Estimation of Technical Efficiency for Rice Farms in Central Thailand Using Stochastic Frontier Approach

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ABSTRACT

As one of Thailand's economic crops, rice plays an important role in generating national income and creating domestic employment for the country. Its production has been increasing because of the expansion of areas planted to rice and not due to increases in productivity. The national average yield is considerably low compared with that of other rice-producing countries.

This study measured the technical efficiency of rice farmers in the central region of Thailand and identified the factors causing technical inefficiency using stochastic frontier analysis (SFA) approach specified as a translog production function. Cross-sectional data were randomly collected from 384 sampled farmers from nine provinces of central Thailand who generally operated their farms using pre-germinated broadcasting method in the major rice crop year 2009/2010.

Results reveal that technical efficiency ranged from 49.69 to 97.17 percent, with a mean of 85.35 percent. Gender, farming experience, good agricultural practices (GAP), and cropping intensity were found to contribute positively toward farm technical efficiency. Farmers should be provided knowledge of GAP and should adopt GAP in their farms' activities. Agricultural extension officers should organize knowledge and experience exchange between successful farmers and other farmers, and promote the use of certified seeds to improve farm efficiency and farmers' income.

Keywords: technical efficiency, stochastic frontier analysis (SFA), rice farms, Thailand
JEL Classification: D2, Q12, R3

INTRODUCTION

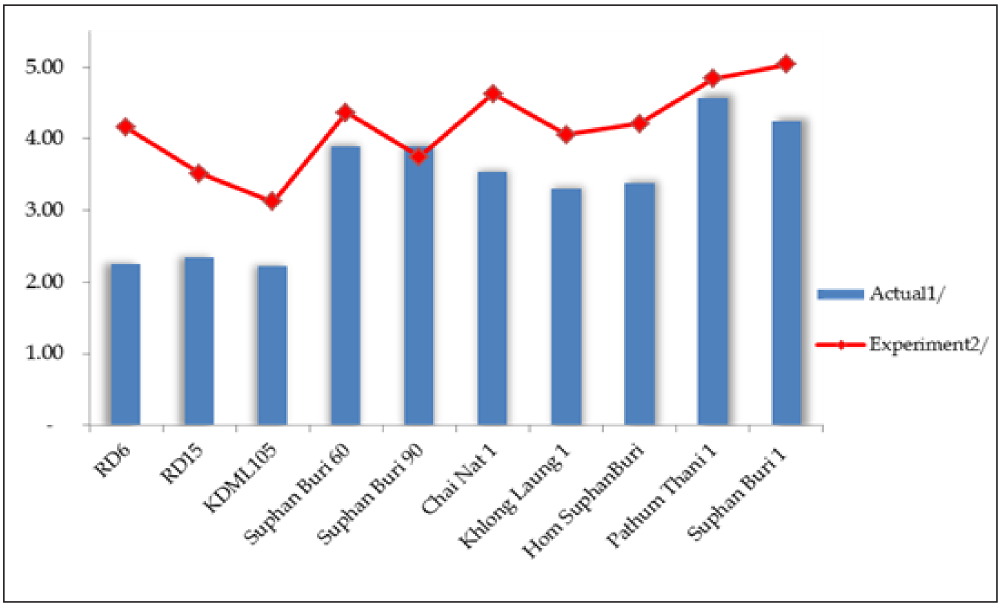
The agricultural sector plays an important role in Thailand's economy, especially rice production, which covers more than 3.71 million households (Office of Agricultural Economics 2010). Thailand has been projected to become a world leader in rice production and trade. The growth of Thai rice production, however, has been due to rice area expansion and not from increases in productivity. Figure 1 shows the gaps between farmers' yields and the maximum yield potential of certain rice varieties. Compared with other top rice-producing countries, Thailand has a lower rice yield (Table 1), averaging 2.88 tons per hectare (t/ha) only between 2003 and 2007. Egypt had the highest average at 9.99 tons/ha, followed by the United States, South Korea, and Japan at 7.71, 6.46, and 6.35 tons/ha, respectively.

Agricultural extension is a very important aspect. It has to do with knowledge transfer from researchers to farmers so that the latter could make better decisions based on their own goals and possibilities (van der Ban and Hawkins 1988). Extension can bridge the gap between potential and actual yield by addressing the technology gap (e.g., use of high-yielding varieties or new machinery) and management gap (e.g., improved farm management practices) (Anderson and Feder 2003). Therefore, extension service was hypothesized to contribute to farm efficiency and lead to increased rice yield.

This study measured the technical efficiency of paddy farms and explored the factors causing technical inefficiency, especially as regards agricultural extension and environmental factors.

The next section briefly reviews relevant literature on technical efficiency measurement, data and variables used, and model specification. The results are then presented and discussed. The last part presents the conclusions and draws some policy implications.

Figure 1. Average actual Thai rice yields for each variety between 2006 and 2008 vis-à-vis their yield potential from experimental fields



Sources: Center of Agricultural Information (2010); Rice Department (2010)

Table 1. Average rice yield of major producing countries, 2003-2007 (tons/ha)

Country	2003	2004	2005	2006	2007	Average
China	6.06	6.31	6.25	6.28	6.42	6.26
India	3.12	2.98	3.15	3.19	3.30	3.15
Indonesia	4.54	4.54	4.57	4.62	4.71	4.60
Bangladesh	3.58	3.54	3.78	3.85	4.01	3.75
Vietnam	4.64	4.86	4.89	4.89	4.98	4.85
Myanmar	3.55	3.78	3.62	3.76	3.98	3.74
Thailand	2.65	2.86	2.96	2.92	3.01	2.88
Philippines	3.37	3.51	3.59	3.68	3.80	3.59
Malaysia	3.36	3.33	3.42	3.39	3.33	3.37
Japan	5.85	6.42	6.65	6.34	6.51	6.35
USA	7.48	7.83	7.44	7.73	8.09	7.71
Pakistan	2.96	2.99	3.17	3.16	3.30	3.12
Egypt	9.75	9.84	9.99	10.07	10.29	9.99
Cambodia	2.10	1.98	2.48	2.49	2.62	2.33
S. Korea	5.92	6.73	6.57	6.71	6.35	6.46
Nepal	2.68	2.86	2.78	2.72	2.56	2.72
Madagascar	2.30	2.45	2.71	2.70	2.77	2.58
Iran	4.76	4.16	4.36	4.14	5.56	4.60
Nigeria	1.41	1.42	1.43	1.48	1.30	1.41
Sri Lanka	3.37	3.65	3.55	3.71	3.93	3.64
Brazil	3.25	3.56	3.37	3.88	3.83	3.58
Rest of the world	3.35	3.45	3.47	3.54	3.58	

Source: Food and Agriculture Organization of the United Nations (2009)

METHODOLOGY

Measurement of Technical Efficiency

The measurement of technical efficiency—the ability of a firm to obtain maximal output from a given set of inputs—was first proposed by Farrell (1957 in Coelli, Rao, and Battese 1998). To explain, Coelli, Rao, and Battese (1998) use the example of a firm that produces a single output (y) with two inputs (x_1 and x_2). Given Isocost line AA' and Isoquant line BB', when the firm uses certain quantities of inputs to produce output at point *P*, technical efficiency is most commonly measured by the ratio of

$$TE_i = \frac{OQ}{OP} \qquad 0 < TE_i \leq 1$$

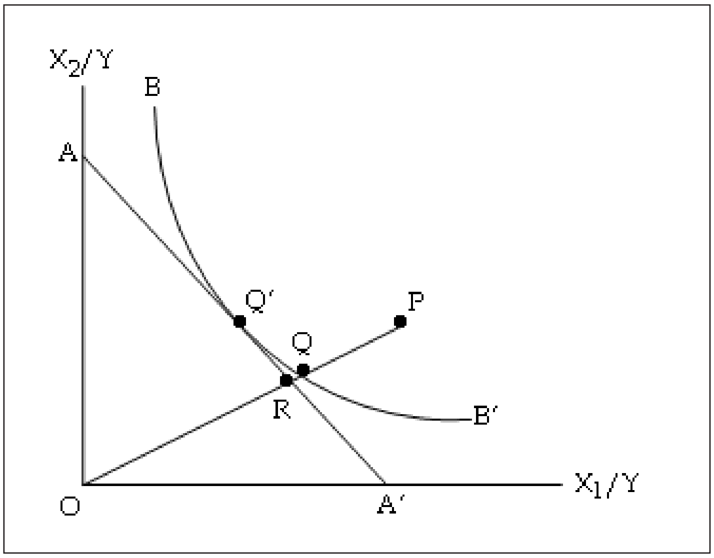
which is equal to $1-QP/OP$ (Figure 2). The resulting ratio, a value between 0 and 1, indicates the degree of technical inefficiency of the firm. A value of 1 indicates full technical efficiency. The ratio of *QP/OP* expresses the amount of inputs required to have a technically efficient production.

The most popular approach for measuring efficiency is stochastic frontier analysis (SFA). As proposed independently by Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broeck (1977), the stochastic frontier production function can be expressed in the following equation:

$$y_i = x_i\beta + v_i - u_i\,, \quad i = 1, 2, \ldots N$$

where y_i denotes the output of the firm or farm, x_i represents the vector of inputs applied in the production, and β is the vector of unknown parameters to be estimated. The error term is decomposed into two components: v_i accounts

Figure 2. Measurement of technical efficiency



Source: Coelli, Rao, and Battese (1998)

for measurement error and other random factors that farmers cannot control and u_i is the inefficiency. The v_i is independent and identically distributed to normal random variables with zero mean and constant variance as N $(0, \sigma_v^2)$. The u_i is assumed to be a non-negative truncation of the N $(0, \sigma^2)$-distribution. The σ^2 is equal to $\sigma_v^2 + \sigma_u^2$ and γ equals σ_u^2/σ^2. The σ^2 is the variance of the normal distribution, which gives the distribution of u_i. If this variance is zero, it means that all u_i and γ are zero, implying that all firms are fully efficient.

Data and Variables

Farmers who planted paddy with pre-germinated broadcasting method were randomly surveyed using proportional stratified sampling method (Figure 3). They were from nine provinces of central Thailand: Chainat, Sing Buri, Lopburi, Ang Thong, Saraburi, Ayutthaya, Pathum Thani, Nonthaburi, and Bangkok.

The pre-germinated broadcasting method is generally adopted in the study area, where rice could be cultivated throughout the year. Central Thailand has the highest rice yield average in the country, but the potential yield of the planted rice varieties has not been reached yet. Cross-sectional data used in this study were collected from 384 sampled farmers in the major crop year 2009/2010.

The variables consist of two sets of data: (1) variables on rice output and input used on a per hectare basis, and (2) determinant variables such as demographic and farm characteristics as well as agricultural extension characteristics. Details are shown in Table 2.

Model Specification

The translog production frontier can be specified as follows:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{5} \beta_j \ln X_{ji} + \sum_{j\leq,k=1}^{5} \beta_{jk} \ln X_{ji} \ln X_{ki} + v_i - u_i$$

where ln represent the logarithm, Y represents the rice output, X_1 represents quantity of seed,

Figure 3. Map of central Thailand and study sites

X_2 represents quantity of fertilizer, X_3 represents quantity of pesticide, X_4 represents quantity of fuel, and X_5 represents labor cost.

The v_i and u_i are as defined above. The u_i accounts for technical inefficiency, whose distribution assumption was proposed by Battese and Coelli (1995). The determinants affecting technical efficiency equation are given as:

$$U_i = \delta_0 + \sum_{m=1}^{12} \delta_m Z_m$$

where Z_m represents the explanatory variables in the inefficiency effect model relevant with the demographic, farm, and agricultural extension characteristics.

Table 2. Variables used in the study

Variable	Description and Measurement
Production function	
Y	Total rice yield (kg/ha)
X_1	Total amount of seeds used (kg/ha)
X_2	Total amount of fertilizers used (kg/ha)
X_3	Total amount of pesticides used (ml/ha)
X_4	Total amount of fuel used (liters/ha)
X_5	Total cost of labor (USD/ha)
Inefficiency effect	
Demographic variables and farm characteristics	
GEND	Gender (male = 1, female = 0)
EDU	Educational level of farmers (higher than primary school = 1, primary school = 0)
EXP	Farming experience (year)
FAML	No. of family labor (person)
FSIZE	Farm size (ha)
FSIZE2	Farm size squared
TENURE	Land tenure (rental land = 1, otherwise = 0)
Agricultural extension variables	
AGMEM	Member of agricultural organization (yes = 1, no = 0)
VISIT	Visit from extension officers (once a month = 1, otherwise = 0)
GAP	GAP certificate (yes = 1, no = 0)
BURN	Burning rice straw (no = 1, otherwise = 0)
PTIME	Length of planting (time)

RESULTS AND DISCUSSION

The results show that on the average, farmers applied 157.36 kilogram (kg) of seeds, 372.10 kg of fertilizers, about 4.1 liters (L) of pesticides, 82.49 L of fuel, and paid about USD (United States Dollar) 223 for labor in order to produce 4.39 t/ha of paddy rice (Table 3). The level of technical efficiency ranged from 49.69 to 97.17 percent, with a mean of 85.35 percent (Table 4). It was found that over 76 percent of the total 320 farmers achieved technical efficiency above 80 percent; 2.5 percent performed below 60 percent of technical efficiency.

This study applied the translog production function in the analysis because it has a flexible functional form (Coelli, Rao, and Battese 1998). The results for the translog production function and the determinants from the SFA approach were simultaneously analyzed but are separately presented in Table 5 and Table 6, respectively.

As shown in Table 5, the estimated coefficients for the logarithm of inputs show a positive value with the exception of pesticide (lnX_3). The estimated coefficients for fuel (lnX_4) and labor cost (lnX_5) are positive and significant at 5 percent level. This indicates that an increase in seed, fertilizer, fuel, and labor cost used would increase the rice output level. Fuel and labor costs especially have a significant impact on rice output. On the other hand, an increase in pesticide would lead to an output decline. This may be due to pesticide application in the third stage of production when it should already be decreased.

As expected, the estimated coefficients are negative, except those for farm size and burning rice straw (Table 6). Of the 12 variables, four are statistically significant:

Table 3. Descriptive statistics for production variables

Variable	Descriptive Statistics Result			
	Mean	Maximum	Minimum	Standard Deviation
Rice yield (kg/ha)	4,393.28	6,250.00	1,875.00	935.16
Seed (kg/ha)	157.36	189.38	118.75	15.47
Fertilizer (kg/ha)	372.10	468.75	87.50	86.88
Pesticide (ml/ha)	4,189.16	10,125	875.00	1,949.91
Fuel (L/ha)	82.49	195.31	10.87	41.33
Labor cost (USD/ha)	223.22	282.20	134.47	33.04

Table 4. Frequency distribution of technical efficiency

Technical Efficiency (%)	Number of Farmers	Percentage
41 – 50	1	0.30
51 – 60	7	2.20
61 – 70	31	9.70
71 – 80	35	10.90
81 – 90	105	32.80
91 – 100	141	44.10
Total	320	100.00

Table 5. Translog Stochastic Frontier Analysis (SFA) model

Variable	Parameter	Coefficient	*t*-ratio
Constant	0	–49.09 (26.43)	–1.857*
($\ln X_1$) Seed	β_1	7.809 (6.298)	1.239
($\ln X_2$) Fertilizer	β_2	2.759 (2.914)	0.946
($\ln X_3$) Pesticide	β_3	–0.623 (0.960)	–0.648
($\ln X_4$) Fuel	β_4	2.560 (1.246)	2.054**
($\ln X_5$) La**or cost	β_5	10.228 (5.052)	2.024**
$(\ln X_1)^2$	β_6	–0.251 (0.535)	–0.470
$(\ln X_2)^2$	β_7	–0.111 (0.085)	–1.313
$(\ln X_3)^2$	β_8	0.033 (0.027)	1.181
$(\ln X_4)^2$	β_9	0.021 (0.025)	0.857
$(\ln X_5)^2$	β_{10}	–0.845 (0.305)	–2.770***
$(\ln X_1)(\ln X_2)$	β_{11}	–0.148 (0.302)	–0.492
$(\ln X_1)(\ln X_3)$	β_{12}	–0.036 (0.180)	–0.201
$(\ln X_1)(\ln X_4)$	β_{13}	–0.372 (0.164)	–2.262**
$(\ln X_1)(\ln X_5)$	β_{14}	–0.475 (0.539)	–0.881
$(\ln X_2)(\ln X_3)$	β_{15}	–0.056 (0.070)	–0.764
$(\ln X_2)(\ln X_4)$	β_{16}	–0.109 (0.070)	–1.556
$(\ln X_2)(\ln X_5)$	β_{17}	0.065 (0.287)	0.226
$(\ln X_3)(\ln X_4)$	β_{18}	0.009 (0.033)	0.282
$(\ln X_3)(\ln X_5)$	β_{19}	0.099 (0.109)	0.905
$(\ln X_4)(\ln X_5)$	β_{20}	–0.048 (0.127)	–0.384

Notes: ***, **, * indicate significant at 1%, 5%, and 10% levels, respectively.
Figures in parentheses in the coefficient column are standard errors.

Table 6. Determinants of technical inefficiency model by translog SFA

Variable	Parameter	Coefficient	*t*-ratio
Constant	δ_0	0.744 (0.190)	3.917***
Demographic variables and farm characteristics			
GEND	δ_1	–0.120 (0.064)	–1.861*
EDU	δ_2	–0.077 (0.064)	–1.197
EXP	δ_3	–0.004 (0.002)	–1.654*
FAML	δ_4	–0.010 (0.040)	–0.256
FSIZE	δ_5	0.052 (0.036)	1.462
FSIZE2	δ_6	–0.002 (0.002)	–1.078
TENURE	δ_7	–0.095 (0.070)	–1.348
Agricultural extension variables			
AGMEM	δ_8	–0.035 (0.056)	–0.626
VISIT	δ_9	–0.048 (0.056)	–0.866
GAP	δ_{10}	–0.290 (0.148)	–1.954*
BURN	δ_{11}	0.100 (0.063)	1.576
PTIME	δ_{12}	–0.338 (0.106)	–3.175***
Sigma-squared	σ^2	0.066 (0.021)	3.087***
Gamma	γ	0.876 (0.047)	18.41***

Notes: ***, **, * indicate significant at 1%, 5%, and 10% levels, respectively.
Figures in parentheses in the coefficient column are standard errors

gender, farming experience, GAP certificate, and cropping intensity. The rest of the variables are insignificant.

The coefficient of gender is negative and significant for technical inefficiency at 10 percent level. This implies that male farmers are more likely to be efficient compared to their female counterparts. This could be because the male farmers have better access to institutional support and capital resources (Olarinde, Ajao, and Okunola 2008; Ross, Dalton, and Featherstone 2009)

Rice farming experience is significantly related and contributes positively toward technical efficiency at 10 percent level. This result was expected since more experienced farmers tend to be more efficient than those who are less experienced. This may be due to the former having more knowledge of the practice and management of paddy farms (Battese and Coelli 1995; Champhech 2003; Ajibefun, Daramola, and Falusi 2006; Begum et al. 2009; Gul et al. 2009).

Having a GAP certificate is one of the agricultural extension variables that showed a positive impact on technical efficiency. This variable reflects the knowledge that farmers have adopted via agricultural extension activities. Farmers who have a GAP certificate are likely to practice sustainable farm practices, resulting in higher farm efficiency (Parikh and Shah 1994; O'Neill, Matthews, and Leavy 1999; Lachaal et al. 2005; Songsrirote and Singhapreecha 2007; Ross, Dalton, and Featherstone 2009).

Normally, rice is planted twice a year, once during the wet season and once during the dry season. The analysis reveals that farmers who cultivate more than once a year are likely to be more technically efficient. In central Thailand, paddy fields are in fertile areas with irrigation systems. Thus, farmers who are able to properly organize their farm activities and manage the irrigation system as well as their resources could have more croppings in a year and are likely to be efficient.

Table 7 shows the results of the hypothesis testing. The first null hypothesis, which posits that the Cobb-Douglas production function is the adequate representative and fitted the data, was rejected. This means the translog stochastic frontier production function was appropriate for the data of sampled farmers. The second null hypothesis, which states that there are no inefficiency effects in the model, was rejected also. This affirms that inefficiency effects existed in the model. The third null hypothesis, which proposes that the explanatory variables in the inefficiency model have no effect, was likewise rejected. This implies that the 12 variables in the study significantly contributed to the inefficiency effect model.

CONCLUSION

The study investigated the technical efficiency and factors affecting technical inefficiency of rice farms in the central region of Thailand, particularly agricultural extension characteristics, using SFA. Data were randomly collected from 384 farmers; data from 320 farmers were analyzed. The explanatory variables explaining technical inefficiency consist of demographic, farm characteristics, and agricultural extension characteristics.

The results reveal that the mean technical efficiency was 85.35 percent, ranging from 49.69 to 97.17 percent. Tests on the hypotheses show that inefficiency existed in rice farms in central Thailand and that the inefficiency model was affected by the factors causing technical efficiency variations across farms, particularly gender, farming experience, GAP certificate, and cropping intensity. That is, male farmers with more experience and have a GAP certificate and those who plant rice more than once a year are more likely to be efficient.

The results imply that effectively applying inputs and resources could increase farm efficiency. Moreover, GAP training programs should be intensified to bridge the gap in farmers' knowledge. Group meetings, where farmers may share experiences on farm practices, should be organized. Likewise, fiscal and policy support should be provided to the farmers so that they can improve their ability to manage their farms.

Table 7. Testing of hypotheses from the Stochastic Frontier Analysis (SFA) approach

Null Hypothesis	LR Value	Critical Value	Decision
Cobb-Douglas production function (H_o: β_{jk} = 0)	28.14	24.99	Rejected H_0
Absence of inefficiency effect (H_o: γ = 0)	61.39	23.07	Rejected H_0
No explanatory variables (H_o: $\delta_1 = \ldots = \delta_{12} = 0$)	40.46	20.41	Rejected H_0

Note: Critical values were adopted from Kodde and Palm (1986)

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