Human Capital and Technical Efficiency: An Analysis of the Stochastic Production Frontier and Inefficiency Effects Model for Thai Manufacturing SMEs

Yot Amornkitvikai, Rangsit University, Thailand

The Asian Conference on Business & Public Policy 2014
Official Conference Proceedings

Abstract

This study employs the 2006 manufacturing sector survey collected by the Foundation of Thailand Productivity Institute (FTPI) in collaboration with the World Bank to empirically examine the impact of human capital's characteristics such as education, tenure, and age upon the technical efficiency of Thai manufacturing SMEs including Thai manufacturers in the aggregate. The one-stage procedure introduced by Battese and Coelli (1995) is applied in this study. Focusing on Thai manufacturing SMEs, the study's results show that workers' education and in-house and outside training play a key role in enhancing SME technical efficiency. Older enterprises and unskilled workers also contribute positively to SME technical efficiency. In contrast, larger firms are likely to be significantly and negatively related to SME technical efficiency. Skilled workers' age and years of tenure are not significantly related to SME technical efficiency performance.

With respect to all Thai manufacturers, their workers' education and skilled workers' age are significantly and positively related to technical efficiency. In contrast, firm size, skilled workers' tenure, and the presence of unskilled workers are found to be significantly and negatively related to their technical efficiency. More importantly, Thai manufacturing SMEs as well as all Thai manufacturers greatly rely on labour input rather than capital input to increase their output. This result implies that over-reliance on labour results in a low-cost labour trap that exists among Thai manufacturing SMEs including all Thai manufacturers. The production of Thai manufacturing SMEs and Thai manufacturers exhibits constant returns to scale and decreasing returns to scale, respectively. They also face a moderate level of technical inefficiency. Empirically evidence-based policies and recommendations are also provided in this study.

Keywords: Thai Manufacturing SMEs, Stochastic Frontier Analysis, Technical Efficiency

1. Introduction

Small and medium-sized enterprises (SMEs) play a key role in Thailand's social and economic development (Brimble et al., 2002). Their contribution to the economy has been significant in terms of business numbers, employment, and production. The contribution of SMEs to employment has gained importance due to the employment of more than 78.8 percent of total workers over the period 2007 to 2012 (see OSMEP (2007-2012)). Manufacturing SMEs alone contribute to the economy by employing about one-third of all workers. While the share of SMEs to total business numbers has remained stable, accounting for about 99.5 percent of total enterprises during 2007-2012, the proportion of manufacturing SMEs to total SMEs and to total enterprises, both at around 28.2 percent in 2007, has dropped to around 17.7 percent and 17.4 percent in 2012, respectively (see OSMEP (2007-2012)). Nevertheless, SMEs still play significant roles and functions in assisting large enterprises, particularly in the context of regional production networks, as they help link all important units of industry and fill gaps in industrial clusters that might not be completed by large enterprises alone (Mephokee, 2003; Regnier, 2000). They also supply goods, services, information, and knowledge for large enterprises, and play a pivotal role in the production process of export goods (Tapaneeyangkul, 2001).

One prominent problem is that Thai SMEs are not fully competitive. The competitiveness of Thai industry, particularly of SMEs, has not advanced to a higher production frontier, but instead has relied greatly on low-cost labour, especially low-cost foreign labour and natural resource (raw materials) advantages rather than technological capabilities or skilled labour. The World Bank (2008) points out that with intensifying global competition and higher commodity prices, Thailand confronts a serious challenge to sustain its growth and become a higher-income country while escaping the middle income trap[1].

According to Thailand's industrial master plan (2012-2031), Thai manufacturing enterprises enjoy a comparative advantage with cheap labour and foreign direct investment without enhanced productivity. They lack (i) new technology, (ii) product and process innovation, (iii) financial access, (iv) skilled labour, (v) raw materials, (vi) high value-added production, and (vii) managerial skills (Ministry of Industry, 2012). More importantly, Thailand's labour productivity growth rate has fallen considerably, from 5.9 percent to 2.1 percent between 2005 and 2010. Similarly, total factor productivity growth declined from 3.6 percent during 1975-1990 to 3.2 between 2005 and 2010 (APO, 2013). The lack of a large, skilled workforce can worsen Thailand's problem of insufficient human capital, which eventually will constrain production efficiency. At present, Thailand is in a difficult competitive position as it cannot continue to depend on cheap labour due to recent increases in the minimum wage; therefore, it must move up the technology hierarchy and improve the efficiency and productivity of its enterprises. Education and employee training, therefore, increasingly become important sources for the development of Thailand's productivity and efficiency, since the shortage of engineers and skilled technical workers can obstruct future productivity growth as critiqued in Liefner and Schiller (2008) and OECD (2013).

---

[1] Thailand had moved rapidly from a low-income country to a middle-income country from the 1970s to mid-1990s due to rapid growth in per capita income. However, in recent years its real GDP growth has slowed and has been lower than that of other developing countries in East Asia (World Bank Office-Thailand, 2008, p. 4).

To address these problems, this paper addresses the following research questions: How do Thai manufacturing SMEs, including Thai manufacturers in the aggregate, perform in terms of technical efficiency? Which of the following characteristics of human capital factors, such as workers' education, age, and tenure, can influence the technical efficiency performance of Thai manufacturing SMEs as well as all Thai manufacturers? How can the technical efficiency of Thai manufacturing SMEs, including Thai manufacturers in the aggregate, be enhanced?

Little research has been conducted, with the exception of, for example, Charoenrat et al. (2013), on the competitiveness and efficiency of Thai SMEs. No empirical study, however, has examined the importance of human capital on efficiency, such as i) skilled workers' years of education as well as education levels of the workforce, ii) skilled workers' years of tenure, iii) skilled workers' age, and iv) unskilled foreign workers, as well as v) in-house and outside training for workers. This study's key objectives are to rectify this gap. To establish a basic understanding relating to the sources of firm performance, a review of the empirical literature will be discussed in Section 2.

2. A review of literature

This section provides a review of the literature regarding the effects of employees' characteristics and firm-specific factors on firm performance.

2.1 Workers' characteristics and firm performance

Human capital has been known as an important factor in a firm's effectiveness, which can be acquired through i) formal education, ii) general vocational training, and iii) knowledge and skilled specific to the firm through accumulating experience in the focal firm and firm-specific training (Yanadori and Kato, 2007). A number of empirical studies have examined the association between firm performance and employees' characteristics as follows:

2.1.1 Workers' education

Education is often used as a proxy for human capital in the literature, such as in Grund and Westergard-Nielsen (2005); Batra and Tan (2003); Batra and Tan (2003) use cross-sectional surveys for six economies (Columbia, Guatemala, Indonesia, Malaysia, Mexico, and Taiwan) to investigate the factors affecting SME efficiency. Their results reveal that higher educational levels among SME workers is associated with higher efficiency across all six economies. Employing panel data of 400 Greek manufacturing firms in 2004, 2006, and 2008, Magoutas et al. (2012) find that human capital, measured by the number of employees with university degrees as a ratio to total employment, has a significant and positive impact on the growth rates of firms. In contrast, Grund and Westergaard-Nielsen (2005) find a negative and significant association between workers' education and firm performance in Danish enterprises.

2.1.2 Workers' tenure

Another workforce characteristic is the tenure of employees, which can contribute significantly to firm performance. At an organization, a firm's average employee tenure captures the stock of firm-specific human capital its workers have obtained. As a result, longer average employee tenure will result in greater firm-specific human capital, leading to better organizational effectiveness (Yanadori and Kato, 2007). A number of empirical studies have investigated the association between employee tenure and firm performance. For instance, Yanadori and Kato (2007) employ data from Japanese firms and find that average employee tenure is significantly and positively related to labour productivity. In contrast, Grund and Westergaard-Nielsen (2005) find mixed results regarding the effects of mean employee tenure on firm performance as measured by value added per employee in Danish firms.

2.1.3 Workers' age

Workforce age plays an important role in determining firm performance. A number of empirical studies have examined the relationship between workers' age and firm performance (Lallemand and Ryck (2009); Grund and Westergaard-Nielsen (2005)). For example, Lallemand and Ryck (2009) use the Structure of Earnings Survey (SES) and Structure of Business Survey from 1995 to 2003 to investigate the workforce age structure on the productivity of large Belgian firms. They find that younger employees are significantly more productive than older employees, and age-structure effects on productivity have substantially decreased over time. Grund and Westergard-Nielsen (2005) employ unbalanced panel data from the Integrated Database for Labour Market Research (IDA) and Statistics Denmark for Center for Corporate Performance during the period 1992-1997. They reveal that both mean age and dispersion of age in firms are inversely u-shaped related to firm performance, implying that younger workers are more likely than older workers to contribute positively to firm performance, but after a certain threshold the workers' mean age has a significant and negative effect on firm performance as measured by value added per employee.

2.1.4 Employee training

Employee training is a human resource management practice that can help firms enhance human capital, leading to performance improvement because employees' knowledge, skills, and abilities can be developed, and the motivation and commitment to their organization's tasks can be increased through employee training programs (Huang et al., 2012). The researchers employ data from Chinese manufacturing firms in 2010 and 2011 and find that employee training may have a positive direct effect on a firm's performance in sustainable development. Nikandrou et al. (2008) use the 1999 Cranet survey to investigate the association between training and development and performance of 5,189 organizations in 14 European countries. The results reveal that employee training and development is very important to European organizations due to the demand for new and increasingly higher skill levels, increased international competition, and rapid changes in technology and organizational structures. Batra and Tan (2003) also find that skilled worker training is significantly related positively to the technical efficiency of SMEs in Columbia, Guatemala, Indonesia, Malaysia, and Mexico.

2.2 Firm age

Firm age can be related significantly to firm efficiency, since older enterprises learn from past mistakes through the learning-by-doing process and improve managerial skills from accumulated experience (Charoenrat et al., 2013). A number of empirical studies have also examined the association between a firm's age and its performance as measured by efficiency (Charoenrat et al. (2013); Tran et al. (2008); Le and Harvie (2010); Burki and Terrell (1998)). Charoenrat et al. (2013) reveal mixed findings between firm age and technical efficiency in Thai manufacturing SMEs. Similarly, Tran et al. (2003) find mixed results between firm age and technical efficiency in the case of non-state manufacturing industries in Viet Nam. Burki and Terrell (1998) employ two-stage Data Envelopment Analysis to examine factors that impact the efficiency of 153 Pakistani small manufacturing firms. They suggest that firm age has a significant and positive effect on efficiency. However, Tran et al. (2008) utilize firm-level data in Vietnam in 1996 and 2001 and find that firm age has an insignificant and negative effect on firm technical efficiency, suggesting no evidence of a "learning by doing" experience. Similarly, Le and Harvie (2010) employ large surveys of domestic non-state manufacturing SMEs in 2002, 2005, and 2007 to investigate the technical efficiency performance in Vietnam, and find that older manufacturing SMEs are likely to be technically inefficient[2].

2.3 Firm size

Firm size can contribute significantly to efficiency due to the economies of scale and scope of larger enterprises (Charoenrat et al., 2013). Several empirical studies have explored the effects of firm size and age on efficiency (Charoenrat et al. (2013); Le and Harvie (2010); Kim (2003); Alvarez and Crespi (2003)). With respect to the effect of firm size on technical efficiency, empirical results are still ambiguous depending on country and sector analysed. For instance, Charoenrat et al. (2013) employ cross-sectional data from the 2007 manufacturing census to examine the significant factors of SME technical efficiency. They reveal that firm size is significantly and positively related to SME technical efficiency. Similarly, Kim (2003) finds that firm size has a significant and positive association with the technical efficiency of Korean manufacturing industries. Alvarez and Crespi (2003) suggest that larger enterprises are more efficient than smaller enterprises among 1,091 Chilean manufacturing small enterprises since small enterprises are likely to face the following challenges: (i) difficulty in accessing external loans for investments, (ii) lack of efficient resources (e.g., human capital), (iii) lack of economies of scale, and (iv) lack of formal contracts with customers and suppliers. An empirical study of Vietnamese SMEs by Le and Harvie (2010) suggest that larger Vietnamese manufacturing SMEs are likely to be technically inefficient compared with small ones. They also explain that small enterprises are more efficient due to flexibility in diversifying and adjusting their businesses and activities in a rapidly changing economy in transition.

[2] Due to the SMEs using old technology or their existence in an environment lacking competition and where state ownership dominates.

2.4 Foreign unskilled labour

Industrialization is likely to lead to an increase in demand for a country's foreign labour; therefore, foreign labour tends to affect the domestic labour market and productivity. A number of empirical studies have examined the correlation between foreign workers and productivity, such as Noor et al. (2011), Llull (2008) and Peri (2009). Llull (2008) also suggests that immigration has a significant and negative impact on productivity, but a positive effect on labour participation and employment in OECD countries. Peri (2009) reveals no evidence across U.S. states that migrants crowd out domestic employment, but they help promote efficient task specialization that increases the total factor of production. Noor et al. (2011) points out that foreign labour is positively and significantly associated with labour productivity in the Malaysian manufacturing sector.

All of these sources, which may be related to firm efficiency, will be empirically examined with an analysis of the stochastic frontier production and inefficiency effects model in this study, as discussed in the following section.

3. Methodology

A firm's performance can be measured by several criteria such as financial performance, efficiency, productivity, growth, employment, exports, and market share. As its measurement gauge, however, this paper employs technical efficiency, which will be discussed as follows:

3.1 Concept of technical efficiency

Technical efficiency is defined as the capacity and ability of a firm to produce at the maximum possible output from a given bundle of inputs and technology. For instance, a firm can operate at its optimal scale (technically efficient point) if its operation is on the production frontier, which can be at points A and B as shown in Figure 1. Nevertheless, this technically efficient concept differs from allocative efficiency, which refers to a firm's ability and willingness to equate its marginal revenue with marginal cost (Kalirajan and Shand, 1999). More importantly, productivity and efficiency, both frequently mentioned in the literature, differ conceptually. "Productivity" basically refers to "total factor productivity", which is defined as the ratio of total outputs over total inputs (Coelli et al., 2005). A technically inefficient firm's operation is beneath the production frontier at point C, since it can obtain the same level of output at point B without requiring greater input (Figure 1) (Coelli et al., 2005). Technical efficiency can be predicted by employing the stochastic frontier production, which was independently proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) within a cross-sectional context. This methodology will be discussed in more detail in Section 3.2.

3.2 The stochastic frontier production and Inefficiency Effects Model

This study applies the one-stage process suggested by Battese and Coelli (1995). They presented a model in which the stochastic frontier production and inefficiency effects model are estimated simultaneously in the context of panel data. Inefficiency effects are stochastic and the model allows for the estimation of both technical change in the stochastic frontier and time-varying technical inefficiencies. Their model can be expressed in general form as follows:

$$Y_{it} = X_{it}\beta + V_{it} - U_{it} \quad ,i = 1,...,N, t=1,...,T, \qquad (1)$$

where

Y_{it} is the production (or the logarithm of the production) of the i[th] firm in the t[th] time period;

X_{it} is a k×1 vector of (transformations of the) input quantities of the i[th] firm in the t[th] time period;

β is a vector of unknown parameters;

V_{it} are random variables assumed to be identically and independently distributed (iid) $N(0,\sigma_v^2)$ and independent of the U_{it}

U_{it} are non-negative random variables that are assumed to account for technical inefficiency in production and to be independently distributed as truncations at zero of the $N(Z_{it}\delta, \sigma_u^2)$ distribution; where the inefficiency effects, U_{it} in the stochastic frontier production can be specified as follows:

$$U_{it} = Z_{it}\delta + W_{it} \qquad (2)$$

where z_{it} is a p×1 vector of variables that may affect a firm's inefficiency; and
δ is an 1×p vector of parameters to be estimated; and
W_{it} is defined by the truncation of the normal distribution with zero mean and variance, σ^2, such that the point of truncation is $z_{it}\delta$ (e.g., $w_{it} \geq - z_{it}\delta$).

This model uses the parameterisation from Battese and Corra (1977), replacing σ_v^2 and σ_u^2 with $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/\sigma^2$. In the model, the technical efficiencies of production can be predicted using the conditional expectations of exp ($-u_{it}$), given the composed error term of the stochastic frontier. Hence, given the above assumptions, the technical efficiency of the i[th] firm can be defined as follows:

$$TE_{it} = \exp(-u_{it}) = \exp(-Z_{it}\delta - W_{it}) \qquad (3)$$

The value of technical efficiency (TE_i) ranges between zero and one. Y_i achieves its maximum feasible output if and only if $TE_i = 1$. $TE_i < 1$ illustrates a measure of the shortfall of observed output from maximum feasible output. The original specification as indicated in equation (1) can also be represented as the log-linear Cobb-Douglas stochastic frontier model version in the context of cross-sectional data, which consists of three main components: (i) a deterministic component, (ii) a noise effect, and (iii) an inefficiency effect (Coelli et al., 2005, p. 243).

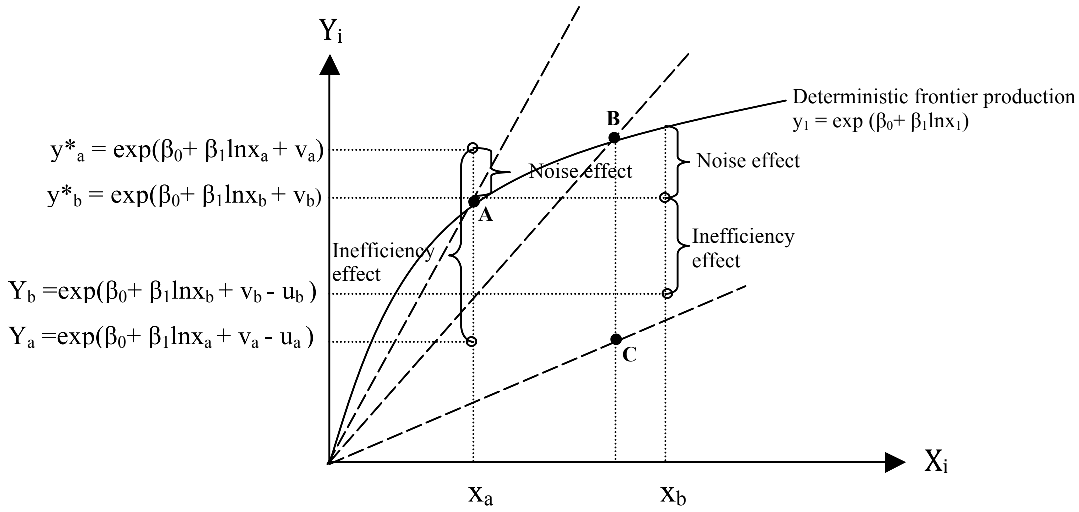
$$\ln y_i = \beta_0 + \beta_1 \ln x_i + v_i - u_i \qquad (4)$$

$$y_i = \exp(\beta_0 + \beta_1 \ln x_i + v_i - u_i)$$

$$y_i = \underbrace{\exp(\beta_0 + \beta_1 \ln x_i)}_{\text{Deterministic Component}} \times \underbrace{\exp(v_i)}_{\text{Noise}} \times \underbrace{\exp(-u_i)}_{\text{Inefficiency}}$$

Stochastic frontier analysis can be explained graphically, as shown in Figure 1.

Figure 1: The stochastic frontier production



Source: Adapted from Coelli et al. (2005, p. 244)

From Figure 1, it is assumed that there are two firms: firm A uses input x_a to produce production $y_{a.}$, while firm B uses input x_b to produce production y_b. If the inefficiency effects of firms A and B are zero ($u_a = 0$ and $u_b = 0$), their (unobserved) outputs would be at y^*_a and y^*_b, respectively. The firms differ in that firm A's (unobserved) frontier production lies above the deterministic frontier, since its "noise effect" (v_a) is positive, while firm B's (unobserved) frontier production lies within the deterministic frontier due to its negative "noise effect" (v_b). Therefore, unobserved frontier productions are likely to lie either above or below the deterministic frontier. However, the observed frontier productions tend to lie below the deterministic frontier[3].

As a result, the Battese and Coelli (1995) model can be applied in the context of cross-sectional data for this study. More specifically, this study uses the method of maximum likelihood (ML), which is preferred to other estimators (e.g., corrected ordinary least squares (COLS) and ordinary least squares (OLS[4])) since ML estimators have asymptotic properties that are desirable for large samples (Coelli et al., 2005, p. 245). Therefore, the Battese and Coelli (2005) model can be estimated here with a set of identified variables to be discussed in the following section:

[3] For example, Firm A lies above the deterministic frontier since the "noise effect" is positive and greater than the inefficiency effect.

[4] Coelli et al. (2005) also argue that the slope estimators obtained from ordinary least squares (OLS) are consistent, but the intercept estimator is biased downwards. Technical efficiency, therefore, cannot be predicted by using OLS.

4. Empirical model

Applying the model of Battese and Coelli (1995), the Cobb-Douglas functional form employed in this paper can be written as:

$$Ln(Y_i) = \beta_0 + \beta_1 ln(K_i) + \beta_2 ln(L_i) + V_i - U_i \qquad (5)$$

Where:

Y_i = Value added of the i^{th} firm

K_i = Total fixed assets of the i^{th} firm

L_i = Total wages and salaries of the i^{th} firm

V_i = Random error ($V_i \sim N(0, \sigma_v^2)$)

U_i = Non-negative random variable (or technical inefficiency) ($U_i \sim N(Z_i\delta, \sigma_u^2)$)

The Inefficiency Effects Model can be written as follows:

$$U_i = \sigma_0 + \sigma_1 Skilled\_edu_i + \sigma_2 Skilled\_tenure_i + \sigma_3 Skilled\_age_i + \sigma_4 Workforce\_edu_i + \sigma_5 Employees\_training_i + \sigma_6 Firm\_size_i + \sigma_7 Firm\_age_i + \sigma_8 Unskilled\_foreign_i + W_i \qquad (6)$$

Where:

$Skilled\_edu_i$= Average number of years of skilled production workers' education in firm *i*;

$Skilled\_tenure_i$ = Average number of years of skilled production workers' tenure;

$Skilled\_age_i$ = Average age of skilled production workers in firm *i;*

$Workforce\_edu_i$= The percentage of workforce in firm i with at least university-level education;

$Employees\_training_i$ = Dummy for in-house and formal outside training;
$Employees\_training_i$ = 1 if firm *i* provides in-house and formal outside training for employees.
= 0, otherwise

$Firm\_size_i$ = Firm size of firm *i*, represented by total number of workers;

$Firm\_age_i$ = Firm age of firm *i*;

$Unskilled\_foreign_i$ = The percentage of foreign unskilled workers of firm *i*;

W_i= Random error ($W_i \sim N(0, \sigma_w^2)$)

5. Data source and data classification

This study utilizes the 2006 Enterprise Survey (Manufacturing Sector Survey) for Thailand collected by the Foundation of Thailand Productivity Institute (FTPI) in collaboration with the World Bank. This survey was conducted by interviewing business owners and top managers of 1,043 firms. According to a number of missing data in the survey as well as the negative values of value-added output, capital input, and labour input in the natural logarithm form of the stochastic production function, 121 firms are excluded from the sample. Finally, 922 firms are used to conduct this study's empirical analysis. For the classification of Thai manufacturing SMEs, an enterprise that either employs fewer than 50 workers or has fixed assets with a value not exceeding 50 million baht is considered to be a small enterprise. Furthermore, an enterprise that either employs between 51 and 200 workers or has fixed assets with a value between 51 and 200 million baht is defined as a medium-sized enterprise. With respect to these criteria, enterprises that have 200 or fewer workers are selected as SMEs for this study. As a result, 643 enterprises are defined as SMEs.

More importantly, the questionnaire administered to the CEOs, general managers, and business owners makes this survey more useful than the 2007 Thai Industrial Census conducted by the National Statistical Office of Thailand; that census does not provide, for example, personal data regarding human capital stock such as average number of years of workers' education, tenure, and age as well as the percentage of foreign unskilled workers. The use of the 2006 Enterprise Survey (Manufacturing Sector Survey) for Thailand with the analysis of stochastic production frontier and inefficiency effects model as explained in Sections 3 and 4 can provide the empirical results in Section 6.2. However, hypothesis tests of the stochastic frontier model and inefficiency effects are crucial to investigate the existence of inefficiency effects model and stochastic inefficiency effects that will be shown in the following section (Section 6.1).

6. Hypothesis tests and empirical results

6.1 Hypothesis tests of the stochastic frontier model and inefficiency effects model

With respect to Equations (5) and (6), two null hypothesis tests are required: (i) the absence of inefficiency effects and (ii) the absence of stochastic inefficiency effects (see Table 1). A likelihood-ratio test (LR test) is used to test these hypotheses as follows:

$$\lambda = -2\{\log[L(H_0)] - \log[L(H_1)]\} \tag{7}$$

where, $\log[L(H_0)]$ and $\log[L(H_1)]$ are obtained from the maximized values of the log-likelihood function under the null hypothesis (H_0) and the alternative hypothesis (H_1), respectively. The LR test statistic has an asymptotic chi-square distribution with parameters equal to the number of restricted parameters imposed under the null hypothesis.

From Table 1, the null hypothesis (i), which specifies that the inefficiency effects are excluded from the model (H_0: $\gamma = \delta_0 = \dots = \delta_8 = 0$), is strongly rejected at the one-percent level of significance, since the LR statistic test is greater than the critical value of approximately chi-square distribution at the one-percent level of significance. This result suggests that the model of inefficiency effects exists in Thai manufacturing SMEs as well as in all Thai manufacturing enterprises. Moreover, the estimates for the variance parameter γ in Tables 2 and 3 are 0.86690 and 0.90877, respectively, which is close to one and suggests that the inefficiency effects are likely to be highly significant in the analysis for the value of production inefficiency among Thai SMEs including all Thai manufacturing enterprises (see Battese and Coelli (1995)).

Table 1: Statistics for Hypothesis Tests of the Stochastic Frontier Model and Inefficiency Effects Model

	Thai manufacturing Enterprises	**Thai manufacturing SMEs**
Null Hypothesis **(i) No technical inefficiency Effects (H_0: $\gamma = \delta_0 = \dots = \delta_8 = 0$)**		
Critical Value	22.53*	22.53*
Decision	Reject	Reject
Null Hypothesis **(ii) Non stochastic Inefficiency (H_0: $\gamma = 0$)**		
LR Statistics	20.29	10.90
Critical Value	5.41*	5.41*
Decision	Reject	Reject

Note: All critical values of the test statistic in Hypotheses (i) and (ii) indicated by * are presented at the 1% level of significance, which contains a mixture of a chi-square distributions obtained from Table 1 of Kodde and Palm (1986).

The null hypothesis (ii) that the inefficiency effects are not stochastic ($\gamma = 0$) is strongly rejected for Thai manufacturing SMEs as well as for all Thai manufacturing enterprises. The rejection of this hypothesis implies that the model of inefficiency effects is not reduced to a traditional mean response function since the variance of the inefficiency effects is not zero (see Battese and Coelli, (1995)). In other words, all the explanatory variables in the inefficiency effects model are not included in the production function in this study, suggesting that the inefficiency effects model is applicable, and therefore the estimated parameters can be identified in the model of inefficiency effects.

6.2 Empirical results

According to Tables 2 and 3, the significant and negative results regarding the effects of employee education as represented by skilled workers' years of education and education levels of the workforce on firm technical inefficiency indicate that employee education plays an important role in enhancing the technical efficiency of Thai manufacturing SMEs including all Thai manufacturers. These results are also consistent with a number of studies that were discussed in Section 2, such as Batra and Tan (2003) and Magoutas et al. (2012), implying that educated workers are more proficient at learning and responding to new information and technology. In addition, education is a significant discriminant of efficient and inefficient firms as suggested by Batra and Tan (2003).

Similarly, the significant and negative estimated coefficient of in-house and outside training for workers at Thai manufacturing SMEs indicates that in-house and outside training play a key role in enhancing technical efficiency, since it can help Thai SMEs develop their human capital, leading to the enhancement of SME performance as suggested by Huang et al. (2012). These results are consistent with the findings of Huang et al. (2012), Nikandrou et al. (2008), and Batra and Tan (2003). However, a significant result of in-house and outside employee training is not found in the case of all Thai manufacturers.

In addition, skilled workers' age is significantly and positively related to the technical efficiency of Thai manufacturing enterprises in the aggregate, suggesting that older employees may accumulate work experience, which helps increase firm efficiency. This result, however, differs from the results of other empirical studies such as Lallemand and Ryck (2009) and Grund and Westergaard-Nielsen (2005). This might be due to cultural differences in human resource management practices; for instance, seniority plays a predominant role in many Thai enterprises. An insignificant result of skilled workers' age is found among Thai manufacturing SMEs.

Skilled workers' tenure has a significant and negative effect on the technical efficiency of Thai manufacturers in the aggregate, but an insignificant finding is found among Thai SMEs. The significant and negative result implies that employee tenure does not capture the stock of firm-specific human capital its workers have obtained, and therefore does not lead to better organizational effectiveness. This finding in the study contradicts other results, such as those from Yandori and Kato (2007) and Grund and Westergaard-Nielsen (2005).

Firm age is significantly and positively related to the technical efficiency of Thai manufacturing SMEs, indicating that older firms learn from past mistakes through the learning-by-doing process and improve managerial skills from accumulated experience. This finding is similar to the empirical results of Burki and Terrell (1998). An insignificant result of firm age, however, is found for Thai manufacturers in the aggregate. Firm size is significantly and negatively related to the technical efficiency of Thai manufacturing SMEs including all manufacturers, implying that larger firms do not gain benefits from economies of scale and scope. This finding is consistent with the findings of Le and Harvie (2010) that suggest small enterprises are more efficient due to flexibility in diversifying and adjusting their businesses and activities in a rapidly changing economy in transition. Unskilled foreign workers contribute positively to the technical efficiency of Thai manufacturing SMEs, but a significant and negative result is found among all Thai manufacturers. This result implies that Thai manufacturing SMEs benefit from hiring inexpensive foreign unskilled labour due to a reduction in production costs.

Table 2: Stochastic Production Frontier and Inefficiency Effects Model for Thai Manufacturing SMEs

	Coefficient	standard-error	t-ratio
Stochastic Production Frontier			
Dependent variable: $Ln(Y_i)$			
Constant	0.48298	(0.54411)	0.88765
$Ln(K_i)$	0.18991	(0.02142)	8.86607*
$Ln\ (L_i)$	0.81245	(0.04322)	18.79583*
Inefficiency effects model			
Dependent variable: U_i			
Constant	-3.09868	(1.50539)	-2.05838*
$Skilled\_edu_i$	-0.11519	(0.04650)	-2.47709*
$Skilled\_tenure_i$	-0.02788	(0.02289)	-1.21807
$Skilled\_age_i$	0.03401	(0.02404)	1.41441
$Workforce\_edu_i$	-0.04273	(0.01253)	-3.40923*
$Employees\_training_i$	-0.66130	(0.31385)	-2.10704*
$Firm\_size_i$	0.00790	(0.00347)	2.27792*
$Firm\_age_i$	-0.14219	(0.04399)	-3.23191*
$Unskilled\_foreign_i$	-0.07034	(0.02578)	-2.72825*
sigma-squared (σ^2)	3.51850	(0.73918)	4.76001*
Gamma (γ)	0.86690	(0.03252)	26.66073*

Note: Standard errors are in brackets; * and ** indicate that the coefficients are statistically significant at 5% and 10%, respectively.

Table 3: Stochastic Production Frontier and Inefficiency Effects Model for Thai Manufacturing Enterprises

	Coefficient	standard-error	t-ratio
Stochastic Production Frontier			
Dependent variable: $Ln(Y_i)$			
Constant	1.52565	(0.32374)	4.71257*
$Ln(K_i)$	0.23596	(0.01887)	12.50673*
$Ln (L_i)$	0.69980	(0.03075)	22.75518*
Inefficiency effects model			
Dependent variable: U_i			
Constant	-2.33592	(1.82367)	-1.28089
$Skilled\_edu_i$	-0.31332	(0.09461)	-3.31157*
$Skilled\_tenure_i$	0.04840	(0.01955)	2.47600*
$Skilled\_age_i$	-0.04872	(0.02060)	-2.36560*
$Workforce\_edu_i$	-0.09441	(0.02533)	-3.72650*
$Employees\_training_i$	0.24791	(0.30529)	0.81205
$Firm\_size_i$	0.00053	(0.00026)	2.01552*
$Firm\_age_i$	0.00627	(0.01078)	0.58141
$Unskilled\_foreign_i$	0.01276	(0.00662)	1.92758**
sigma-squared (σ^2)	5.24906	(1.40442)	3.73753*
Gamma (γ)	0.90877	(0.02548)	35.66426*

Note: Standard errors are in brackets; * and ** indicate that the coefficients are statistically significant at 5% and 10%, respectively.

The weighted average technical efficiency of Thai manufacturing SMEs and Thai manufacturers in the aggregate are approximately 68.62 percent and 65.81 percent, respectively, signifying a moderate level of technical inefficiency that is reducing potential output. According to the sum of significantly estimated coefficients of capital and labour inputs as shown in Tables 2 and 3, the production of Thai manufacturing SMEs is under constant returns to scale (1.00236), but the production of all Thai manufacturing firms face decreasing returns to scale (0.93576). In addition, their production relies greatly on labour input rather than capital input.

7. Conclusion and policy implications

This study employs the 2006 manufacturing sector survey collected by the Foundation of Thailand Productivity Institute (FTPI) in collaboration with the World Bank to empirically examine the significant importance of human capital characteristics, such as skilled workers' education, tenure, and age as well as the presence of unskilled foreign workers on the technical efficiency performance of Thai manufacturing SMEs including Thai manufacturers in the aggregate. The effects of other determinants, such as i) firm size and ii) firm age on firm technical efficiency, are also investigated. This study applied the one-stage procedure introduced by Battese and Coelli (1995).

The study's results indicate that skilled employees who attain more years of education, workers' education to at least a bachelor's level, and in-house and outside training play a key role in promoting the technical efficiency of Thai manufacturing SMEs. Government policies that focus on enhancing employee knowledge and training should be implemented to increase SME efficiency. More importantly, linkages between educational institutions and industry in Thailand should be encouraged to promote a skilled labour supply in specific sectors. Older SMEs contribute positively to their technical efficiency. Young SMEs, therefore, should be given first priority for government assistance through financial and non-financial support. Unskilled foreign workers contribute positively to SME technical efficiency. Enhancing the skills of workers, especially of foreign unskilled workers through education and job training programs, is important to increase SME production efficiency. Nevertheless, larger SMEs are likely to have less technical efficiency or face diseconomies of scale in the long run. Government policies, therefore, might encourage those large SMEs to establish new subsidiaries in order to optimize efficiency in the long run. Skilled workers' age and years of tenure are insignificantly related to SME technical efficiency.

Focusing on Thai manufacturing enterprises in the aggregate, skilled workers who attain more years in education, employees with at least a bachelor's degree, and older skilled workers tend to contribute negatively to technical efficiency. In addition, larger Thai manufacturing enterprises do not gain benefits from economies of scale and scope, while the tenure of skilled workers and the employment of unskilled workers do not enhance a firm's technical efficiency. This study also reveals that Thai manufacturing SMEs as well as all Thai manufacturers basically rely on labour input rather than capital input to increase output. This result implies that over-reliance on labour, resulting in a low-cost labour trap, exists among Thai manufacturing SMEs including all Thai manufacturers. The production of Thai manufacturing SMEs including all Thai manufacturers also exhibits constant returns to scale and decreasing returns to scale, respectively. Finally, they all face a moderate level of technical inefficiency. Consequently, specific policies are required for Thai manufacturing SMEs including all Thai manufacturers, such as i) enhancement of input efficiencies (e.g., more skilled labour) to be able to move toward their most efficient production frontier given current technology, and ii) utilization of improved technology that helps shift their current frontier outward. In other words, upgrading technology helps them to develop the value chain while avoiding labour-intensive production and the low value-added trap in their production as suggested by Le and Harvie (2010).

8. References

Aigner, D., Lovell, C.A.K., & Schmidt, P.Z. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics*, *6*(1), 21-37.

Alvarez, R. & Crespi, G. (2003). Determinants of Technical Efficiency in Small Firms. *Small Business Economics*, *20* (1), 233-244.

APO. (2013). *APO Productivity Databook*. Tokyo: Asian Productivity Organization. Retrieved November 1, 2014, from http://www.apotokyo.org/publications/files/APO_Productivity_Databook_2013.pdf

Battese, G.E. & Coelli, T.J. (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. *Empirical Economics*, *20* (2), 325-332.

Battese, G.E. & Corra, G.S. (1977). Estimation of a Production Frontier Model: With Application to the Pastoral Zone of Eastern Australia. *Australian Journal of Agricultural Economics*, *21* (3), 19-179.

Batra, G. & Tan, H. (2003). *SME Technical Efficiency and Its Correlates: Cross-Natioinal Evidence and Policy Implications* (World Bank Institute Working Paper). Washington D.C.: Work Bank. Retrieved November 1, 2014, from http://info.worldbank.org/etools/docs/library/74068/china/readings/oct30/tan30engl.pdf

Brimble, P., Oldfield, D., & Monsakul, M. (2002). Policies for SME recovery in Thailand. In Harvie, C. and Lee, B.C. (Eds.), *The role of SMEs in National Economies in East Asia*. Cheltenham: Edward Elgar.

Burki, A. & Terrell, D. (1998). Measuring Production Efficiency of Small Firms in Pakistan. *World Development*, *26*(1), 155-169.

Charoenrat, T., Harvie, C., & Amornkitvikai, Y. (2013). Thai Manufacturing Small and Medium Sized Enterprise Technical Efficiency: Evidence from Firm-Level Industrial Census Data. *Journal of Asian Economics*, *27*, 42-56.

Coelli, T.J., Rao, D.S.P., O'Donnell, C.J., & Battese, G.E. (2005). *An Introduction to Efficiency and Productivity Analysis* (2nd ed.). New York, USA: Springer.

Grund, C., & Westergaard-Nielsen, N. (2008). Age Structure of the Workforce and Firm Performance. *International Journal of Manpower*, *29*(5), 410-422.

Kalirajan, K.P. & Shand, R.T. (1999). Frontier Production Functions and Technical Efficiency Measures. *Journal of Economic Surveys*, *13*(2), 149-172.

Kim, S. (2003). Identifying and Estimating Sources of Technical Inefficiency in Korean Manufacturing Industries. *Contemporary Economic Policy*, *21* (1), 132-144.

Kodde, D. & Palm, F. (1986). Wald criteria for jointly testing equality and inequality restrictions. *Econometrica*, *54* (1), 1243-1248.

Lallemand, T. & Rycx, F. (2009). Wald criteria for jointly testing equality and inequality restrictions. *De Economist*, *157* (1), 273-292.

Le, V. & Harvie, C. (2010). How do Vietnamese SMEs perform? Technical Efficiency of SMEs in the Manufacturing Sector and Its Sub-Sectors. In *Korea and the World Economy, IX Conference* (pp. 1-37). University of Incheon, Korea: The Association of Korean Economic Studies. Retrieved October 25, 2014, from http://ro.uow.edu.au/cgi/viewcontent.cgi?article=3243&context=commpapers

Liefner, I. & Schiller, D. (2008). Academic Capabilities in Developing Countries - A Conceptual Framework with Empirical Illustrations from Thailand, *Research Policy*, *37* (2), 276-293.

Llull, J. (2008). *The Impact of Immigration on Productivity* (CEMFI Working Paper No. 0802). Madrid: Center for Monetary and Financial Studies. Retrieved October 15, 2014, from ftp://ftp.cemfi.es/wp/08/0802.pdf

Magoutas, A., Papadogonas, T.A., & Sfakianakis, G. (2012). Market Structure, Education and Growth. *International Journal of Business and Social Science*, *3* (12), 88-95.

Mephokee, C. (2003). *The Thai SMEs Development Policies: Country Report*. Bangkok: Thammasat University.

Ministry of Industry (2012). *National Industry Development Master Plan (2012-2031)*. Retrieved October 17, 2014, from the Ministry of Industry website:http://www.oie.go.th/sites/default/files/attachments/industry_plan/National_Industrial_Development_Master_Plan.pdf

Noor, Z., Isa, N., & Jalil, S. (2011). The Impact of Foreign Workers on Labour Productivity in Malaysian Manufacturing Sector. *International Journal of Economics and Management*, *5* (1), 169-178.

OECD (2013). *OECD Reviews of Innovation Policy: Innovation in Southeast Asia* (Research Report). Retrieved 14 April, 2014, from Orgnaization for Economic Cooperation and Development website: http://www.oecd-ilibrary.org/science-and-technology/innovation-in-southeast-asia-2012_9789264128712-en

OSMEP (2007). *The 2nd SMEs Promotion Plan (2007-2011).* Retrieved April 16, 2014, from Office of Small and Medium Sized Enterprises Promotion website: http://eng.sme.go.th/SiteCollectionDocuments/SMEs%20Promotion%20Plan/SME-Master-Plan-2.pdf

OSMEP (2012). *The White Paper on Small and Medium Enterprises of Thailand in 2011 and 2012*. Retrieved April 17, 2014, from Office of Small and Medium Enterprises Promotion website: http://www.sme.go.th/Lists/EditorInput/DispForm.aspx?ID=1865

OSMEP (2010). *The White Paper on Small and Medium Enterprises of Thailand in 2010 and Trends 2011*. Retrieved April 17, 2014, from Office of Small and Medium Enterprises Promotion website: http://www.sme.go.th/Lists/EditorInput/DispF.aspx?List=15dca7fb%2Dbf2e%2D464e%2D97e5%2D440321040570&ID=1430

OSMEP (2009). *The White Paper on Small and Medium Enterprises of Thailand in 2009 and Trends 2010*. Retrieved April 17, 2014, from Office of Small and Medium Enterprises Promotion website:

http://www.sme.go.th/Lists/EditorInput/DispF.aspx?List=15dca7fb%2Dbf2e%2D464e%2D97e5%2D440321040570&ID=664

OSMEP (2008). *The White Paper on Small and Medium Enterprises of Thailand in 2008 and Trends 2009*. Retrieved April 17, 2014, from Office of Small and Medium Enterprises Promotion website:
http://www.sme.go.th/Lists/EditorInput/DispF.aspx?List=15dca7fb%2Dbf2e%2D464e%2D97e5%2D440321040570&ID=11

OSMEP (2007). *The White Paper on Small and Medium Enterprises of Thailand in 2007 and Trends 2008*. Retrieved April 17, 2014, from Office of Small and Medium Enterprises Promotion website:
http://www.sme.go.th/Lists/EditorInput/DispF.aspx?List=15dca7fb%2Dbf2e%2D464e%2D97e5%2D440321040570&ID=10

Peri, G. (2009). *The Effect of Immigration on Productivity: Evidence from US States* (NBER Working Paper 15507). Cambridge, MA: National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w15507.pdf

Regnier, P. (2000). *Small and medium enterprises in distress: Thailand, the East Asian crisis and beyond*, Burlington: Ashgate Publishing.

Tapaneeyangkul, P. (2001). *Government Policies in Assisting SMEs for Sustainable development*. Bangkok: The Office of Small and Medium Enterprise Promotion.

Tran, T., Grafton, R. & Kompas, T. (2008). Firm Efficiency in a Transitional Economy: Evidence from Vietnam. *Asian Economic Journal, 22* (1), 47-66.

World Bank-Thailand (2008). *Thailand Economic Monitor April 2008* (Research Report). Retrieved from the Word Bank website:
http://siteresources.worldbank.org/INTTHAILAND/Resources/Economic-Monitor/TEM-April-2008.pdf

Contact email: yot.a@rsu.ac.th