# วิสาหกิจขนาดกลางและขนาดย่อมในภาคอุตสาหกรรมการผลิตของประเทศไทยมีประสิทธิภาพเชิงเทคนิคหรือไม่: วิธีการ Stochastic Frontier Analysis (SFA) และวิธีการ Data Envelopment Analysis (DEA)

# Are Thai Manufacturing SMEs Technically Efficient: Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) Approaches

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## บทคัดย่อ

การศึกษาครั้งนี้ใช้วิธีการ SFA และ DEA เพื่อวัดประสิทธิภาพเชิงเทคนิคของวิสาหกิจขนาดกลางและขนาดย่อม (SMEs) ในภาคอุตสาหกรรมการผลิตของประเทศไทย ผลลัพธ์ของการวิจัยพบว่าประสิทธิภาพเชิงเทคนิคของ SMEs มีค่าต่ำซึ่งอาจนำไปสู่การลดผลิตภาพ ดังนั้นนโยบายที่จำเป็นต่อการเพิ่มประสิทธิภาพเชิงเทคนิคของ SMEs ได้แก่ ความง่ายต่อการเข้าสู่แหล่งเงินทุน และเครดิต ความเท่าเทียมกันจากการช่วยเหลือจากภาครัฐ การพัฒนาระบบการศึกษาและโครงสร้างทางสาธารณูปโภคที่สำคัญ การส่งเสริมด้านเทคโนโลยีรวมไปถึงการบริหาร และการจัดการอย่างเป็นระบบ

**คำสำคัญ:** ประสิทธิภาพเชิงเทคนิค, วิธีการ Stochastic Frontier Analysis (SFA), วิธีการ Data Envelopment Analysis (DEA), วิสาหกิจขนาดกลางและขนาดย่อม (SMEs), อุตสาหกรรมการผลิตของประเทศไทย

## Abstract

This study applies stochastic frontier analysis (SFA) and data envelopment analysis (DEA) approach to measure the technical efficiency of Thai manufacturing SMEs. The empirical results from both SFA and DEA revealed that the overall simple average technical efficiency is relatively low, which can potentially reduce their output contribution. Therefore, specific policies are required to improve the technical efficiency of SMEs and these include easier access to financial services, credit

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facilities, equity in terms of the political operation, educational system, extensive infrastructural development, and technological upgrading, marketing and management.

**Keywords:** Technical Efficiency, Stochastic Frontier Analysis (SFA), Data Envelopment Analysis (DEA); Small and Medium sized Enterprises (SMEs); Manufacturing

## Introduction

Small and Medium sized Enterprises (SMEs) play a pivotal role in accelerating Thai economic development. SMEs provide backward linkages for large enterprises through supply of goods, services, information and knowledge. The number of Thai SMEs was 1,835,873 enterprises, representing 99 per cent of all enterprises in the country and employ more than seven million workers, accounting for 73 per cent of total employment during the period 1994 to 2009. The value of exports by SMEs was THB 1,311,493 million or 33.02 per cent of total exports on overage over the period 2000 to 2009 (Office of Small and Medium Enterprises Promotion (OSMEP), 2001-2009).

The contribution of SMEs to GDP, at current prices, was approximately 38.84 per cent of total GDP over the period 1999-2009 (Office of Small and Medium Enterprises Promotion, 2001-2009). The average number of manufacturing SMEs was approximately 460,002, or 27.14 per cent of total SMEs over the period 1994 to 2009. The employment contribution of manufacturing SMEs is around 2,630,800 workers during 1994 to 2009 which, on average, is equivalent to about 27.13 per cent of total employment in the private sector in this period. The contribution of manufacturing SMEs to total SME GDP is about THB 748,749 million, or 28.68 per cent of total SME output in 1994 - 2009 (OSMEP, 2001-2009); Charoenrat and Harvie (2013); Charoenrat et al., (2012).

Despite their obvious significance Thai SMEs face a number of disadvantages that act as barriers to their development. These barriers comprise: financial constraints, lack of technical and innovation skills, lack of integration in domestic and international markets, lack of export knowledge among others (Charoenrat and Harvie (2012); Charoenrat et al., (2013). However, there is a dearth of evidence on Thailand's manufacturing SMEs particularly in terms of their technical efficiency and their determinants. The primary motivation of this study is to identify the under-performance of Thai manufacturing SMEs in terms of their output and technical efficiency, and investigate factors that influence their relatively poor performance.

This paper is the first empirical study to use SFA and DEA to estimate and explain the technical efficiency of Thai manufacturing SMEs in 2007. Therefore, the major aim of this study is to estimate the level of technical efficiency of Thai manufacturing SMEs in 2007. The estimation is performed by the size of manufacturing SMEs (small and medium) and by sub-manufacturing sectors of operation classified by the Standard International Trade Classification (SITC): Revision 4. We also identify appropriate policies to improve Thai manufacturing SMEs.

The paper is structured as follows. Section 2 explains the methodology and a brief concept of efficiency. Section 3 outlines data and key variables for SFA and DEA approaches. Section 4 compare and discuss the results obtained from the SFA and DEA approaches. Policy Implications and conclusions are presented in Section 5.

## Methodology

A firm's performance is measured by its technical and allocative efficiencies. Technical efficiency can be estimated by either Stochastic Frontier Analysis (SFA) or Data Envelopment Analysis (DEA) approaches (Coelli, 1996b; Herrero and Pascoe, 2002; Coelli *et al.*, 2005; Kontodimopoulos *et al.*, 2010). SFA is a parametric approach where the form of the production function is assumed to be known and is estimated statistically (Coelli, 1996a; Coelli *et al.*, 2005). (Admassie and Matambalya, 2002; Coelli *et al.*, 2005; Arunsawadiwong, 2007; Zahid and Mokhtar, 2007).

On the other hand, DEA is a non-parametric approach that involves the use of linear programming to construct a frontier. It does not require assumptions concerning the form of the production function. Instead, the best practice production function is created empirically from observed inputs and outputs. (Admassie and Matambalya, 2002; Vu, 2003; Coelli *et al.*, 2005; Arunsawadiwong, 2007; Zahid and Mokhtar, 2007). However, the SFA and DEA approaches each have their advantages as well as disadvantages, and that there is no specific set of criteria to select the best method for estimating technical efficiency. Thus, it is quite reasonable to estimate the technical efficiency performance of Thai manufacturing SMEs utilising both methods in an attempt to validate the results, as recommended in many empirical studies such as Kalaitzandonakes and Dunn (1995); Sharma *et al.* (1997); Wadud (2003); Minh *et al.*(2007); O'Donnell *et al.* (2009); Amornkitvikai and Harvie (2010) and Kontodimopoulos *et al.* (2010).

## Data and Variables

This study uses the most substantive and most recently available cross-sectional firm-level data of Thai manufacturing in 2007 from the World Bank Enterprise Survey. The scope of this census consists of enterprises engaged in manufacturing industry activities (Category D International Standard Industrial Classification of all Economic Activities, ISIC: Rev.3 The 2007 industrial census is based upon samples of firms in the manufacturing industry, consisting of small, medium and large enterprises. This study, however, only focuses on data for Thai manufacturing SMEs. The total number of observations is 1,043.

The key variables are output value added (*Y*), labour input (*L*), capital input (*K*).

Output value added (*Y*) is defined as the value of gross output minus intermediate consumption. Labour input (*L*) includes the number of workers in the enterprise, including owner or partner, unpaid workers, skilled and unskilled labour. Capital input (*K*) is measured by the net value of fixed assets less depreciation at the end of the year.

## The Analytical Framework

This section consists of two sections: (1) the stochastic frontier production function (SFA), and (2) the DEA model

## A Stochastic Frontier Production Function (using SFA)

In empirical research a Cobb-Douglas production function is the most commonly used functional form for SFA to estimate technical efficiency. The two-factor Cobb-Douglas production function in logarithmic form utilising cross-sectional data can be expressed as follows:

$$lnY_i = \beta_0 + \beta_1 ln(K_i) + \beta_2 ln(L_i) + (V_i - U_i) \quad i = 1,\ldots, N, \qquad (1)$$

Where:

$Y_i$ = value added of firm $i$;

$K_i$ = the net value of fixed assets of firm $i$;

$L_i$ = the total number of employees of firm $i$;

$V_i$ = a random variable which is assumed to be an independently and identically distributed normal variable with zero mean and variance $\left(V_i \sim iidN(0, \sigma_V^2)\right)$, and is assumed to be independently distributed of $U_i$; and

$U_i$ = a non-negative random variable assumed to account for technical inefficiency in the production function, and is assumed to be independently distributed as truncations at zero of the normal distribution, $\left(U_i \sim N(0, \sigma_U^2)\right)$.

## The DEA Model

The output-orientated VRS model assumes that firms are not operating at optimal scale efficiency due to government regulations, imperfect competition and financial restrictions (Coelli *et al.*, 2005; Cooper *et al.*, 2006; Amornkitvikai, 2011). It is used assuming fixed input quantities and maximized output production. Thus, the output-orientated DEA model under the assumption of VRS can be expressed as follows (Coelli *et al.*, 2005; McDonald, 2009; Amornkitvikai, 2011):

$$Max_{\phi,\lambda} \quad \phi,$$

*Subject to*

$$\begin{aligned} -\phi y_i + Y\lambda &\geq 0, \\ x_i - X\lambda &\geq 0, \quad j = 1, 2, \ldots, I, \\ I1'\lambda &\leq 1, \\ \lambda &\geq 0 \qquad (2) \end{aligned}$$

Where:

$\phi$ is a scalar (an efficiency parameter). $1 \leq \phi < \infty$ and $\phi - 1$ represents the proportional increase in output ($y_i$) that can be obtained by the *i-th* firm, while holding input quantities ($x_i$) constant (Coelli *et al.*, 2005; Minh and Long, 2005; Minh *et al.*, 2007; Amornkitvikai, 2011);

$\frac{1}{\phi}$ is the technical efficiency score that varies between zero and unity and defines a technical efficiency score for the *i-th* firm;

$x_i$ is an input vector for the *i-th* firm;

$\lambda$ is a vector of constants; and $I1'\lambda$ represents non-increasing returns to scale (NIRS).

## Comparing the Empirical Results between the SFA and DEA Approaches

This section aims to compare and discuss the empirical results obtained from the SFA and DEA approaches. Due to the technical efficiency differences in the two approaches, Spearman rank correlation coefficients between the technical efficiency scores obtained from the SFA and DEA approaches (Sharma *et al.*, 1997; Minh *et al.*, 2007; Kontodimopoulos *et al.*, 2010; Amornkitvikai, 2011) were conducted to examine the ranking consistency for Thai manufacturing SMEs in 2007.

Table 1 summarises the results of returns to scale from the SFA and DEA approaches for 2007. As presented in Table 9 the results from both SFA and DEA are found to be quite inconsistent in terms of types of returns to scale. Based upon a stochastic production function (the SFA approach) it can be observed that almost all Thai manufacturing SME categories have experienced IRS in 2007, with the exception of medium-sized enterprises. However, the results of returns to scale from the output-orientated VRS DEA model (the DEA approach) shows that all manufacturing SME categories experienced DRS in 2007 (see Table 1).

**Table 1: Results of Returns to Scale from the SFA and DEA Approaches**

| Categories | SFA | DEA |
|---|---|---|
| Small Enterprises | IRS | DRS |
| Medium Enterprises | DRS | DRS |
| SITC 0: Food | IRS | DRS |
| SITC 1: Beverages | IRS | DRS |
| SITC 2: Crude materials | IRS | DRS |
| SITC 5: Chemicals | IRS | DRS |
| SITC 6: Manufactured goods | IRS | DRS |
| SITC 7: Machinery | IRS | DRS |
| SITC 8: Miscellaneous | IRS | DRS |

**Note:** CRS is Constant Returns to Scale, DRS is Decreasing Returns to Scale, IRS is Increasing Returns to Scale**.**

DEA precludes the possibility of evaluating the marginal products and the elasticity of substitution of the production technology. DEA produces no standard errors with deviations from a frontier treated as technical inefficiency, leaving no provision for random shocks of any type (Coelli *et al.*, 2005; Cooper *et al.*, 2006; Arunsawadiwong, 2007; Assaf, 2007). On the other hand SFA is employed because of its superior conceptual treatment of noise. This approach takes into account measurement errors as well as other random factors, such as the effect of weather, and luck on the value of output variables, together with the combined effects of unspecified input variables in the production function (Coelli, 1996a; Wadud, 2003; Coelli *et al.*, 2005).

As presented in Table 2 the overall simple average technical efficiency scores obtained from the SFA approach are slightly lower than those obtained from the DEA approach in both 1997 and 2007, due to SFA making adjustments for a statistical noise variance (Coelli *et al.*, 2005; O'Donnell *et al.*, 2009). There may be no measurement error as well as other random factors in cross-sectional firm-level data from the 2007 industrial census. Thus, the cause of a statistical noise may arise from the misspecification of a stochastic production function (Coelli *et al.*, 2005; O'Donnell *et al.*, 2009). Unlike the DEA approach, the SFA approach does not guarantee that a firm will select a riskless production plan (O'Donnell *et al.*, 2009).

Furthermore, the empirical results from both SFA and DEA suggest that the technical efficiency performance of most Thai manufacturing SMEs is relatively low in 2007 (see Table 2), and that the government's first SME promotion plan, covering the period 2002-2006, aimed at improving the efficiency and capacity of SMEs has proven to be largely ineffective. Thus, specific policy recommendations are essential to improve the technical efficiency of all categories of manufacturing SMEs. Policy will also require the provision of more skilled workers, in conjunction with greater access to capital and technology by SMEs.

**Table 2: The Simple Average Technical Efficiency Scores from the SFA and DEA Approaches**

| **Categories** | **SFA** | **DEA** |
|---|---|---|
| Small Enterprises | 0.42 | 0.62 |
| Medium Enterprises | 0.65 | 0.74 |
| SITC 0: Food | 0.48 | 0.62 |
| SITC 1: Beverages | 0.54 | 0.68 |
| SITC 2: Crude materials | 0.36 | 0.66 |
| SITC 5: Chemicals | 0.55 | 0.73 |
| SITC 6: Manufactured goods | 0.39 | 0.65 |
| SITC 7: Machinery | 0.59 | 0.70 |
| SITC 8: Miscellaneous | 0.42 | 0.68 |
| **Technical Efficiency** | **0.48** | **0.67** |

## Policy Implications and Conclusions

Thai manufacturing SMEs have played a crucial role in the Thai economy in terms of business numbers, employment and economic growth over the period 1994 to 2009 (OSMEP, 2007b, 2008, 2009). They contribute greatly to the social and economic development of the country. This paper has conducted a comprehensive study of the technical efficiency performance of Thai manufacturing SMEs in 2007, by using the SFA and DEA approaches to test for the robustness of the results. Its findings are important as manufacturing SMEs remain vital to future growth and employment generation in Thailand.

The empirical results from SFA and DEA approaches highlight that the overall simple average technical efficiency of all categories of Thai manufacturing SMEs in 2007 is relatively low. From these results, it is specified that manufacturing SMEs have a high degree of technical inefficiency in the operation in 2007. Therefore, specific policy recommendations are required to improve the technical efficiency of Thai manufacturing SMEs. The basic law and first SME promotion Act were declared in 2000. The first SME promotion plan from 2002 to 2006 provided a strategic direction for developing SMEs. The objective of this plan is to develop more entrepreneurs and facilitate SMEs in meeting international quality standards. This plan aimed to enhance the efficiency and capacity of SME operators with the objective of enhancing their international competitiveness (Mephokee, 2003; OSMEP, 2003; Punyasavatsut, 2007).

However, the results of the first plan were not accomplished because the SME promotion plan was not implemented in unity and lacked a powerful driving force from the policy level to the operational level. Government agencies are not well integrated to support Thai SMEs in accordance with the SME promotion plan. Thus, the Thai government should formulate policies to promote and support SMEs, such as managerial and technical assistance, and training programme and provide financial assistance to avoid management risks and financial problems, promote efficiency in logistics management and in marketing facilities.

Furthermore, it is imperative that relevant government agencies have to be well equipped to play an effective role in order to promote and improve the quality of manufacturing SMEs both qualitatively and quantitatively. This involves improving coordination at both the national and sub-national levels, improving the procedure and structure of government agencies and developing the qualifications of human resources in the public sector. Furthermore, the Thai government should place more emphasis on policies concerning a durable collaboration between public and private sectors, such as the promotion of manufacturing SME growth and integration, cross-border linkages, on-going learning and innovation.

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