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Yot Amornkitvikai

*Rangsit University, Thailand*

Charles Harvie

*University of Wollongong*

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Finance, Ownership, Executive remuneration, Stochastic Frontier Analysis (SFA), Technical efficiency, Thailand



# Finance, Ownership, Executive Remuneration and Technical Efficiency: A Stochastic Frontier Analysis (SFA) of Thai Listed Manufacturing Enterprises

Yot Amornkitvikai<sup>1\*</sup>

Charles Harvie<sup>2\*</sup>

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This study employs a stochastic frontier analysis (SFA) to predict the technical efficiency of Thai listed manufacturing enterprises, using unbalanced panel data for 178 enterprises covering the years 2000 to 2008. The empirical findings indicate that these enterprises have been operating under “decreasing returns to scale”, and rely heavily on labour input. Managerial ownership, controlling ownership, type of firm ownership, executive remuneration and firm size are found to have a significant and positive correlation with technical efficiency. Firm leverage is also found to be positively correlated with technical efficiency, but is not statistically significant, and liquidity is found to have a significant negative correlation with firm technical efficiency. Both internal and external financing have a significant negative correlation with technical efficiency, but external financing is less important. The paper also provides evidence-based policy recommendations to enhance the technical efficiency and competitiveness of Thai listed manufacturing enterprises.

**Keywords:** Finance; Ownership; Executive remuneration; Stochastic Frontier Analysis (SFA); Technical efficiency; Thailand

**JEL Classification:** D22, D24, G32, G34, O47

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<sup>1</sup> Rangsit University, Thailand; \*yot.amorn@gmail.com

<sup>2</sup> University of Wollongong, \*charvie@uow.edu.au

## 1. INTRODUCTION

In recent years Thailand has faced the real challenge of sustaining its growth and escaping from its middle-income trap (World Bank Office, Thailand 2008). For Thailand to transition to higher income and quality growth in the long term, measures to improve productivity and competitiveness over the long term in all sectors (agriculture, industry and services) are urgently needed. The manufacturing sector has been one of the most important sectors in the East and Southeast Asian countries, as economic growth in this region since the early 1980s has resulted primarily from their rapid expansion in manufacturing exports (Jongwanich 2007). However, firm-level inefficiency was exposed by the 1997 Asian Financial Crisis, which highlighted lack of transparency in corporate governance and a corrupt and mismanaged banking system (i.e., excessive lending to non-productive assets, lack of adequate debt monitoring) among the crisis-affected countries in South East Asia, including Thailand.

The problem of weak corporate governance was related to factors such as the dominance of controlling shareholders, the separation of voting and cash-flow rights (or the disparity between control and ownership), and the limited protection of minority rights (Claessens et al. 2000; East Asia Analytical Unit 2000). Other firm-specific factors (inadequate firm size, lack of business experience, inefficient managerial skills and lack of internal competition) also contributed to the inefficiency of Thai listed manufacturing firms. After the 1997 Asian financial crisis, however, the corporate-governance system in Thai capital markets was strengthened by enhancing the institutional framework for accounting and auditing practices, improving listed companies' disclosure practices, encouraging best practices for directors of listed companies and relaxing foreign ownership controls (East Asia Analytical Unit 2000; Talerngsri & Vonkhorporn 2005; Sally 2007).

Firm-specific factors that affect firm performance, as measured by technical efficiency, have not, however, been empirically examined in the case of Thai listed manufacturing enterprises. Most previous studies have measured firm performance using profitability and financial ratios (Chang & Shin 2007; Cho 1998; Claessens et al. 2000; Dewenter & Malatesta 2001; Joh 2003; Lee 2008; McConnell & Servaes 1990; Smith 1990; Xu & Wang 1999). Some empirical studies conducted in Thailand have specifically measured the performance of Thai listed manufacturing enterprises using profitability and financial ratios (Wiwattanakantang 2001; Yammeesri & Lodh 2003), but none of these has measured their performance in terms of technical efficiency. The objectives of this paper are to: (i) measure the technical efficiency of Thai listed manufacturing enterprises; (ii) identify and measure firm-specific and business environmental factors that significantly affect their inefficiency; and (iii) determine evidence-based policy implications and provide recommendations to enhance their efficiency and competitiveness. Specifically, the paper will address the following research questions:

- How do Thai listed manufacturing enterprises perform in terms of technical efficiency?;
- What are the important factors that significantly contribute to their technical efficiency performance?; and
- How can the overall technical efficiency performance of these enterprises be enhanced?

This paper is organised as follows: Section 2 provides a review of the relevant literature. Section 3 describes data sources and data classification. Section 4 presents empirical models using SFA. Section 5 contains an analysis of the hypothesis tests used.

Section 6 discusses the economic significance of the results, including policy implications and recommendations. Conclusions are provided in the final section.

## 2. LITERATURE REVIEW

Most firms, especially listed enterprises, use financial indicators (e.g., return on assets and return on equity) to evaluate their financial performance; in fact, their financial performance is based on efficiency and productivity improvements and price variations (e.g., input and product prices) (Fried et al. 2008, p.11). Efficiency and productivity<sup>3</sup> measures are key drivers in firm performance (Fried et al. 2008). Technical efficiency measures the ability of a firm to produce the maximum output from given inputs and production technology (Coelli et al. 2010, p.51). Technical efficiency is a relative concept, since it compares a firm's performance to a best-practice input-output association (Alauddin et al. 1993). In other words, the efficiency of a firm is a comparison between theoretical maximum output from the given input and the output actually observed, or between optimal and observed values of the input required to produce its output, or some combination of the two (Fried et al. 2008). The term "optimum" refers to the production frontier where a firm is technically efficient. Therefore, the concept of technical efficiency, which has a value bounded between 0 and 1, is defined by the ratio of observed output  $Y_i$  for the  $i^{th}$  firm relative to potential maximum output  $Y_i^*$ , given the input vector,  $X_i$ , as follows (Coelli et al. 2005, p.244):

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{\exp(x_i'\beta + v_i - u_i)}{\exp(x_i'\beta + v_i)} = \exp(-U_i) \quad (1.1)$$

In examining firms' behaviour and effectiveness, this paper draws not only upon theories of technical efficiency, but upon agency theory as suggested by Jensen and Meckling (1976). For publicly listed firms, agency problems arise when authority over the firm is transferred to professional managers due to the dispersion of shareholders. In addition, managers may not pay much attention to managing the firm's resources, as an owner-manager does, and might transfer resources to maximise their own benefits (Jensen & Meckling 1976). This paper applies agency theory for an empirical analysis of listed manufacturing enterprises in Thailand, where the legal framework, business environment and corporate structure are quite different from other countries. The following literature reviews the effects of firm-specific and environmental variables on firm performance, including technical efficiency; variables include finance (e.g., leverage and liquidity; internal and external financing); ownership (e.g., controlling or concentrated ownership, managerial ownership, types of firm ownership); executive remuneration; and other firm-specific factors (e.g., firm size, firm age).

Very few empirical studies have examined the effect of leverage (financial constraints) on a firm's technical efficiency (Dilling-Hansen et al. 2003; Mok et al. 2007; Sena 2006; Weill 2008). Sena (2006) and Mok et al. (2007) used a leverage ratio, represented by the ratio of total debt to total assets, to investigate the effect of financial constraints on technical efficiency. This debt ratio captures the degree of constraint on a firm's expansion. Their empirical results revealed that firms with high leverage tend to experience an increase in their technical efficiency. This was confirmed by Goldar et al.

<sup>3</sup> The concept of productivity and efficiency are different. The productivity of a firm is defined as the ratio of total outputs to total inputs. Technical efficiency means the capability and ability of a firm to produce at the maximum possible output from a given bundle of inputs and a given technology (Coelli et al. 2005, pp.3-5).

(2003), who applied the quick ratio  $[(\text{current assets} - \text{inventory})/\text{current liabilities}]$  to examine the importance of the liquidity of Indian engineering firms on their technical efficiency; they found that liquidity has a significant negative effect on technical efficiency.

A number of theoretical studies focus on the relative efficiency of internal versus external financing (Jensen 1986; Gertner et al. 1994; Stein 1997), the conclusions from which are still controversial. Gertner et al. (1994) and Stein (1997) argue that a firm's capital is allocated more efficiently through internal rather than external financial resources, since internal financing can increase monitoring incentives, decrease entrepreneurial incentives and result in better asset allocation. However, Jensen (1986) argues that internal financing causes an agency problem, since managers have the opportunity to abuse internal funds: they can easily mobilise internal funds to maximise their own interests, and often lack the desire or necessity to maximise shareholders' interests because there is no external monitoring from banks or financial institutions (Kim, 2003).

Empirical studies have also revealed inconclusive findings about the nature of technical efficiency. For example, in studying the Turkish rubber industry, Gökçekus (1995) found no significant correlation between the relative efficiency of internal versus external financial resources on a firm's technical efficiency. In contrast, Kim (2003) found that the ratio of total interest payments on borrowed capital to total capital as a proxy for external financing has a positive effect on a firm's technical efficiency.

Ownership structure is also one of the important firm-specific factors affecting a firm's performance. There are both costs and benefits associated with controlling ownership. The presence of controlling ownership (shareholders with large stakes) can cause firm performance to deteriorate, since the interest of controlling shareholders may not align with those of non-controlling shareholders (Bebchuk et al. 1999; Shleifer & Vishny 1997). There is a possibility that large shareholders may conduct corrupt activities, which, because of the size of their share, may have significant effects. On the other hand, according to agency theory, firms with controlling shareholders are likely to perform better than those with dispersed shareholders, since a high level of ownership concentration can reduce agency costs.

A number of empirical studies have used accounting or financial measures to examine the effect of controlling ownership on performance (Demsetz & Lehn 1985; Leech & Leahy 1991; McConnell & Servaes 1990; Wiwattanakantang 2001; Yammeesri & Lodh 2003; Zeitun & Tian 2007). The empirical results, however, are still inconclusive. For example, Zeitun and Tian (2007) also found a significant positive association between ownership concentration and firm performance, as evaluated by the accounting performance measure (ROE and ROA) for 59 Jordanian publicly traded firms between 1989 and 2002. Leech and Leahy (1991) found a significant negative association between ownership concentration and a firm's value and profitability for 470 UK listed companies between 1983 and 1985. In the case of Thailand, Wiwattanakantang (2001) and Yammeesri and Lodh (2003) found that controlling ownership is positively associated with a firm's performance, as evaluated by accounting or financial measures (ROA, sales-assets ratio, stock returns and profitability). Similarly, managerial ownership can help align the potentially conflicting interests of shareholders and managers (Jensen & Meckling 1976). Very few empirical studies have examined the effect of managerial ownership on a firm's technical efficiency (Liao et al. 2010). Liao et al. calculated the percentage of equity owned by managers and the percentage owned by the board, and examined the effects of these variables on a firm's technical efficiency as measured by a two-stage Data Envelopment Analysis (DEA). They found that managerial and board

equities are positively correlated with a firm's technical efficiency, but their results were not statistically significant. In addition, very few empirical studies have examined the effect of executive remuneration on a firm's technical efficiency. Baek and Pagán (2002) conducted a stochastic frontier analysis (SFA) to measure a firm's technical efficiency, and found that the level of CEO total compensation was positively correlated with a firm's technical efficiency for the S&P 1,500 firms.

A number of empirical studies have found a positive correlation between foreign ownership and technical efficiency ( Bottasso & Sembenelli 2004; Fukuyama et al. 1999; Goldar et al. 2003). Very few empirical studies of the association between family ownership and firm performance in the financial literature have linked family ownership with a firm's technical efficiency. Lauterbach and Vaninsky (1999) used dummy variables for family and partnership ownership in a two-stage DEA approach to examine their effect on a firm's technical efficiency. Their results revealed a significant negative correlation between family and partnership ownership and technical efficiency for 280 Israeli firms. In the case of Thailand, Wiwattanakantang (2001) and Yammeesri and Lodh (2003) investigated the effect of family ownership on a firm's performance based on accounting or financial measures. Both studies, however, used a cut-off shareholding level of at least 25 per cent for Thai listed enterprises, since shareholders must have at least 75 per cent of their voting rights to obtain the absolute power over a public limited firm, according to Section 31 of the Public Limited Companies Act B.E. 2535 of Thailand. Both empirical studies revealed a significant positive association between family ownership and firm performance as measured by accounting performance (ROA). Many empirical studies have also investigated the effect of firm size on performance based on technical efficiency. Because these studies examine firms in different countries and sectors, results are quite varied. Empirical studies have also used different proxies for firm size, which can be represented as either (i) total assets (Kim 2003; Sheu & Yang 2005; Liao et al. 2010); (ii) the number of employees (Bottasso & Sembenelli 2004); and (iii) intermediate inputs (Hossain & Karunaratne 2004; Lundvall & Battese 2000; Oczkowski & Sharma 2005). Moreover, a number of empirical studies have investigated the effect of firm age on a firm's technical efficiency (Lundvall & Battese 2000). Their findings are also quite mixed, as they examine different countries and sectors.

### 3. DATA SOURCES AND DATA CLASSIFICATION

#### Data Sources

The raw data used in this study was obtained from the Stock Exchange of Thailand (SET). This study used annually consolidated financial reports, which record all business activities of listed firms, including those of their subsidiary companies. Form 56-1 is an annual company report required by The Securities and Exchange Commission (SEC) where all Thai listed firms must disclose their annual business performance for shareholders and investors. The form consists of three main parts: (i) executive summary, (ii) company-issued securities and (iii) confirmation of accuracy. Part (ii) was used for this study.

#### Data Classification

This study classified listed manufacturing firms into the SET's eight industrial sectors: (1) Agro and Food Industry, (2) Consumer Products, (3) Financials, (4) Industrials, (5) Property and Construction, (6) Resources (energy and utilities), (7) Services and (8) Technology. To conform to the International Standard Industrial Classification for all

economic activities (ISIC), it was necessary to remove some listed firms that are not classified as manufacturing firms. In addition, this study also included listed manufacturing firms that had been delisted from the SET between 2000 and 2008. As a result, data for 178 listed manufacturing firms over the period 2000 to 2008 (summarised in Table 1) was used to conduct the empirical analysis.

**Table 1**  
Classification of Listed Manufacturing Firms in the Stock Exchange of Thailand from 2000 to 2008

No. of Sectors	Manufacturing Sectors	No. of Listed Firms
1	Agro & Food Industry	
	1.1 Agribusiness	20
	1.2 Food & Beverage	20
	<b>Total</b>	<b>40</b>
2	Consumer Products	
	2.1 Fashion	18
	2.2 Home & Office Products	11
	2.3 Personal Products & Pharmaceuticals	4
	<b>Total</b>	<b>33</b>
3	Industrials	
	3.1 Automotive	12
	3.2 Industrial Materials & Machinery	19
	3.3 Packaging	13
	3.4 Paper & Printing Materials	2
	3.5 Petrochemicals & Chemicals	13
	<b>Total</b>	<b>59</b>
4	Publishing	7
5	Construction Materials	27
6	Technology (Computer components)	12
	<b>Total listed manufacturing firms</b>	<b>178</b>

**Source:** Authors

#### 4. EMPIRICAL MODEL

Two approaches can be used to measure a firm's technical efficiency: a non-parametric approach such as Data Envelopment Analysis (DEA) or a parametric approach such as Stochastic Frontier Analysis (SFA). In contrast to the DEA approach, SFA requires functional forms for the production frontier, and assumes that firms may deviate from the production frontier not only because of technical inefficiency but also measurement errors, statistical noise or other non-systematic influences (Admassie & Matambalya 2002).

In addition, SFA requires strong distribution assumptions for both statistical random errors (i.e., normal distribution) and non-negative technical-inefficiency random variables. The latter can include half-normal distribution for the time-invariant inefficiency model (Pitt & Lee 1981) as well as truncated normal distribution for both the time-invariant inefficiency model (Battese & Coelli 1988) and the time-variant inefficiency model (Battese & Coelli 1992, 1995).

The DEA approach does not impose functional forms; moreover, it uses linear programming to construct a frontier that envelops the data on all firms. Hence, all firms



are compared to the firms that perform the "best". DEA also overcomes restrictions on the production and distribution of various residuals.

However, this paper employs only the SFA approach<sup>4</sup> based on the Battese and Coelli (1995) model, since that model focuses on the one-stage process, in which the stochastic frontier production used to predict technical efficiency is estimated simultaneously with a model used to examine the significant factors in a firm's technical inefficiency. This one-stage process is crucially different from the two-stage approach<sup>5</sup>, as it can resolve "bias" due to the omission of relevant variables in the first stage of frontier estimation. More specifically, this study uses unbalanced panel data for 178 Thai listed manufacturing firms between 2000 and 2008, which is suitable for application of this model. The Battese and Coelli (1995) model consists of two main components. The first component is the estimation of a time-varying stochastic frontier production function that contains two errors: (i) random errors ( $V_{its}$ ) and non-negative random variables ( $U_{its}$ ). The random errors, which are assumed to be independently and identically distributed normal random variables with zero means and variances,  $\sigma_v^2$  ( $V_{it} \sim iid N(0, \sigma_v^2)$ ), can be observed, for example, when the problems of omitted variables and model misspecification arise. The non-negative random variables, which are assumed to be independently and identically distributed normal random variables as truncations at zero with  $Z_{it}\delta$  means and variances  $\sigma_u^2$  ( $U_{it} \sim iid N(0, \sigma_u^2)$ ), are known as the technical-inefficiency effects. In addition, these two types of variables are assumed to be independently distributed for all time periods ( $t=1,2,\dots,T$ ) and all firms ( $i=1,2,\dots,N$ ).

The second component links firm-specific variables (i.e., type of firm ownership, firm age and firm size) with the inefficiency effects or non-negative random variables. In other words, this component aims to examine what firm-specific variables significantly affect a firm's inefficiency, with the objective of answering one of this paper's key research questions. More importantly, the economic significance of the results can make a valuable contribution to policy analysis and recommendations for both policy-makers and entrepreneurs. The stochastic frontier production function and the inefficiency-effects model can be simultaneously estimated by the method of maximum likelihood (ML), which has desirable large-sample (or asymptotic) properties. According to Coelli et al. (2005, p.245), the method of maximum likelihood is preferred to other estimation techniques in computing measures of technical efficiency, such as ordinary least squares (OLS) and corrected ordinary least squares (COLS). OLS estimates cannot be used to compute a firm's technical efficiency, since the estimated "intercept" coefficient obtained from the OLS is "biased downwards"<sup>6</sup> even though the estimated "slope" coefficients are consistent. In addition, the ML estimator is asymptotically more efficient than the COLS

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<sup>4</sup> The basic stochastic production function frontier was independently proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and Broeck (1977) within a cross-sectional context as defined by  $Y_i = f(X_i; \beta) \exp(V_i - U_i)$ , where  $Y_i$  represents the output for the  $i^{th}$  firm;  $X_i$  denotes a  $(1 \times k)$  vector of inputs;  $\beta$  is a  $(k \times 1)$  vector of unknown parameters to be estimated;  $V_i$  represents the random error that accounts for the measurement error (i.e., omitted variables); and  $U_i$  denotes a non-negative random variable or technical inefficiency. Aigner, Lovell and Schmidt (1977) applied the method of maximum likelihood under the assumptions of a half-normal model, assuming that the inefficiency components ( $U_{is}$ ) are independently and identically distributed half-normal random variables with variance  $\sigma_u^2$  ( $u_i \sim iid N^+(0, \sigma_u^2)$ ), and the statistical components ( $V_{is}$ ) are independently and identically distributed normal random variables with zero means and variances  $\sigma_v^2$  ( $v_i \sim iid N(0, \sigma_v^2)$ ).

<sup>5</sup> The stochastic production function frontier and the inefficiency-effects model are estimated separately.

<sup>6</sup> When  $E(\hat{\beta}) < \beta$  (Wooldridge 2006, p.98)

estimator (Coelli et al. 2005, p.245). More specifically, the ML estimator<sup>7</sup> is consistent and asymptotically efficient (Gujarati 2003; Coelli et al. 2005; Wooldridge 2006). The only software that can be used to conduct a single-step process is FRONTIER 4.1, in which the stochastic frontier production function and the model of technical-inefficiency effects are estimated simultaneously by the method of maximum likelihood estimation (Quasi-Newton methods) (Coelli 1996). This software uses the parameterisation from Battese and Corra (1977) by replacing  $\sigma_v^2$  and  $\sigma_u^2$  with  $\sigma^2 = \sigma_v^2 + \sigma_u^2$  and  $\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$ . The technical inefficiency for the  $i^{th}$  firm in the Battese and Coelli (1995) model is given by  $TE_{it} = \exp(-U_{it}) = \exp(-Z_{it}\delta - W_{it})$ . Applying the model of Battese and Coelli (1995) tests the stochastic frontier production functions in the Cobb-Douglas and translog functional forms for adequate functional form. The Cobb-Douglas functional form can be written as:

$$\ln(Y_{it}) = \beta_0 + \beta_1 \ln(L_{it}) + \beta_2 \ln(K_{it}) + \beta_3 \ln(IM_{it}) + \beta_4 (t) + V_{it} - U_{it} \quad (1.2)$$

The translog functional form can be written as:

$$\begin{aligned} \ln(y_{it}) = & \beta_0 + \beta_1 \ln(L_{it}) + \beta_2 \ln(K_{it}) + \beta_3 \ln(IM_{it}) + \beta_4 (t) + \frac{1}{2}\beta_5 \ln(L_{it}^2) + \\ & \frac{1}{2}\beta_6 \ln(K_{it}^2) + \frac{1}{2}\beta_7 \ln(IM_{it}^2) + \frac{1}{2}\beta_8 (t^2) + \beta_9 \ln(L_{it}) * \ln(K_{it}) + \\ & \beta_{10} \ln(L_{it}) * \ln(IM_{it}) + \beta_{11} \ln(L_{it}) * (t) + \beta_{12} \ln(K_{it}) * \ln(IM_{it}) + \\ & B_{13}(K_{it}) * (t) + B_{14}(IM_{it}) * (t) + V_{it} - U_{it} \end{aligned} \quad (1.3)$$

where:

$Y_{it}$  = Sales revenue deflated by the manufacturing Producer Price Index (PPI) of firm  $i$  at time  $t$

$L_{it}$  = Employee expenses deflated by the manufacturing Producer Price Index (PPI) of firm  $i$  at time  $t$

$K_{it}$  = Net productive fixed assets deflated by the Producer Price Index (PPI) of capital goods of firm  $i$  at time  $t$

$IM_{it}$  = Intermediate inputs deflated by the Producer Price Index (PPI) of intermediate inputs of firm  $i$  at time  $t$

$V_{it}$  = Random error ( $V_{it} \sim N(0, \sigma_v^2)$ )

$U_{it}$  = Non-negative random variable (or technical inefficiency) ( $U_{it} \sim N(Z_{it}\delta, \sigma_u^2)$ )

The inefficiency-effects model can be written as follows:

$$\begin{aligned} U_{it} = & \sigma_0 + \sigma_1 LEV_{it} + \sigma_2 LIQ_{it} + \sigma_3 INF_{it} + \sigma_4 EXF_{it} + \sigma_5 AGE_{it} + \sigma_6 SIZE_{it} \\ & + \sigma_7 TOP5_{it} + \sigma_8 MGR_{it} + \sigma_9 EXP_{it} + \sigma_{10} FAM_{it} + \sigma_{11} FGR_{it} + W_{it} \end{aligned} \quad (1.4)$$

where:

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<sup>7</sup> Under the method of maximum likelihood estimation the probability distribution of the error terms must only be assumed (Gujarati 2003, p.113). The assumptions underlying OLS, therefore, are not required for the ML method; these OLS assumptions include (i) linear in the parameter, (ii) random sampling, (iii) no perfect collinearity (no perfect linear associations among the explanatory variables), (iv) zero conditional mean (the error term has an expected value of zero, given any values of the explanatory variables), (v) homoskedasticity (the error term has a constant variance, given any values of the explanatory variables), (vi) normality (e.g., the error term is independent of the explanatory variables, and normally distributed with zero mean and variance  $\sigma^2$ ), and (vii) no serious correlation (the error terms in two different time periods are uncorrelated) (Wooldridge 2006, pp347-354).

- $LEV_{it}$  = Leverage of firm  $i$  at time  $t$ , represented by the ratio of total debt to total assets (the D/A Ratio)
- $LIQ_{it}$  = Liquidity of firm  $i$  at time  $t$ , represented by the ratio of current assets to current liabilities (the Current Ratio)
- $INF_{it}$  = Dummy for internal financing;  
 $INF_{it} = 1$  if firm  $i$  at time  $t$  borrows from related parties  
 $= 0$ , otherwise
- $EXF_{it}$  = External financing, represented by total interest expenses deflated by the general Producer Price Index (PPI)
- $AGE_{it}$  = Age of firm  $i$  at time  $t$ , represented by the number of operating years
- $SIZE_{it}$  = Size of firm  $i$  at time  $t$ , represented by the logarithm form of total assets
- $TOP5_{it}$  = Controlling ownership of firm  $i$  at time  $t$ , represented by the percentage of equity owned by the five largest shareholders
- $MGR_{it}$  = Managerial ownership of firm  $i$  at time  $t$ , represented by the equity owned by top executives and board members
- $EXP_{it}$  = Exports of firm  $i$  at time  $t$ , represented by the ratio of export revenue to total sales revenue
- $FAM_{it}$  = Dummy for a family-owned firm:  
 $FAM_{it} = 1$  if firm  $i$  at time  $t$  is a family-owned firm  
 $= 0$ , otherwise
- $FGR_{it}$  = Dummy for a foreign-owned firm:  
 $FGR_{it} = 1$  if firm  $i$  at time  $t$  is a foreign-owned firm  
 $= 0$ , otherwise
- $W_{it}$  = Random error ( $W_{it} \sim N(0, \sigma_W^2)$ )

## Hypotheses

A number of hypotheses, which have been developed from a review of the literature in Part 2, were tested:

**Hypothesis 1:** *Financial constraints (leverage) have a significant positive correlation with a firm's technical efficiency for Thai listed manufacturing enterprises. Vice versa, the more liquidity, the lower the technical efficiency of Thai listed manufacturing enterprises.*

**Hypothesis 2:** *External financing has a significant positive correlation with a firm's technical efficiency for Thai listed manufacturing enterprises. Vice versa, internal financing has a significant negative correlation with a firm's technical efficiency for Thai listed manufacturing enterprises.*

**Hypothesis 3:** *Controlling ownership has a significant positive correlation with a firm's technical efficiency for Thai listed manufacturing enterprises.*

**Hypothesis 4:** *Managerial ownership has a significant positive correlation with a firm's technical efficiency for Thai listed manufacturing enterprises.*

**Hypothesis 5:** *Foreign and family ownership<sup>8</sup> have a significant positive correlation with the technical efficiency of Thai listed manufacturing enterprises; foreign-owned firms*

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<sup>8</sup> This refers to majority foreign and family ownership using a cut-off shareholding level of 25 per cent (Wiwattanakantang 2001; Yammeesri & Lodh 2003).

*perform best in terms of technical efficiency relative to other ownership types for Thai listed manufacturing enterprises.*

**Hypothesis 6:** *Executive remuneration has a significant positive correlation with a firm's technical efficiency for Thai listed manufacturing enterprises.*

All of these hypotheses were examined using a one-stage process as suggested by Battese and Coelli (1995), in which the stochastic frontier production (Equation 1.3) and the model of technical-inefficiency effects (Equation 1.4) are estimated simultaneously using maximum likelihood estimation. Particular focus was placed on finance (Hypotheses 1 and 2), ownership (Hypotheses 3, 4, and 5) and executive remuneration (Hypothesis 6). Table 3 gives the empirical results for each hypothesis.

## 5. HYPOTHESIS TESTS

A number of null hypotheses need to be tested for estimation of the stochastic frontier production function and the model of inefficiency effects: (i) the validation of the Cobb-Douglas production function, (ii) the absence of technical progress, (iii) the absence of neutral technical progress: (iv) the absence of inefficiency effects, (v) the absence of stochastic inefficiency effects and (vi) the insignificance of joint inefficiency variables (Table 2). A likelihood-ratio test (LR test) was used to test these hypotheses:

$$\lambda = -2\{\log [L(H_0)] - \log [L(H_1)]\} \quad (1.5)$$

where  $\log [L(H_0)]$  and  $\log [L(H_1)]$  are obtained from the maximised values of the log-likelihood function under the null hypothesis ( $H_0$ ) and the alternative hypothesis ( $H_a$ ) 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 ( $H_0$ ), except Hypotheses (iv) and (v), which have a "mixed" chi-square distribution (Kodde & Palm 1986). Hypotheses (iv) and (v) involve the restriction that  $\gamma$  is equal to zero, which defines a point on the boundary of the parameter space (Coelli 1996, p. 6).

The null hypothesis (i) tests whether the Cobb-Douglas production function is adequate for Thai listed manufacturing firms. Following equations (1.2) and (1.3), the null hypothesis ( $H_0 : \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = \beta_{10} = \beta_{11} = \beta_{12} = \beta_{13} = \beta_{14} = 0$ ) is strongly rejected at the 5 per cent level of significance for all Thai listed manufacturing enterprises. Therefore, the Cobb-Douglas production function is not an adequate specification for the case of the SET's manufacturing sector, compared with the specification of the translog production function model. This also indicates that input and substitution elasticities are not constant among firms (Lundvall & Battese 2000).

The null hypothesis (ii) that there is no technical progress ( $H_0 : \beta_4 = \beta_8 = \beta_{11} = \beta_{13} = \beta_{14} = 0$ ) is rejected at the 5 per cent level of significance for the SET's manufacturing sector, indicating that technical progress exists. The null hypothesis (iii) that technical progress is neutral ( $H_0 : \beta_{11} = \beta_{13} = \beta_{14} = 0$ ) is also rejected at the 5 per cent level of significance for the SET's manufacturing sector. This indicates that technical change not only affects average output, but also changes marginal rates of technical substitution. In other words, the marginal rate of substitution is not dependent on time, indicating that *Hicks* neutral technology does not exist for the SET's manufacturing sector. The estimates of  $\beta_{11}$  and  $\beta_{13}$  in Table 3 are also significantly negative and positive, respectively, for the SET's manufacturing sector. This evidence implies that there exists labour-using and capital-saving technical progress for all listed

manufacturing enterprises over the period 2000 to 2008. The null hypothesis (iv), which specifies that inefficiency effects are absent from the model ( $\gamma = \delta_0 = \delta_1 \dots = \delta_{11} = 0$ ), is strongly rejected at the 5 per cent level of significance, which implies that the model of inefficiency effects exists for the SET's manufacturing sector.

The null hypothesis (v) that inefficiency effects are not "stochastic" ( $\gamma = 0$ ) is strongly rejected, implying that the model of inefficiency effects is not reduced to a traditional mean response function. In other words, all the explanatory variables in the inefficiency-effects model are not included in the production function, implying that the inefficiency effects model exists, and, therefore, that its estimated parameters can be identified. As a result, the average response function, in which all listed manufacturing firms are assumed to be fully technically efficient, is not found for the SET's manufacturing sector, given the assumptions of the translog stochastic frontier and the inefficiency-effects model. In addition, if the estimate of the variance parameter ( $\gamma$ ) is close to 1, it indicates that overall residual variation ( $U_{it}$ s and  $V_{it}$ s) results largely from inefficiency components ( $U_{it}$ s). The estimated  $\gamma$  (0.908) shown in Table 3 is high for the SET's manufacturing sector, indicating that much of the variation in the composite error term is due to inefficiency effects ( $U_{it}$ s).

**Table 2**  
Empirical results for the Hypotheses Tests of the Stochastic Frontier and Inefficiency-Effects Models

Null Hypothesis	Manufacturing Sector		
	LR Statistics	Critical Value	Decision
<b>(i) Cobb-Douglas</b>			
$(H_0: \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = \beta_{10} = \beta_{11} = \beta_{12} = \beta_{13} = \beta_{14} = 0)$	211.94	18.31	Reject $H_0$
<b>(ii) No technical progress</b>			
$(H_0: \beta_4 = \beta_8 = \beta_{11} = \beta_{13} = \beta_{14} = 0)$	25.93	11.07	Reject $H_0$
<b>(iii) Neutral technical change</b>			
$(H_0: \beta_{11} = \beta_{13} = \beta_{14} = 0)$	33.92	7.81	Reject $H_0$
<b>(iv) No inefficiency effects</b>			
$(H_0: \gamma = \delta_0 = \delta_1 = \dots = \delta_{11} = 0)$	576.21	20.41*	Reject $H_0$
<b>(v) Non stochastic inefficiency</b>			
$(H_0: \gamma = 0)$	1207.1	2.71*	Reject $H_0$
<b>(vi) No joint inefficiency</b>			
$(H_0: \delta_1 = \delta_2 = \dots = \delta_{10} = \delta_{11} = 0)$	120.45	19.68	Reject $H_0$

**Source:** Authors' estimates

Note: All critical values for the test statistics are subject to the 5 per cent level of significance; \* indicates a mixture of the  $\chi^2$  distribution (Kodde & Palm, 1986); all null hypotheses are subject to Equation 1.3.

The last null hypothesis specifies that inefficiency effects are not a linear function of all explanatory variables ( $H_0: \delta_1 = \delta_2 = \dots = \delta_{10} = \delta_{11} = 0$ ). In other words, the null hypothesis specifies that all parameters of the explanatory variables are equal to zero. All LR test statistics are greater than the critical value of an approximately chi-square distribution at the 5 per cent level of significance. This implies that the null hypothesis –

that all coefficients of the explanatory variables are equal to zero – is strongly rejected at the 5 per cent level of significance for the SET’s manufacturing sector, given the specification of the translog stochastic frontier and the model of inefficiency effects (Table 2). According to the rejection of the last null hypothesis test, the model of inefficiency effects of the SET’s manufacturing sector can be assumed to be independently and identically distributed as truncations at zero of the normal distribution with mean,  $Z_{it}\delta$  and variance,  $\sigma_u^2$  (Battese & Coelli 1995). It is also common that some of the individual coefficients of the translog stochastic frontier are statistically insignificant due to high multicollinearity among the inputs (Lundvall & Battese 2000; Oczkowski & Sharma 2005).

## 6. ECONOMIC SIGNIFICANCE OF THE RESULTS

The average technical-efficiency score for all listed manufacturing enterprises predicted by the SFA is 0.79 (or 79 per cent). A measure of returns to scale, given by the sum of the elasticity of output with respect to each input (0.887)<sup>9</sup>, indicates the existence of decreasing returns to scale for Thai listed manufacturing enterprises (Kim 1992; Margono & Sharma 2004). Under the translog specification for technology, Equation 1.3, the rate of technical change is given by  $\partial \ln y / \partial t = \beta_4 + \beta_8 * t + \beta_{11} * \ln(l_{it}) + \beta_{13} * \ln(k_{it}) + \beta_{14} * \ln(im_{it})$  (Kim 1992). Table 3 gives the rate of technical change as 0.026 for the SET’s manufacturing sector, indicating that the rate of technical change increases at 2.6 per cent per year.

An estimated  $\gamma$  close to 1 implies that the error variation is mainly due to inefficiency effects. For this study  $\gamma$  is equal to 0.908; this indicates that overall error variation ( $U_{it}$ s and  $V_{it}$ s) is mostly due to inefficiency components ( $U_{it}$ s), and insignificantly caused by random error terms ( $V_{it}$ s). This suggests that firm-specific and environmental variables jointly explain the inefficiency-effects model very well; Table 3 summarises these empirical results. Results also indicate that leverage (financial constraints) has a positive correlation with the technical efficiency of all listed manufacturing enterprises, as suggested by Sena (2006) and Mok et al. (2007), but is not statistically significant at the 5 per cent level of significance. This implies that financially constrained firms tend to use their financial resources and control input costs effectively, resulting in an enhancement of their technical efficiency. This result is consistent with that of Goldar et al. (2003). The empirical evidence also confirms that external financing has a significant and negative correlation with a firm’s technical efficiency, contradicting results obtained by Kim (2003), but the association is very weak, since the size of the “external financing” coefficient is very small (close to zero). In addition, “internal financing” is found to have a negative correlation with a firm’s technical efficiency. This implies that the agency problem exists for the use of internal funds, since managers do not appear to maximise shareholders’ interests or have strong incentives to abuse internal funds, as suggested by Jensen (1986). This is especially the case in underdeveloped countries, where firms’ managerial responsibilities are often not fully developed and their information is not fully publicised, and therefore managers can attempt to maximise their benefits rather than the firm’s value (Kim 2003, p.134). The coefficient for “executive remuneration” is also found to have a significant positive correlation with firm technical

<sup>9</sup> As shown in Table 3, returns to scale is calculated as the sum of (i) the elasticity of output with respect to capital input  $e_k = \beta_2 + \beta_6 * \ln(k_{it}) + \beta_9 * \ln(l_{it}) + \beta_{12} * \ln(m_{it}) + \beta_{13} * t$ , (ii) the elasticity of output with respect to labour input  $e_l = \beta_1 + \beta_5 * \ln(l_{it}) + \beta_9 * \ln(k_{it}) + \beta_{10} * \ln(m_{it}) + \beta_{11} * t$ , and (iii) the elasticity of output with respect to intermediate inputs  $e_{im} = \beta_3 + \beta_7 * \ln(m_{it}) + \beta_{10} * \ln(l_{it}) + \beta_{12} * \ln(k_{it}) + \beta_{14} * t$

efficiency, as suggested by Baek and Pagán (2002), indicating that listed manufacturing firms with higher levels of executive remuneration tend to be more technically efficient.

The empirical results also confirm that managerial ownership has a significant positive correlation with technical efficiency, consistent with results obtained by Liao et al. (2010). This indicates that the agency problem is reduced, since managerial ownership can help align the potentially conflicting interests of shareholders and managers, as suggested by Jensen and Meckling (1976).

**Table 3**  
Maximum-Likelihood Estimates for Parameters of the Stochastic Frontier Production Function and the Inefficiency-Effects Model

I. The Stochastic Frontier Production Function			II. The Inefficiency-Effects Model		
Stochastic Variables	Parameter	Stochastic Frontier	Inefficiency Variables	Parameters	Inefficiency-Effects Model
Constant	$\beta_0$	4.219* (0.485)	Constant	$\delta_0$	14.72* (1.017)
log(L)**	$\beta_1$	0.971* (0.119)	LEV (Leverage)	$\delta_1$	-0.005 (0.016)
log(K)**	$\beta_2$	-0.729* (0.110)	LIG (Liquidity)	$\delta_2$	0.235* (0.014)
log(IM)**	$\beta_3$	0.229 (0.151)	INF (Internal financing)	$\delta_3$	0.470* (0.109)
t	$\beta_4$	0.106* (0.042)	EXF (External financing)	$\delta_4$	0.00008* (0.00001)
$\frac{1}{2} (\log(L))^2$	$\beta_5$	0.079* (0.021)	AGE (Age)	$\delta_5$	-0.007 (0.008)
$\frac{1}{2} (\log(K))^2$	$\beta_6$	-0.100* (0.025)	SIZE (Firm size)	$\delta_6$	-1.041* (0.065)
$\frac{1}{2} (\log(IM))^2$	$\beta_7$	0.127* (0.028)	TOP 5 (Controlling ownership)	$\delta_7$	-0.046* (0.005)
$\frac{1}{2} (t^2)$	$\beta_8$	-0.005 (0.005)	MGE (Managerial ownership)	$\delta_8$	-0.019* (0.004)
log(L)*log(K)	$\beta_9$	0.088* (0.023)	EXP (Executive remuneration)	$\delta_9$	-0.455* (0.045)
log(L)*log(IM)	$\beta_{10}$	-0.209* (0.025)	FAM (Family -owned firm)	$\delta_{10}$	-3.180* (0.284)
log(L)* t	$\beta_{11}$	-0.018* (0.007)	FGR (Foreign -owned firm)	$\delta_{11}$	-2.966* (0.331)
log(K)*log(IM)	$\beta_{12}$	0.091* (0.019)	Variance parameters sigma-square	$\sigma^2$	1.363* (0.071)
log(K)*t	$\beta_{13}$	0.015* (0.006)	gamma	$\gamma$	0.908* (0.007)
log(IM)*t	$\beta_{14}$	-0.005 (0.007)	Log-likelihood function		-771.01

**Source: Authors' estimates**

Note: Standard Errors (SE) are in parentheses; \* indicates that the coefficients are statistically significant at the 5 per cent level; \*\* L is the labour input, K is the capital input, and IM is the intermediate input (Equation 1.3); the stochastic frontier production function and the inefficiency-effects model are estimated simultaneously using FRONTIER 4.1; the empirical results refer to Equations 1.3 and 1.4.

This study found controlling ownership to have a positive correlation with technical efficiency; this finding is similar to the results of Wiwattanakantang (2001) and Yammeesri and Lodh (2003), who found that controlling ownership is positively correlated with a firm's performance as evaluated by accounting or financial measures (e.g., ROA, sales-assets ratio, stock returns and profitability). This result supports the agency theory that controlling shareholders are likely to perform better than dispersed shareholders, since a high level of ownership concentration can reduce agency costs.

Results based on the classification of different ownership types among listed manufacturing firms indicate that family-owned firms and foreign-owned firms have a significant positive correlation with technical efficiency. The significant positive correlation between foreign ownership and technical efficiency found from this paper is consistent with the empirical results obtained from a number of other studies (Fukuyama et al. 1999; Goldar et al. 2003; Bottasso & Sembenelli 2004). This paper's findings of a significant positive correlation between family ownership and technical efficiency specifically for Thai firms is similar to the empirical studies of Wiwattanakantang (2001) and Yammeesri and Lodh (2003), except that their studies focused on firm performance as measured by profitability and financial ratios. In the current study, the magnitude of the estimated coefficients for types of firm ownership indicated that family-owned firms perform the best, followed by foreign-owned firms, given other types of firm ownership as the base category. Moreover, this study found strong evidence that a firm's size tends to have a statistically positive correlation with its technical efficiency. The study also found that the effect of a firm's age on its technical efficiency was positive, but not statistically significant.

### Policy Implications and Recommendations

This study's results can contribute to evidence-based policy implications and recommendations for policy-makers and entrepreneurs of Thai listed manufacturing enterprises.

#### *Financing*

The empirical evidence related to Hypothesis 1 suggested that listed manufacturing firms with high leverage are likely to have high technical efficiency. This can imply that they control input costs and use financial resources effectively. Moreover, it is possible that listed manufacturing firms with high leverage might be investing in capital-intensive projects. Vice versa, listed manufacturing firms, which have more liquidity, tend to have low technical efficiency. Therefore, the SET can help promote productive investments for listed manufacturing firms by facilitating fundraising for their productive investments. The SET can help promote foreign and local investments in listed manufacturing enterprises that prefer to invest in productive investment projects. The government, via the BOI, can play an important role in promoting productive investments for listed manufacturing firms. In practice, the BOI introduced measures after 4 March 2009 encouraging investors to improve their production, along with an increase in their revenues and maintenance of their employment (Board of Investment 2010).

The empirical evidence for Hypothesis 2 indicates that internal financing has a significant positive correlation with the technical efficiency of listed manufacturing enterprises, while external financing does not exert an important impact on technical efficiency due to a small estimated coefficient (close to zero). More importantly, it is not possible for listed manufacturing enterprises to use only external or internal financing.



Therefore, internal financing transactions should be fully disclosed to avoid an agency problem, as managers may use internal funds for their own interests and fail to maximise shareholders' benefits.

External financing is also found to have a negative correlation with technical efficiency, although this effect is small, as indicated by the very small magnitude of the estimated external-financing coefficient. A possible reason for this negative correlation arises from the varying interest-payment obligation on loans and the current economic situation (e.g., financial institutions normally prefer a floating interest rate, which can be altered according to interest rates announced by the Bank of Thailand and the financial costs of each financial institution). More importantly, listed manufacturing firms are obligated to pay principle and interest to debtors on time as stated in their loan agreements. However, they might not be able to pay their loans and interest regularly due to unexpected circumstances (such as political unrest, global financial crisis, unexpected interest rate hikes or currency appreciation). Therefore, interest payments, or the cost of external financing, could decrease the competitiveness and efficiency of listed manufacturing enterprises.

Equity instruments can also be useful in obtaining external financing; these can take the form of new shares issued to existing shareholders (rights offering), to a specific group of strategic investors (private placement) or to the public (public offering). This is because listed manufacturing firms only pay dividends to shareholders when they gain profits; this provides more flexibility than a loan repayment. More importantly, providing information for minority shareholders with respect to their roles and voting rights is very important for establishing a checks-and-balances mechanism, which can reduce the agency problem. Adequate monitoring by certified financial analysts should be emphasised to avoid any financial actions that could adversely affect shareholders' benefits.

#### *Controlling and Managerial Ownership*

Both controlling and managerial ownership were found to have a significant and positive correlation with the technical efficiency of listed manufacturing firms (Hypotheses 3 and 4). To avoid possible agency problems caused by controlling and managerial ownership, the SET should continuously promote a good corporate-governance system. For example, in the area of managerial ownership, the Employee Stock Option Program (ESOP) can be promoted, as this can encourage the participation of managerial ownership. However, the ESOP may cause control and price dilutions for existing shareholders. Minority shareholders can play an important role in the monitoring of listed manufacturing firms' operations; therefore, information on the roles and voting rights of minority shareholders should be disseminated so as to establish a checks-and-balances mechanism between listed manufacturing firms' management and shareholders.

#### *Family and Foreign Ownership*

Both family and foreign ownership were found to have a significant positive correlation with the technical efficiency of listed manufacturing enterprises (Hypothesis 5). Family-owned firms perform the best, followed by foreign-owned firms. Therefore, foreign and family ownership of listed manufacturing firms should be promoted. Foreign shareholding limits can be relaxed up to 100 per cent if listed and non-listed manufacturing firms are not in any of the three lists of prohibited businesses, and have been approved by the BOI. To legally increase the foreign ownership of listed

manufacturing enterprises, BOI financial and non-financial privileges should be promoted. Alternatively, Non-Voting Depository Receipts (NVDRs) can be used to avoid the foreign shareholding limit in cases where listed manufacturing firms are not eligible to receive BOI privileges. In addition, the Department of Business Development (DBD) can promote foreign investment, since all foreign business operations in Thailand must be approved by the DBD. Therefore, effective procedures for obtaining foreign business operations, as well as providing accurate and prompt information for foreign investors, can be promoted to boost the confidence of foreign investors. These can help increase the number of listed enterprises owned by foreign investors. The most difficult task, however, is to promote the confidence of foreign investors in the securities of Thai listed manufacturing firms. Hence, corporate governance among listed manufacturing enterprises should be continuously strengthened. Accounting and auditing best practices, including rules and responsibilities of boards of directors, should be continuously strengthened to be in line with international standards. To promote family ownership, small and medium-sized enterprises (SMEs) can be a target group, since they are primarily operated by family members. Generally, they prefer not to be listed in the SET, since they are afraid of losing their control and having to follow SET and SEC rules and regulations. All information regarding how they can benefit from being listed in the SET and what procedures and criteria are required should be fully disclosed. Family-owned firms, however, may contribute to an agency problem, since they may implement policies beneficial mainly, or even exclusively, to themselves. Good corporate governance among family-owned firms should be strengthened to avoid such an agency problem.

#### *Executive Remuneration*

Executive remuneration was found to have a significant positive correlation with the technical efficiency of listed manufacturing enterprises (Hypothesis 6). This suggests that attractive executive remunerations tied to firm and individual performance should be promoted. Executive remuneration can be provided in a number of ways such as salary, employee benefits and perquisites, short-term incentives (such as bonuses) and long-term incentives (such as stock options) (Ellig 2002). Listed manufacturing enterprises should establish a compensation committee, the members of which should be completely independent from management. In addition, executive remuneration should be based on the firm's financial performance. Available director-compensation surveys or comments from a consulting firm should be considered as the benchmark, as these can reduce the likelihood of unreasonable executive compensation. Providing information for minority shareholders with respect to their roles and voting rights is also very important, since executive remuneration must ultimately be approved by shareholders.

#### *Firm size*

Finally, firm size was found to have a significant and positive correlation with the technical efficiency of listed manufacturing firms. Therefore, the SET and SEC should promote an increase in the size of listed manufacturing enterprises. For example, fundraising used for productive investments (e.g. improving production technology) should be promoted and facilitated. In addition, listed manufacturing firms in the MAI can be encouraged to apply for listing in the SET if they meet its listing criteria.

## 7. CONCLUSIONS

This study applied the stochastic frontier analysis (SFA) approach, based on the one-step process of the Battese and Coelli (1995) model, to measure the technical efficiency of 178 Thai listed manufacturing enterprises over the period 2000 to 2008, and the factors affecting this efficiency both positively and negatively. Empirical evidence from the SFA highlights that the firms' technical-efficiency performance is relatively high, with an average technical efficiency score of 0.79 (or 79%). Despite this efficiency, listed manufacturing enterprises have been operating under decreasing returns to scale over the period 2000 to 2008. All listed manufacturing enterprises have progressed in applying labour-using and capital-saving techniques over the period 2000 to 2008; but these improvements have relied primarily on the effective use of basic production resources such as labour input.

This study's empirical results reveal that financially constrained firms tend to improve their technical efficiency through the effective control of input costs and financial resources. In contrast, financially healthy firms are likely to neglect increasing their technical efficiency due to financial liquidity. External financing tends to decrease a firm's technical efficiency, but its importance is very weak due to a very small estimated coefficient. There is evidence that internal financing has a significant negative association with a firm's technical efficiency. This result highlights that managers tend to use internal funds ineffectively due to a lack of external monitoring. Kim (2003, p.134) also emphasised that this normally occurs in several underdeveloped countries, where firms' managerial skills are not fully strengthened and their information is not fully disclosed, and managers therefore have the opportunity to maximise their benefits rather than the firm's value.

Controlling and managerial ownerships have a significant positive correlation with a firm's technical efficiency. This result implies that a group of people who receive direct benefits from the firm through dividends relative to the level of their cash flow or voting rights tend to monitor the firm carefully and effectively. Conversely, dispersed shareholders or managers who do not hold any ownership over a firm's cash flow or voting stocks are likely to monitor the firm ineffectively, since they perceive that they only receive small dividends or monthly salaries not linked to performance. Similarly, executive remuneration is found to have a significantly positive correlation with technical efficiency. In practice, the amount of bonuses or increased salaries that boards of directors and managers will receive depends upon the firm's annual net profits. In some listed firms, the amount of executive remuneration (specifically, bonuses) that executives receive is based on the percentage of the firm's annual net profits. Hence, a firm that provides high executive remuneration tends to achieve an increase in technical efficiency. An examination of the association between types of firm ownership and technical efficiency found that foreign-owned firms and family-owned firms contribute positively to firm technical efficiency. In addition, family-owned firms perform the best, followed by foreign-owned firms, given other types of firm ownership as the base category. Firm size is also one of the factors that positively affect a firm's technical efficiency due to economies of scale. While firm age was found to have a positive correlation with firm technical efficiency, the result was not statistically significant.

The economic significance of this paper is the provision of robust, evidence-based policy implications and recommendations for use by policy-makers and entrepreneurs of listed manufacturing enterprises, aimed at enhancing their technical efficiency and competitiveness.

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