Performance measurement of the Thai oil palm farms: a non-parametric approach

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Abstract

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The primary purpose of this study is to measure technical efficiency in Thai oil palm farms. The study decomposes technical efficiency into its pure technical and scale components. The data envelopment analysis (DEA) approach and farm-level cross-sectional survey data of Thai oil palm farms in 2000 are used. The empirical results provide valuable information on efficiency levels, and also suggest that there are significant possibilities to increase efficiency levels in the Thai oil palm farms. In addition, scale inefficiency makes a greater contribution to overall inefficiency.

Key words : technical efficiency, pure technical efficiency, scale efficiency, data envelopment analysis, Thai oil palm farms

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บทคัดย่อ

วิรัช กระแสร์ฉัตร์
การวัดผลการดำเนินงานของสวนปาล์มน้ำมันของไทย: วิธีนอนพาราเมตริกซ์
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จุดประสงค์หลักของการศึกษาครั้งนี้เพื่อวัดประสิทธิภาพการผลิตทางเทคนิคของสวนปาล์มน้ำมันของไทย ซึ่งประสิทธิภาพการผลิตทางเทคนิคสามารถแบ่งออกเป็น 2 ส่วนประกอบ คือ ประสิทธิภาพการผลิตทางเทคนิคที่แท้จริง (pure technical efficiency) และประสิทธิภาพการผลิตด้านขนาด (scale efficiency) การศึกษาครั้งนี้ใช้วิธี data envelopment analysis (DEA) กับข้อมูลที่ได้จากการสำรวจสวนปาล์มน้ำมันในปีการเพาะปลูก 2543 ผลการวิเคราะห์ได้ให้ข้อมูลที่มีคุณค่าเกี่ยวกับระดับประสิทธิภาพการผลิต และเสนอแนะว่ายังมีความเป็นไปได้ที่จะเพิ่มระดับประสิทธิภาพการผลิตของสวนปาล์มน้ำมันของไทย นอกจากนี้พบว่าความไม่มีประสิทธิภาพการผลิต ส่วนใหญ่มาจากความไม่มีประสิทธิภาพการผลิตด้านขนาด

ภาควิชาบริหารธุรกิจเกษตร สถาบันเทคโนโลยีพระจอมเกล้าเจ้าคุณทหารลาดกระบัง ลาดกระบัง กรุงเทพฯ 10520

1. Introduction

Palm oil is an important crop in the Thai economy for two main reasons. First, palm oil is a raw material for producing cooking oil, so that the continuity of palm oil production is crucial for stabilising the cooking oil price. In addition, it is important for cooking fats, margarine and raw material for industrial manufacturing, such as the pharmaceutical and cosmetic industries. As indicated in Suriyapee (2000), in 1997, around 63 per cent of total oil consumption in Thailand was produced from oil palm. Second, as a primary agricultural product, oil palm is a source of income and employment both in production and in manufacturing, at present and in the future.

Due to the importance of palm oil in the Thai economy, the Thai government increased support for development of the palm oil industries in its four year plan (1995-1998). One main policy focused on increasing palm oil production by supporting new high-yielding varieties, and providing agricultural funds for purchasing fertiliser (Ministry of Agriculture and Cooperatives, 1994). Since this development plan was implemented in 1995, both production and, in particular, planted areas of oil palm have increased rapidly.

There are at least three causes for worry concerning the future development of the oil palm industry in Thailand. First, the relatively high growth rate of palm oil production in Thailand has been achieved mainly through the expansion of cultivated areas, as indicated by the Ministry of Agriculture and Cooperatives (2000). Second, although, the high growth rate of oil palm production has been recognised, its yield in Thailand has generally been rather low. Compared with some selected Asian oil palm-growing countries, the yield of palm oil in Thailand was the lowest in 1997 (Ministry of Agriculture and Cooperatives, 2000). Finally, the Thai government has significantly influenced Thai agriculture through a variety of policies over the past three decades. The most important policies in the agricultural economy were export taxes on agricultural products, and quotas and tariffs on machinery and fertiliser imports. They could cause imperfect competition in those inputs and in output markets. In addition, Thailand has experienced cheap land and labour, little agricultural research and no shortage of food for many years. Because of the above factors, economists and policy makers have raised the question about the technical efficiency of Thai oil palm production, especially at farm level.

The main purpose of this study is to measure technical efficiency (decomposed into its pure technical and scale components) of oil palm production at farm level in Thailand. To estimate efficiency scores, the DEA method is applied to farm-level cross-sectional survey data of oil palm farms in three districts of the Southern Region in Thailand. Previous studies have investigated technical efficiency and its components at both the farm and aggregate levels in Thai agriculture (e.g., Tantavaruk, 1985; Chayaputi, 1993; Krasachat, 2000a; 2000b). However, this study, to our knowledge, has been the first application of DEA in order to measure technical efficiency and its components at the farm level in Thai agriculture. This enables more detailed understanding of the nature of technical efficiency in Thai agriculture and, in particular, Thai oil palm farms.

This paper is organised into five sections. Following this introduction, the analytical framework is described. Next, data and their sources are described. The last two sections cover the empirical findings of this study, and conclusions and suggestions for further research.

2. Analytical Framework

Coelli (1995), among many others, indicated that the DEA approach has two main advantages in estimating efficiency scores. First, it does not require the assumption of a functional form to specify the relationship between inputs and outputs. This implies that one can avoid unnecessary restrictions about functional form that can affect the analysis and distort efficiency measures, as mentioned in Fraser and Cordina (1999). Second, it does not require the distributional assumption of the inefficiency term.

According to Coelli, *et al*. (1998), the constant returns to scale (CRS) DEA model is only appropriate when the farm is operating at an optimal scale. Some factors such as imperfect competition, constraints on finance, etc. may cause the firm to be not operating at an optimal level in practice. To allow for this possibility, Banker, *et al*. (1984) introduced the variable returns to scale (VRS) DEA model. Due to the consequence of the heavy intervention by the government in both output and input markets in Thai agriculture as mentioned earlier, farmers may well have been prevented from operating at the optimal level in farm production. Therefore, technical efficiency in this study is calculated using the input-oriented variable returns to scale (VRS) DEA model. Following Fare, *et al*. (1985), Coelli, *et al*. (1998) and Sharma, *et al*. (1999), the VRS model is discussed below.

Let us assume there is data available on K inputs and M outputs in each of the N decision units (i.e., farms). Input and output vectors are represented by the vectors x_i and y_i, respectively for the i-th farm. The data for all farms may be denoted by the $K\times N$ input matrix (X) and $M\times N$ output matrix (Y). The envelopment form of the input-oriented VRS DEA model is specified as:

$$\begin{aligned} &\min_{\theta,\lambda} \theta, \\ &\text{st} \quad -y_i + Y\lambda \geq 0, \\ &\qquad \theta x_i - X\lambda \geq 0, \\ &\qquad N1'\lambda = 1 \\ &\qquad \lambda \geq 0, \end{aligned} \tag{1}$$

where θ is the input technical efficiency (TE) score having a value $0 \leq \theta \leq 1$. If the θ value is equal to one, indicating the region is on the frontier, the vector λ is an N×1 vector of weights which defines the linear combination of the peers of the i-th farm. Thus, the linear programming problem needs to be solved N times and a value of θ is provided for each farm in the sample.

Because the VRS DEA is more flexible and envelops the data in a tighter way than the CRS DEA, the VRS TE score is equal to or greater than the CRS or 'overall' TE score. The relationship can be used to measure scale efficiency (SE) of the i-th farm as:

$$SE_i = \frac{TE_{i,\,CRS}}{TE_{i,\,VRS}} \tag{2}$$

where SE = 1 implies scale efficiency or CRS and SE < 1 indicates scale inefficiency. However, scale inefficiency can be due to the existence of either increasing or decreasing returns to scale. This may be determined by calculating. an additional DEA problem with non-increasing returns to scale (NIRS) imposed. This can be conducted by changing the DEA model in equation (1) by replacing the $N1'\lambda = 1$ restriction with $N1'\lambda \leq 1$. The NIRS DEA model is specified as:

$$\begin{aligned} &\min_{\theta,\lambda} \theta, \\ \text{st} \quad & -y_i + Y\lambda \geq 0, \\ & \theta x_i - X\lambda \geq 0, \\ & N1'\lambda \leq 1 \\ & \lambda \geq 0, \end{aligned} \qquad (3)$$

If the NIRS TE score is unequal to the VRS TE score, it indicates that increasing returns to scale exist for that region. If they are equal, then decreasing returns to scale apply.

Note that efficiency scores in this study are estimated using the computer program, **DEAP** Version 2.1 described in Coelli (1996).

3. Data

The data used in this study are based on a direct interview survey of 63 randomly selected oil palm farm households in three districts of Surat Thani province of Thailand. The selected districts were Phun Pin, Phra Saeng and Chai Buri. These are predominantly palm oil producing and have a similar climate and soil type. The data were for the 2000 crop year (January-December). The farms selected were owner operated and had faced a similar economic and marketing environment for inputs and outputs. In addition, all the farms used a similar technology for palm oil production except for differences in intensity and management.

One output and six inputs are used in the empirical application of this study. The six inputs groups are fertiliser, hired labour, family labour, capital, land and "other inputs". These input and output variables are defined in Table 1 whilst Table 2 provides summary statistics for all of the variables included in the empirical model.

4. Empirical Results

Technical and scale efficiency scores of Thai agricultural production were calculated using equations (1) and (2) at the sample means. However, the results must be viewed with caution, especially due to the small sample size of data. Table 3 indicates that the mean values of overall technical, scale and pure technical, efficiency are 0.677, 0.759 and 0.883, respectively. Note that the overall technical efficiency of a oil palm farm is the product of its scale efficiency and its pure technical efficiency. These empirical results suggest two important findings. First, there are significant possibilities to increase efficiency levels in the Thai oil palm farms. The average overall technical

Table 1 Variable definitions and measurement.

Variables	Units	Definitions
Palm oil output (y)	Metric Tons	Quantity of palm oil produced per farm
Fertiliser (x_1)	Kg	Quantity of chemical fertiliser used per farm
Hired labour (x_2)	Baht	Cost incurred for using hired labour per farm
Family labour (x_3)	Man-days	Amount of family labour used per farm
Capital (x_4)	Baht	Cost incurred for using mechanics and tools per farm including the costs of maintenance, repairs, depreciation and interest
Land (x_5)	Rai	Planted area per farm (1 rai = 0.16 hectare)
Other inputs (x_6)	Baht	Total costs incurred for using pesticide, herbicides and all variable expenses per farm, except the above inputs

Table 2 Summary statistics of data sample.

Variables	Minimum	Maximum	Mean	Std. Deviation
y	20.00	522.00	119.14	92.14
x_1	514.00	15600.00	2980.10	2427.60
x_2	960.00	146464.00	22480.81	24962.19
x_3	4.00	9248.00	543.03	1310.28
x_4	31.20	303598.80	35189.85	53497.52
x_5	10.00	130.00	31.33	20.53
x_6	540.00	26720.00	5506.34	5614.66

Table 3 Technical and scale efficiency scores of Thai oil palm farms.

	Overall technical efficiency	Scale efficiency	Pure technical efficiency
Average	0.677	0.759	0.883
Std. deviation	0.263	0.226	0.180
Minimum	0.116	0.220	0.284
No. of efficient farms	15	15	34

inefficiency could be reduced by 32 per cent, on average, by operating at optimal scales and by eliminating pure technical inefficiencies via the adoption of the best practices of efficient oil palm farms. Second, the results also indicate that scale inefficiency for the Thai oil palm farms makes a greater contribution to overall inefficiency.

The scale efficiency results are summarised in Figure 1. The DEA results suggest that, of 63 observations, 24 per cent operated at their optimal scale, 8 per cent operated above their optimal scale and 68 per cent operated below their optimal scale.

The characteristics of each of the above three groups of oil palm farms are shown in Table 4. This indicates that the largest increase in overall technical efficiency could be achieved by eliminating the problem of increasing returns to scale, while eliminating the problem of decreasing returns to scale would increase overall technical efficiency to a lesser extent. This implies, from an agricultural policy viewpoint, that if production efficiency of Thai oil palm farms is to be improved, increasing farm size would be better than decreasing the size of farms.

Although the analytical results in general indicate that there exist advantages in increasing farm size, it would be better to use them to focus on efficiency improvement at the level of individual oil palm farms. Jaforullah and Whiteman (1999) indicated that there is a positive relationship between the availability of extension services and farm technical efficiency. An increase in the rate of diffusion of technology and optimal farm management practices, encouraged by extension services and programs, should increase the technical efficiencies of the inefficient oil palm farms in Thailand.

5. Conclusions and Suggestions for Further Research

An input-oriented DEA model was used for estimating overall technical, scale and pure technical, efficiencies in the oil palm farms of Thailand.

The empirical results indicate that there are significant possibilities to increase efficiency levels in the Thai oil palm farms. The average overall technical inefficiency could be reduced by 32 per

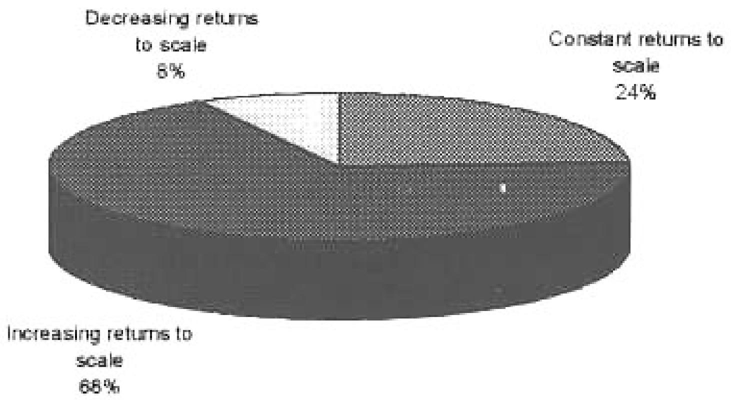

Figure 1 The scale efficiency of Thai oil palm farms.

cent, on average, by operating at optimal scales and by eliminating pure technical inefficiencies through the application of the best practices of efficient oil palm farms. In addition, the results also indicate that scale inefficiency for the Thai oil palm farms provides a greater contribution to overall inefficiency.

The results indicate advantages in increasing farm size in the Thai oil palm farms. However, extension services should be used to increase the technical efficiencies of these inefficient farms in Thailand. As mentioned above, the results must be viewed with caution due to the small sample size of data.

The analysis presented in this paper can be improved in a number of areas. Some areas of further research should be considered. These include: comparing stochastic and DEA frontier analyses; and investigating the determinants of technical inefficiency in the Thai oil palm farms.

Table 4 Technical efficiency and the scale of Thai oil palm farms.

Oil palm farms	Constant returns to scale	Decreasing returns to scale	Increasing returns to scales
Number	15	5	43
Area (rai)[1]			
Average	37.93	41.60	27.84
Minimum	12	22	10
Maximum	110	70	130
Average values of technical efficiency			
Overall technical efficiency	1.00	0.74	0.56
Pure technical efficiency	1.00	0.82	0.85

[1] 1 rai = 0.16 hectare

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