied ISO 9000 effects on the marginal product of labor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Number of firms = 47
accounting for 77 percent of the total number of firms in the sample. The others were in leather products, handicrafts and spectacles. In terms of employment size, 18 cases were small-sized firms (1-50 workers), 24 medium-sized firms (51-500 workers), and the rest large firms (501 or more workers).

4.2 Empirical estimation

The translog production technology is used to estimate an aggregate production function. When compared with a Cobb-Douglas production function, a translog function is relatively flexible, allowing for varying production elasticities and varying returns to scale. Gains in productivity over time mainly arise from shifts in the production frontier. Assuming the use of translog production technology, the output of each enterprise is related to its inputs and its firm-characteristics[5]:

\[ V_i = A_o K_i^{\alpha_1} L_i^{\alpha_2} \exp (H \cdot Q + u_i) \]

- \( V_i \) = Value added.
- \( K_i \) = Capital input.
- \( L_i \) = Labour input.
- \( Q \) = Column vector of firm-characteristics.
- \( H \) = Row vector of parameters corresponding to \( Q \).
- \( u_i \) = Normally distributed disturbance term.

The adoption of the ISO system may affect the productivity of enterprises. If the ISO system produces a wholly disembodied shift in the production frontier, then the production function may appear as indicated below, where \( ISO_i \) is a dummy variable:

\[ V_i = A_o K_i^{\alpha_1} L_i^{\alpha_2} \exp (\phi_S ISO_i + H \cdot Q_i + u_{1i}) \]

If the effects of the ISO scheme are reflected in the marginal products of input factors due to embodied effects, then a slightly general production function may be specified as:

\[ V_i = A_o K_i^{(\alpha_1 + \phi_K ISO_i)} L_i^{(\alpha_2 + \phi_L ISO_i)} \exp (H \cdot Q_i + u_{2i}) \]

where \( \alpha_i, \phi_K, \phi_L \) and \( \phi_S \) are coefficient parameters. \( V_i \) is the value added of firm \( i \) at constant 2000 prices[6]. \( L_i \) is the number of workers and staff, and \( K_i \) is capital, measured by the net value of fixed assets deflated by a capital price index[7]. The price index of machinery and equipment was used as the capital price index. The base period of the price indexes was the year 2000. \( ISO \) is a dummy variable which takes the value of 1 for firms adopting ISO 9000, and 0 for firms not doing so.

The introduction of ISO 9000 certification may affect the productivity of enterprises. If ISO 9000 produces a Hicks-neutral, wholly disembodied shift in the production frontier, then the production function may appear as in model (1). If the effects of ISO 9000 certification...
9000 are reflected in the marginal products of capital and labor due to embodied effects, then a slightly general production function may be specified as in model (2).

Since the sample data are comprised firms from different types of industries, the effects of inter-industry heterogeneity on productivity may be expected. To consider the fixed effect model accounting for the heterogeneity of firms in different industries, the models with industry-specific effects is estimated by adding six industry dummies in both models (1) and (2)[8]. The computational forms of models (1) and (2) involved in the study are:

Model 1

\[ \ln V = \text{Intercept} + \alpha_1 \ln K + \alpha_2 \ln L + \alpha_3 (\ln K)^2 + \alpha_4 (\ln L)^2 + \alpha_5 K^* \ln L \]

\[ + \kappa \text{DummyI} + h \text{EXPORT} + \phi_2 \text{ISO} \]

Model 2

\[ \ln V = \text{Intercept} + \alpha_1 \ln K + \alpha_2 \ln L + \alpha_3 (\ln K)^2 + \alpha_4 (\ln L)^2 + \alpha_5 K^* \ln L \]

\[ + \kappa \text{DummyI} + h \text{EXPORT} + \phi_K \text{ISO}_K + \phi_L \text{ISO}_L \]

4.3 Empirical results

The econometric computation was executed using FRONTIER 4.1 software for panel data[9]. The frontier function equations (4) and (5) were estimated for five basic models, respectively:

(1) **Model 1.0**: This is a flexible model in that \( u_{it} \) have a time-varying structure and are assumed to have a truncated normal distribution with a mean \( \mu \) and a variance \( \sigma^2_u \).

(2) **Model 1.1**: \( u_{it} \) are assumed to have a time-varying structure and a half-normal distribution (i.e. \( \mu = 0 \)).

(3) **Model 1.2**: This model assumes the existence of the time-invariant inefficiency effect and that \( u_{it} \) have a truncated normal distribution (i.e. \( \eta = 0 \)).

(4) **Model 1.3**: \( u_{it} \) are assumed to have a time-invariant structure and a half-normal distribution (i.e. \( \mu = \eta = 0 \)).

(5) **Model 1.4**: This is the conventional mean response production function, in which all firms are assumed to be fully technically efficient (i.e. \( \gamma = \mu = \eta = 0 \)).

The empirical results for these five models with respect to equations (4) and (5) are presented in Tables II and III, respectively. The tests of various hypotheses on the different distributional assumptions are performed by using the likelihood ratio test. The relevant statistics for the tests of hypotheses are presented in Tables IV and V.

In the first step, given the specification of the stochastic frontier with time-varying effects (i.e. Model 1.0), the null hypothesis stated that there are no technical inefficiency effects in the model (i.e. \( H_0: \gamma = \mu = \eta = 0 \)). The first row in Table IV gives a test statistic of 120.37, which is greater than the critical value of 7.81. This test result suggests that the conventional mean response production function is not an adequate
<table>
<thead>
<tr>
<th></th>
<th>Model 1.0</th>
<th>Model 1.1</th>
<th>Model 1.2</th>
<th>Model 1.2a</th>
<th>Model 1.2b</th>
<th>Model 1.3</th>
<th>OLS Model 1.4</th>
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<tbody>
<tr>
<td>ln K</td>
<td>-0.687</td>
<td>-0.652</td>
<td>-0.697</td>
<td>-0.629</td>
<td>0.424</td>
<td>0.656</td>
<td>-0.176</td>
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<td></td>
<td>(-2.284)</td>
<td>(-2.031)</td>
<td>(-2.349)</td>
<td>(-2.150)</td>
<td>(-2.044)</td>
<td>(-2.044)</td>
<td>(-0.480)</td>
</tr>
<tr>
<td>ln L</td>
<td>0.709</td>
<td>0.873</td>
<td>0.765</td>
<td>0.896</td>
<td>0.640</td>
<td>0.868</td>
<td>1.139</td>
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<tr>
<td></td>
<td>(2.018)</td>
<td>(2.147)</td>
<td>(2.033)</td>
<td>(2.377)</td>
<td>(5.915)</td>
<td>(2.139)</td>
<td>(2.102)</td>
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<tr>
<td>(ln K)^2</td>
<td>0.058</td>
<td>0.061</td>
<td>0.061</td>
<td>0.095</td>
<td>0.063</td>
<td>0.179</td>
<td>0.199</td>
</tr>
<tr>
<td></td>
<td>(1.324)</td>
<td>(1.344)</td>
<td>(1.418)</td>
<td>(2.191)</td>
<td>(1.410)</td>
<td>(2.841)</td>
<td></td>
</tr>
<tr>
<td>(ln L)^2</td>
<td>-0.060</td>
<td>-0.066</td>
<td>-0.065</td>
<td>-0.016</td>
<td>-0.062</td>
<td>0.105</td>
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<td></td>
<td>(-0.926)</td>
<td>(-0.906)</td>
<td>(-0.224)</td>
<td>(-0.959)</td>
<td>(-0.988)</td>
<td></td>
<td></td>
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<tr>
<td>ln K * ln L</td>
<td>0.082</td>
<td>0.070</td>
<td>0.076</td>
<td>-0.017</td>
<td>0.065</td>
<td>-0.285</td>
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<tr>
<td></td>
<td>(0.802)</td>
<td>(0.664)</td>
<td>(0.817)</td>
<td>(-0.162)</td>
<td>(0.639)</td>
<td>(-1.250)</td>
<td></td>
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<tr>
<td>Dummy1</td>
<td>0.934</td>
<td>0.232</td>
<td>0.401</td>
<td>0.598</td>
<td>0.238</td>
<td>0.434</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.915)</td>
<td>(0.487)</td>
<td>(0.926)</td>
<td>(1.061)</td>
<td>(0.518)</td>
<td>(-0.965)</td>
<td></td>
</tr>
<tr>
<td>Dummy2</td>
<td>-1.289</td>
<td>-1.343</td>
<td>-1.274</td>
<td>-1.153</td>
<td>-1.350</td>
<td>-1.280</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-3.815)</td>
<td>(-3.888)</td>
<td>(-3.889)</td>
<td>(-2.750)</td>
<td>(-3.454)</td>
<td>(-3.574)</td>
<td></td>
</tr>
<tr>
<td>Dummy3</td>
<td>-0.349</td>
<td>-0.394</td>
<td>-0.355</td>
<td>-0.388</td>
<td>-0.402</td>
<td>-0.604</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.918)</td>
<td>(-0.904)</td>
<td>(-1.017)</td>
<td>(-0.968)</td>
<td>(-0.931)</td>
<td>(1.617)</td>
<td></td>
</tr>
<tr>
<td>Dummy4</td>
<td>-0.340</td>
<td>-0.207</td>
<td>-0.321</td>
<td>-0.210</td>
<td>-0.506</td>
<td>-0.134</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.819)</td>
<td>(-1.136)</td>
<td>(-0.801)</td>
<td>(-0.413)</td>
<td>(-1.095)</td>
<td>(2.722)</td>
<td></td>
</tr>
<tr>
<td>Dummy5</td>
<td>-0.106</td>
<td>-0.170</td>
<td>-0.028</td>
<td>-0.890*10^-3</td>
<td>-0.173</td>
<td>-0.387</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.108)</td>
<td>(-0.444)</td>
<td>(-0.085)</td>
<td>(-0.219*10^-2)</td>
<td>(-0.445)</td>
<td>(1.757)</td>
<td></td>
</tr>
<tr>
<td>Dummy6</td>
<td>-0.308</td>
<td>-0.387</td>
<td>-0.299</td>
<td>-0.415</td>
<td>-0.380</td>
<td>-0.709</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-1.085)</td>
<td>(-1.224)</td>
<td>(-1.064)</td>
<td>(-1.174)</td>
<td>(-1.213)</td>
<td>(-2.624)</td>
<td></td>
</tr>
<tr>
<td>Export</td>
<td>-0.128</td>
<td>-0.159</td>
<td>-0.126</td>
<td>-0.303</td>
<td>-0.390</td>
<td>-0.158</td>
<td>0.121</td>
</tr>
<tr>
<td></td>
<td>(-0.560)</td>
<td>(-0.665)</td>
<td>(-0.583)</td>
<td>(-1.269)</td>
<td>(-1.629)</td>
<td>(-0.652)</td>
<td>(0.461)</td>
</tr>
<tr>
<td>ISO</td>
<td>0.832</td>
<td>0.300</td>
<td>0.390</td>
<td>0.517</td>
<td>0.282</td>
<td>0.314</td>
<td>-0.665</td>
</tr>
<tr>
<td></td>
<td>(1.755)</td>
<td>(1.424)</td>
<td>(1.795)</td>
<td>(2.474)</td>
<td>(1.223)</td>
<td>(1.468)</td>
<td>(-2.715)</td>
</tr>
<tr>
<td>γ</td>
<td>0.972</td>
<td>0.912</td>
<td>0.975</td>
<td>0.975</td>
<td>0.975</td>
<td>0.975</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(8.290)</td>
<td>(36.789)</td>
<td>(84.209)</td>
<td>(88.969)</td>
<td>(60.343)</td>
<td>(40.176)</td>
<td></td>
</tr>
<tr>
<td>ρ</td>
<td>5.331</td>
<td>0</td>
<td>5.363</td>
<td>6.306</td>
<td>5.951</td>
<td>5.951</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(-2.835)</td>
<td>(-2.538)</td>
<td>(-1.723)</td>
<td>(-1.727)</td>
<td>(-1.727)</td>
<td>(-1.727)</td>
<td></td>
</tr>
<tr>
<td>η</td>
<td>0.019</td>
<td>0.117</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-142.513</td>
<td>-145.495</td>
<td>-142.675</td>
<td>-149.554</td>
<td>-150.522</td>
<td>-145.683</td>
<td>-202.068</td>
</tr>
</tbody>
</table>

Notes: *Significant at 10%; ** significant at 5%; t-values are in parentheses
Table III.
Estimates for the parameters of the stochastic frontier production function: equation (5)

<table>
<thead>
<tr>
<th></th>
<th>Model 2.0</th>
<th>Model 2.1</th>
<th>Model 2.2</th>
<th>Model 2.3</th>
<th>OLS Model 2.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.665</td>
<td>3.574</td>
<td>3.649</td>
<td>3.586</td>
<td>1.027</td>
</tr>
<tr>
<td>ln K</td>
<td>-0.700</td>
<td>-0.654</td>
<td>-0.679</td>
<td>-0.662</td>
<td>-0.302</td>
</tr>
<tr>
<td>ln L</td>
<td>1.146</td>
<td>1.234</td>
<td>1.111</td>
<td>1.231</td>
<td>1.426</td>
</tr>
<tr>
<td>(ln K)^2</td>
<td>0.090</td>
<td>0.092</td>
<td>0.091</td>
<td>0.096</td>
<td>0.214</td>
</tr>
<tr>
<td>(ln L)^2</td>
<td>1.135</td>
<td>1.220</td>
<td>1.158</td>
<td>1.233</td>
<td>1.214</td>
</tr>
<tr>
<td>ln K*ln L</td>
<td>0.016</td>
<td>0.004</td>
<td>0.008</td>
<td>-0.002</td>
<td>-0.326</td>
</tr>
<tr>
<td>Dummy1</td>
<td>0.333</td>
<td>0.193</td>
<td>0.327</td>
<td>0.199</td>
<td>-0.367</td>
</tr>
<tr>
<td>Dummy2</td>
<td>-1.122</td>
<td>-1.133</td>
<td>-1.003</td>
<td>-1.101</td>
<td>(0.955)</td>
</tr>
<tr>
<td>Dummy3</td>
<td>0.016</td>
<td>0.004</td>
<td>0.008</td>
<td>-0.002</td>
<td>-0.326</td>
</tr>
<tr>
<td>Dummy4</td>
<td>(0.144)</td>
<td>(0.037)</td>
<td>(0.077)</td>
<td>(0.016)</td>
<td>(2.468)**</td>
</tr>
<tr>
<td>Dummy5</td>
<td>0.096</td>
<td>0.092</td>
<td>0.091</td>
<td>0.096</td>
<td>0.214</td>
</tr>
<tr>
<td>Dummy6</td>
<td>0.016</td>
<td>0.004</td>
<td>0.008</td>
<td>-0.002</td>
<td>-0.326</td>
</tr>
<tr>
<td>Export</td>
<td>-0.238</td>
<td>-0.236</td>
<td>-0.217</td>
<td>-0.236</td>
<td>0.092</td>
</tr>
<tr>
<td>ISO_Lab</td>
<td>-0.222</td>
<td>0.210</td>
<td>0.499</td>
<td>0.175</td>
<td>1.216</td>
</tr>
<tr>
<td>ISO_K</td>
<td>-0.222</td>
<td>0.210</td>
<td>0.499</td>
<td>0.175</td>
<td>1.216</td>
</tr>
<tr>
<td>g</td>
<td>0.018</td>
<td>0.018</td>
<td>0.018</td>
<td>0.018</td>
<td>0.018</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-142.037</td>
<td>-144.838</td>
<td>-142.162</td>
<td>-145.037</td>
<td>-199.059</td>
</tr>
</tbody>
</table>

Notes: *Significant at 10%; ** significant at 5%; t-values are in parentheses

Table IV.
Results of tests of hypotheses involving parameters for the distribution of firm effects, \( \mu_i \), equation (4)

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Null hypothesis, Ho</th>
<th>( \chi^2 ) statistic</th>
<th>( \chi^2_{0.05} ) value</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1.0</td>
<td>( \gamma = \mu = \eta = 0 )</td>
<td>120.37</td>
<td>7.81</td>
<td>Reject Ho</td>
</tr>
<tr>
<td>Model 1.0</td>
<td>( \mu = 0 )</td>
<td>5.96</td>
<td>3.84</td>
<td>Reject Ho</td>
</tr>
<tr>
<td>Model 1.0</td>
<td>( \eta = 0 )</td>
<td>0.32</td>
<td>3.84</td>
<td>Accept Ho</td>
</tr>
<tr>
<td>Model 1.0</td>
<td>( \mu = \eta = 0 )</td>
<td>6.34</td>
<td>5.99</td>
<td>Reject Ho</td>
</tr>
<tr>
<td>Model 1.2</td>
<td>( \gamma = 0 )</td>
<td>114.03</td>
<td>2.71(^{a})</td>
<td>Reject Ho</td>
</tr>
</tbody>
</table>

Notes: \(^{a}\)This is a mixed chi-squared statistic. See Kodde and Palm (1986)
representation of the sample data. Hence, the null hypothesis of no technical inefficiency is rejected. The next step is to test the half-normal model (Model 1.1) versus the alternative truncated model (Model 1.0). The result from row 2 in Table IV suggests that the null hypothesis (the inefficiency component is assumed to have a half-normal distribution) is rejected. Furthermore, the hypothesis assuming the time-invariant model (Model 1.2) for firm effects would not be rejected. In the fourth step, the null hypothesis that $\mu$ and $\eta$ are jointly equal to zero is tested. The result of the test statistic from the fourth row of Table IV indicates that the truncated normal and time-invariant models are appropriate for defining the distribution of the firm effects (Model 1.2). Model 1.2a was obtained by the assumption that there is no fixed industrial effect on the production process. The likelihood ratio test statistic of 12.59 suggests that the hypothesis of no joint industrial effect is rejected. To check whether the translog production technology is an appropriate form of production function in our samples firms when compared to the Cobb-Douglas production technology, we performed a likelihood ratio test between Models 1.2 and Model 1.2b, a test statistic of 15.69 rejects the hypothesis of a Cobb-Douglas technology. Finally, given Model 1.2, the ML estimate for $\gamma$ is statistically significant with a value of 0.98[10], suggesting that the inefficiency effects make a significant contribution in the analysis of manufacturing production in the sample firms involved.

The results of the above set of tests of the hypotheses refer to equation (4), which specifies the Hicks-neutral, disembodied shift in the production function due to the effects of ISO. Equation (5) is referred for the study of the embodied effects. The test statistics of a similar set of tests of the hypotheses are contained in Table V (following the procedures explained in the preceding paragraph). Various test results suggest that the specification in Model 2.2, assuming a truncated normal distribution and time-invariant models, is appropriate for use in defining the distribution of the firm effects (Model 2.2). Hence, Models 1.2 and 2.2 are the preferred specifications for the discussion of the disembodied and embodied ISO effects, respectively, on production.

5. Discussion and interpretation of the results
The estimated results of Model 1.2 in Table II demonstrate that positive effects of the ISO certification on the output of the sample firms are mildly significant at the 10% level of significance. That is, it produced a Hicks-neutral, wholly disembodied shift of the production function in the sample firms. Hence, the empirical results supported the first hypothesis that ISO 9000 certification could improve firm performance in terms of productivity. This finding is compatible with the empirical evidence in other

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Null hypothesis, Ho</th>
<th>$\chi^2$ statistic</th>
<th>$\chi^2_{0.05}$ · value</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 2.0</td>
<td>$\gamma = \mu = \eta = 0$</td>
<td>114.04</td>
<td>7.81</td>
<td>Reject Ho</td>
</tr>
<tr>
<td>Model 2.0</td>
<td>$\mu = 0$</td>
<td>5.60</td>
<td>3.84</td>
<td>Reject Ho</td>
</tr>
<tr>
<td>Model 2.0</td>
<td>$\eta = 0$</td>
<td>0.25</td>
<td>3.84</td>
<td>Accept Ho</td>
</tr>
<tr>
<td>Model 2.0</td>
<td>$\mu = \eta = 0$</td>
<td>6.00</td>
<td>5.99</td>
<td>Reject Ho</td>
</tr>
<tr>
<td>Model 2.2</td>
<td>$\gamma = 0$</td>
<td>120.05</td>
<td>2.71$^a$</td>
<td>Reject Ho</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Kodde and Palm Statistic)</td>
<td></td>
</tr>
</tbody>
</table>

Table V. Results of tests of hypotheses involving parameters for the distribution of firm effects, $\mu_{it}$, equation (5)

Notes: $^a$This is a mixed chi-squared statistic. See Kodde and Palm (1986)

To disentangle the embodied effects of ISO 9000 on the productivity of the sample firms, Model 2.2 examines its effects on the marginal products of capital and labor. The results of Model 2.2 show that the coefficient of the interaction terms between ISO and labor was positive but only weakly significant at the 15 percent level. We suspected that staff members of some sample firms may have obtained the benefits from the compliance with the ISO system of production procedures. This is especially the case for those staff members familiar with the procedures of ISO 9000 implementation and certification. However, there could be also cases of the lack of consensus on the implementation of the ISO 9000 documentation system between senior managers and the work force, particularly during the initial stage of implementing ISO 9000. This is especially the case in firms with established but incompatible procedures of documentation. As it takes time for all administrative staff to become familiar with the new system, it is common for a firm to implement both the in-house and the ISO documentation procedures concurrently, to minimize the risks of disruption and even the loss of vital products and market information. Without a clear consensus between the senior and junior managerial staff, during the transitional period, the implementation of ISO 9000 may lead to unnecessarily high transaction costs due to the duplication of paperwork, and may even give rise to discontent among managerial staff. This is well illustrated by the experience of a Taiwanese-financed electronic components manufacturer. During the first four months of the implementation of ISO 9000 in the firm, a large proportion of the managerial staff still prepared their documentation under the previous system. Subsequently, the firm failed its first internal audit in 1998, and the General Manager ordered everyone to work overtime for a week to prepare the documents under the new system (Field survey, March 2003). These effects of ISO 9000 on labor in the sample firms may explain the marginally positive ISO embodied effects on the marginal products of labor input.

In the case of capital input, the results of the regression suggest a negative but insignificant embodied ISO effect on the marginal product of capital. This finding can be reconciled by the fact that some workers find it too troublesome to fully follow ISO procedures of documentation in operating machinery. This is the case in both large-scale firms with systematic work floor management as well as in small-and-medium-size firms. For instance, the automated cake-making machine in a cake-making factory fails to place all paper containers (cups) correctly into the metal mould before the injection of the cake mixture. The ISO 9000 procedures demand that workers switch off the machine for investigation and then document every detail of the process whenever they encounter a problem during its operation. The detailed investigation and documentation approach outlined by ISO 9000 may cause unnecessary interruptions and even lead to the suspension of the operation of the whole production line, as there will be no baked cakes for the packaging machine further down the production line to process. If workers are allowed to make adjustments to the machine according to their work experience (such as spraying edible oil on the mechanism of the machine that releases the paper cups to see whether this improves the situation), rather than having to follow the documented rules rigidly, they could continue operating the machine in somewhat safer conditions, as long as they judge that no critical faults or quality problems will arise during production (Field
survey, March–June 2003). Hence, based on the sample firms, when workers do not fully appreciate the documented procedures on the operation of machinery under ISO 9000, the expected beneficial effects of ISO 9000 on the utilization of capital will not be realized[11].

Turning to the relationship between the control variable of export-orientedness and productivity, the empirical results indicate that this relationship was statistically insignificant in both Models (1.2) and (2.2). A relationship between exports and productivity was not observed. This finding is compatible with empirical results for firms in other countries. For example, the empirical results of studies on firms in the UK (Bleaney and Wakelin, 2002), the USA (Bernard and Jensen, 1999), and in some developing countries (Aitken et al., 1997) do not support the common conjecture of a relationship between exports and productivity. In the case of the sample firms in China, it is suspected that the negative relationship between exports and productivity may be partly attributed to the high transaction costs of exporting, due to various government policies. Yeung and Mok (2002, pp. 239-241) explained that the high transaction costs are due to the ambiguity, complexity and inflexibility of government policies on the labor, capital, and products markets. For instance, foreign-financed firms have to keep detailed daily records for local governments and Customs of the value and quantity of the raw materials they import, their inventory of stock, and their exports of products, to fulfill rules on the verification of imports and exports. The aims of this government policy are to prevent the illegal reselling of tariff-free imported raw materials in the local market and tax evasion among foreign-financed firms. Nonetheless, this imposes tremendous administrative costs on daily operations, partly offsetting the profits (and lowering the efficiency) of export-oriented foreign-financed firms. This, coupled with the opening of the Chinese government’s move to open its local market to firms with foreign direct investment shortly before the country’s admittance to the World Trade Organization (WTO), has meant that foreign-financed firms in China appear to be paying more attention to capturing a share of the local Chinese market[12].

6. Conclusions
To conclude, this paper contributes to the literature by empirically examining the effects of ISO 9000 certification on the technical efficiency of foreign-financed manufacturing firms in Guangdong province in southern China. Instead of using conventional indicators of performance, such as financial ratios where its accuracy may be undermined by earnings management, differentiated asset evaluations, or the bias in debt-to-equity ratios, this paper adopts frontier efficiency scores to evaluate performance at firm level. Employing a translog production technology method, the production function was estimated for 47 foreign-financed manufacturing firms in Guangzhou in the period 1999-2001. Despite the limitations of the small sample size and its subsequent applicability for other firms (especially in other countries than China), the findings of this paper should be of general interest to firms seeking compliance with ISO 9000 certification or other similar international standards.

The implementation of ISO 9000 was found to be able to improve the productivity of foreign-financed firms in the form of a Hicks-neutral, wholly disembodied shift of the production frontier in Model 1, and thus the research hypothesis on ISO 9000 certification is accepted. An in-depth investigation through Model 2 was able to disentangle the embodied ISO effects on labor, and capital. Regarding the use of labor
in production, the positive but only weakly significant effects of ISO 9000 certification on the marginal product of labor may be due to difficulties in the implementation of the system (partly due to labor’s inertia and resistance to change). This seemed to be particularly the case during the initial period of the ISO certification. Regarding the utilization of capital, the ISO system produced an insignificant negative embodied shift in the production frontier. This finding can be explained by the fact that some workers did not appreciate the procedures under ISO 9000 for documenting the operation of machinery. This implicitly suggests that flexibility is the key in the real world of manufacturing; i.e. workers should be allowed a certain level of flexibility in implementing the documented procedures. The above explanations may explain some of the reasons why about 1,300 organizations in China voluntarily withdrew from the ISO 9000 system by the end of 2000 (ISO, 2003b, p. 4)[13]. It is therefore suggested that managers should send out an unambiguous signal to administrative and shop floor staff on the determination of implementing the ISO standard, and develop strategic plans to labor’s inertia and resistance to change during the transitional period. It must, however, be emphasized that these empirical results may have been partially distorted by the fact that the sample firms had a relatively short history of adoption of ISO 9000 of only four years or less. Hence, the above empirical results have to be crosschecked with firms that have a longer history of adoption of the ISO system.

Notes
1. In 2000, the ISO revised the standard and replaced the three 1994 versions (i.e. ISO 9001/2/3:1994) with ISO 9001:2000. This means that, nowadays, ISO 9001:2000 is the only certification standard in the ISO 9000 series that can be certified by a third-party accredited auditor (ISO, 2003a).
2. A common measurement of export-orientedness is the ratio of exports to sales value to account for inventory changes. However, the questionnaire did not survey the information of sales value. The gross output value is then selected as a proxy to sales value.
3. Comparing with the conventional growth accounting approach which assumes resources are used efficiently and the total factor productivity (TFP) growth can only originate from technological progress, the stochastic frontier approach decomposes TFP growth into changes in technical efficiency and technological progress (Mahadevan, 2002, p. 49). Efficiency and productivity are used interchangeably in the literature, partly because both concepts are related to a firm’s capacity to transform input to output. Dilling-Hansen et al. (2003, p. 86) argued that this is a simplistic treatment. Efficiency is a relative concept (for a firm’s input-output combination relative to the theoretical best practice) and measured by the deviation from the production frontier (output maximization), whilst productivity is measured by the slope of the production frontier. Therefore, an improvement in productivity may not equivalent to an improvement in efficiency, i.e. a rise/fall in productivity is still possible when the firm is at its most efficient level (the firm’s input-output combination moves along the production frontier).
4. A detailed discussion of the stochastic frontier can be found in Kumbhakar and Lovell (2000) and Coelli et al. (2005).
6. The value added is obtained by deducting the raw material inputs from the gross output. However, in the questionnaire survey, the sample firms did not clearly explain whether the raw materials included other intermediate inputs, such as water and energy. Hence, any
comparisons of the results of other similar studies using value added as the output value have to be made with caution.

7. There are two common problems in handling the measurement of capital stock in China. The first is that capital stock includes non-technical facilities, such as schooling and medical facilities (McGuckin et al., 1992). This is a common phenomenon in China’s state-owned and collective enterprises, which bear the responsibility for performing a social function by providing workers with welfare support. However, in the case of foreign-financed firms in China, the proportion of non-technical facilities in capital stock is negligible, as foreign-financed firms do not bear a similar responsibility. Hence, no adjustment in capital stock is needed in this regard. The second problem is that, in their method of calculating the values of fixed assets, Chinese firms adopt the perpetual inventory method by adding the investment of each year to the amount of fixed assets from the previous year, less depreciation. The capital data used in the paper were the fixed assets net of depreciation, but it only spanned a short period of three years. With the limited number of observations, the capital stock is not adjusted with respect to the second problem of the perpetual inventory method. Hence, an upward bias may have occurred in the measurement of the capital stock. The coefficient of the variable of capital would then be underestimated.

8. The firms in the dataset were from seven types of industrial sectors. Industry dummy1 equals 1 if a firm is in the food and beverage sector (three cases) and 0 otherwise. Similar definitions apply to industry dummy2 to dummy6 for the paper and printing sector (five cases), the metal products sector (four cases), the textile and clothing sector (five cases), the plastic products sector (six cases), and the electronics sector (13 cases), respectively. Firms from other sectors not specified above were grouped into the omitted industry dummy. Nonetheless, there could be considerable differences in production processes between industrial sectors. The adding of the dummy variables caters for the shifting of the intercept, but assumes the same production elasticities for each industrial sector. Under the constraint of the limited data observation, the inclusion of the industrial dummies by making such a strong assumption is considered to be the possible way for us to handle the heterogeneity in our sample firms.

9. The program FRONTIER 4.1 was written by Professor Tim Coelli. See Coelli (1996).

10. The statistic has a mixed chi-squared distribution. The critical value for the testing of the hypothesis is obtained from Kodde and Palm (1986).

11. Yeung and Mok (2005) provide a detailed explanation of how the ISO accreditation affects the competitiveness of firms in China.

12. China was formally admitted to the WTO after the country’s representative signed the treaty of accession in November 2001.

13. Another 128 organizations in China had their ISO 9000 certification withdrawn when they failed their recertification audit (ISO, 2003b, p. 4).

References


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