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Efficiency change in Thailand rice production: Evidence from panel data analysis

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The impact of modern rice varieties (Mvs) adoption over the past few decades has undergone changes in Thailand's rice production. This has led to the increase in average rice yields in both wet and dry seasons. At the present time, the average rice yield per rai nearly reached the maximum point given the current production technology. The findings indicated that the cost of rice production increased to about 85.67% from those in the last few decades. Machinery, fertilizer and land use costs came out most significant in the outlay. Therefore, even though the paddy price sharply increased in the 2007/08 crop year, production costs went even higher, causing many farmers to suffer from production loss. By estimating the production frontier, it reveals that rice production in general operates in a decreasing return to scale, suggesting the ineffectual yield of the input factor use to rice performance. The technical efficiency score of 88.32% in 1987/88 crop year and decreasing to 72.63% in 2007/08 crop year denotes a production trend that is less than the potential output possible over time. The study suggests crop diversification as one strategy to improve production efficiency at the farm level and supervised credit on fertilizers and seeds to farmers to provide farm managerial support.

Key words: Rice production, technical efficiency, time-varying model, efficiency change, Thailand.

INTRODUCTION

Rice production in Thailand has been changing continuously from the beginning of the Green Revolution in the 1960s. Key changes occurred with the development of the irrigation system especially in the Central Plain region, called the zone of Chao Phraya Project. With irrigation, the modern rice varieties (MVs) became widely adopted because of their high yield performance, high response to fertilizer in irrigated environment, and early maturity. The latter characteristics has allowed farmers to cultivate two to three crops a year, increasing the demand for hired labor as a consequence of higher cropping intensity. The adoption of MVs in Thailand over the past few decades has also driven many changes in rice production. These included the application of new technologies, use of chemical fertilizers. From adoption of new rice varieties that are non-photo period sensitive. This enabled farmers to obtain a higher average rice yield in the wet season, from 267 kg per rai in 1971-75 to 370 kg per rai in 2006-10, and the dry season, from 514 kg per rai in 1971-75 to 674 kg per rai in 2006-10. At present however, the average rice yield per rai has nearly reached the maximum point under the present technology of production. Increasing rice yield per rai under the present technology could be achieved by improving the socio-economic characteristics and production management of farmers (Songsrirod, 2007).

In other words, technical efficiency of rice production can be increased by improvements in farmer characteristics, farm characteristics, environmental condition and agricultural practices (Alviar, 1979). Improving the aforementioned factors would improve the technical efficiency of farmers and increase rice productivity. Studies have shown that Thai farmers had been producing rice below the ultimate potential output (Sriboonchitta and

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Wiboonpongse, 2000; Wiboonpongse et al., 2005; Pochatarn, 2005; Songsrirod, 2007). The findings suggest there is scope to increase their production efficiency. Patmasiriwat and Isvilanonda (1990) found that there still existed some inefficiency in the Thai farmers and that their actual output was 10% lower than the potential output. The farmers in the irrigated area had higher production efficiency than those in other areas. This indicates that the development of irrigation system and the release of new rice varieties have contributed to the improvement of production efficiency of Thai farmers. They used the cross-sectional data only in the 1987/88 crop year, which, obviously cannot be used to explain the changes in efficiency of rice production over time.

This paper attempting to recollect the data from the same farming of households for 2007/08 crop year. The panel data can be used to explain the change of technical efficiency between the 1987/88 and 2007/08 crop years. It could also explain more systematically and clearly the rice production changes in Thailand, especially the efficiency of rice production and productivity of input factors including labor. This would be useful for planning and policy making to solve the problems associated with inefficiencies in rice production and to improve the well-being of Thai farmers.

DATA USE AND COLLECTION

This study used farmer household panel data in 1987/88 and 2007/08 crop years. The different production environments for the study were represented by sample villages. In Suphan Buri Province, Wang Yang (SP1) represented an irrigated area, Sra Ka Jom (SP2) a rainfed and drought-prone area, and Jorakhe Yai (SP3) a flood-prone area. Three more villages were selected in Khon Kaen Province, namely, Khokna-ngam (KK1) as the representative of irrigated area, Kai Na (KK2) of rainfed area, and Ban Meng (KK3) of rainfed and drought-prone area. The data in 2007/08 crop year were taken from the repeat sample survey conducted by Thailand Research Fund and the Faculty of Economics, Kasetsart University.

The data covered the wet and dry seasons of 2007/08 crop year, under the project, “Dynamic of Thailand’s rice production economy and the future outlook”. The survey was carried out in August to September 2008. The survey data indicated that of the 295 farming households surveyed in 1987/88 crop year, 228 households remained in rice production in 2007/08 crop year (or 76% of the number of sample households in 1987/88 crop year).

ANALYTICAL FRAMEWORK

Time-varying production frontier model

Technical efficiency in production is defined as the ability of the farmer to produce at the maximum output (frontier production), given quantities of inputs and production technology (Aigner et al., 1977). The level of technical efficiency of a particular firm is characterized by the relationship between observed production and some ideal or potential production (Greene, 1993). The approaches for estimating technical efficiency can be generally categorized under the distinctly opposing techniques of non-parametric and parametric approach (Seiford and Thrall, 1990). The parametric or econometric approach has been motivated to develop stochastic frontier models based on the deterministic parameter frontier of Aigner and Chu (1968). The Stochastic Frontier Analysis (SFA) acknowledges the random noise around the estimated production frontier. In a simple case of a single output and multiple inputs, the approach predicts the outputs from input by the functional relationships $y_i = f(x_i, \beta) + \varepsilon_i$, where i denote the efficient observation being evaluated and β are the parameters to be estimated. The residual ε_i is composed by a random error v_i (the effect of uncontrolled variable such as weather etc.) and an inefficiency component u_i.

Many previous researches estimated technical efficiency of rice production using cross-sectional data. These researches however failed to explain obviously the change of rice production over time period. This issue could be resolved by using panel data production frontier model to minimize the limitations of cross-sectional model. Moreover, it is expected that access to panel data will either enable some of the strong distribution assumptions used with cross-sectional data to be relaxed or results in estimates of technical efficiency be with more desirable statistical properties. Moreover, the efficiency changes through time will be found. By utilizing panel data, the production frontier model has two concepts. The first is the time-invariant concept, which considers panel data production frontier that allows technical efficiency to vary across producers, but it is assumed to be constant through time for each producer. In this framework, several conventional panel data model can be adapted to the problem of estimating technical efficiency. However, the assumption of time invariance of technical efficiency may be considered slightly, particularly in long panel. The second concept is the time-varying production frontier, in which technical efficiency is allowed to vary across producers and through time for each producer. Cornwell et al. (1990) and Kumbhakar (1990) were perhaps the first to propose a stochastic production frontier panel data model with time-varying technical efficiency. This model is given by Equation (1):

$$\ln y_{it} = \beta_{ot} + \sum_n \beta_n \ln x_{nit} + v_{it} + u_{it}$$
$$= \beta_{it} + \sum_n \beta_n \ln x_{nit} + v_{it} \qquad (1)$$

Where $u_{it} = \beta_t * u_i, \varepsilon_{it} = v_{it} - u_{it} = v_{it} - \beta_t * u$ and

$\varepsilon_i = (\varepsilon_{i1},..., \varepsilon_{it}) * \beta_{ot}$ is the production frontier intercept common to all producers in the period t, $\beta_{it} = \beta_{ot} - u_{it}$ is the intercept for producer i in period t, and all other

Table 1. Variables, definition and unit of analysis used in the time-varying frontier model.

Variable	Definition	Unit of measure
PROD	Paddy rice yield	Kg
SEED	Seed use	Kg
FERT	Fertilizer use	Kg
HLAB	Hired labor	Man-days
FLAB	Family labor	Man-days
MACH	Machinery hour	Hours
CHEM	Chemical value	Baht
SP1	The dummy variable for SP1	1=SP1, 0=otherwise
SP3	The dummy variable for SP3	1=SP3, 0=otherwise
KK1	The dummy variable for KK1	1=KK1, 0=otherwise
KK2	The dummy variable for KK2	1=KK2, 0=otherwise
KK3	The dummy variable for KK3	1=KK3, 0=otherwise
YEAR07	The binary indicator for 2007/08 crop year	1=2007/08 crop year, 0=otherwise

SP1, SP3, KK1, KK2 and KK3 is the dummy variable represent the differential of production environment; the SP2 is the base area.

variables are as previously defined.

A maximum likelihood estimation for u_i can be obtained from the mean or mode of u_i / ε_i , which are given by (2)

$$E(u_i / \varepsilon_i) = \mu_* \left[\frac{\phi(-\mu_{*i} / \sigma_*)}{1 - \varphi(-u_{*i} / \sigma_*)} \right] \quad (2)$$

Where $u_{*i} = -\frac{(\sum_t \beta_t * \varepsilon_{it})\sigma_v^2}{(\sigma\int_v^2 + \sigma_u^2 \sum_t \beta_t^2)}$ and $\sigma_* = \frac{\sigma_u \sigma_v}{\sqrt{\sigma_v^2 + \sigma_u^2 \sum_t \beta_t^2}}$

Once u_i has been estimated, u_{it} can be estimated from $u_{it} = u_i * \beta_t$. The minimum square error predictor of technical efficiency is explained by (3),

$$E(\exp\{u_{it}\} / \varepsilon_i) = E(\exp\{-u_i \beta_t\} / \varepsilon_i) \quad (3)$$

Since the technical efficiency of each firm (TE_i) is equal to $\exp(-u_i)$ this can lead to the determination of technical efficiency of each firm from Equation (4),

$$TE_i = \exp(-E(u_i / \varepsilon_i)) \quad (4)$$

This study applied the time-varying production frontier model to measure the technical efficiency of rice production in 1987/88 and 2007/08 crop year. Farm-level Cobb-Douglas production frontier equations are estimated for rice farming both in the wet and dry seasons. The estimating equations for the production frontier are demonstrated in (5)

$$\begin{aligned} \ln PROD_{it} &= \beta_0 + \beta_1 \ln(SEED_{it}) + \beta_2 \ln(FERT_{it}) + \beta_3 \ln(HLAB_{it}) + \beta_4 \ln(FLAB_{it}) \\ &+ \beta_5 \ln(MACH_{it}) + \beta_6 \ln(CHEM_{it}) + \beta_7 SP1_{it} + \beta_8 SP3_{it} + \beta_9 KK1_{it} + \beta_{10} KK2_{it} \\ &+ \beta_{11} KK3_{it} + \beta_{12} YEAR07_{it} + V_{it} + U_{it} \end{aligned} \quad (5)$$

Except for the intercept parameters β_0, the variables in this equation are indexed by i and t; these represent the i[th] farm (i=1,2,3,…,295 in 1987/88 and i=1,2,3,…,228 in 2007/08 crop year) in the t[th] period (t=1 and 2). The dependent variable $PROD_{it}$ is paddy rice yield (kg). The independent variables consist of conventional factors including labor, capital, variable input and production environment as defined in Table 1. To calculate, the technical efficiency score of rice production between 1987/88 and 2007/08 crop year, the maximum likelihood estimate for u_i can be obtained from the mean or mode of u_i / ε_i , which are given by production frontier Equation (5).

Inefficiency model

The determinants of technical efficiency in this study are divided into five groups, namely, household's characteristics, farm's characteristics, formal education and agricultural practice, labor use and machinery adoption, and household financial status and credit access (Adulavidhaya, 1994; Pitipunya, 1995). The Tobit model, which determines lower censored equal to 0 and upper censored equal to 1 is applied for the technical efficiency model. The maximum likelihood technique is used to estimate the parameters in the model (Green, 1993). STATA 10 is the appropriate statistical package for estimating the parameters. The technical efficiency model is as follows[1]:

$$\begin{aligned} TE_i &= \delta_0 + \delta_1 AGE_i + \delta_2 HHS_i + \delta_3 LOWNER_i + \delta_4 FSIZE_i + \delta_5 CINTEN_i \\ &+ \delta_6 EDU_i + \delta_7 ATCHEM + \delta_8 ATVARIE_i + \delta_9 ATOTHER_i + \delta_{10} RHLAB_i + \delta_{11} RMACH_i \\ &+ \delta_{12} ADCBHAVR_i + \delta_{13} ADTP_i + \delta_{14} RFINCOM_i + \delta_{15} CREDIT_i + \delta_{16} RRCRE_i + W_i \end{aligned} \quad (6)$$

[1] As there was no data base of some variables in the 1987/88 crop year, some variables were not used to estimate the technical efficiency model in 1987/88 crop year.

Table 2. Variables, definition and unit of analysis used in the inefficiency model.

Variable		Definition	Unit of measurement
Technical efficiency	**TE**	**Technical efficiency score**	**Ratio scale**
Household's characteristics	AGE	Age of household head	Year
	HHS	Household size	Persons
Farm's characteristics	LOWNER	The ratio of rice land ownership	Ratio scale
	FSIZE	Farm size	Rai
	CINTEN	Cropping intensities	Times per crop year
Formal education and agricultural practice	EDU	Education of household head	Year
	ATCHEM	Agricultural training with chemical applied	1=trained, 0=otherwise
	ATVARIE	Agricultural training with rice variety	1=trained, 0=otherwise
	ATOTHER	Agricultural training in rice production	1=trained, 0=otherwise
Labor use and machinery adoption	RHLAB	The number of hired labor to total labor	Ratio scale
	RMACH	The ratio of machinery labor to total labor	Ratio scale
	ADCBHARV	Adoption of combine harvester	1=adopted, 0=otherwise
	ADTP	Adoption of transplanting technique	1=adopted, 0=otherwise
Financial Status and credit access	RFINCOM	The ratio of farm income to total household income	Ratio scale
	CREDIT	Credit access	1=access credit for rice,0=otherwise
	RRCRE	% of credit for rice production to total household dept	Ratio scale

Except for the intercept parameters δ_0, the variables in this equation are indexed by i representing the i^{th} farm (i=1,2,3,…,295) in 1987/88 crop year and the i^{th} farm (i=1,2,3,…,228) in 2007/08 crop year. Dependent variable TE_i is the technical efficiency score. Independent variables are defined in Table 2.

Changes of resource use in Thailand rice production

The changes in rice production in Thailand were not only in labor saving technology and intensive use of chemical fertilizer but also the increase in the average age of household heads in the agricultural sector. The "aging" of the Thai farmers, the movement of the younger family members of the farm household to the non-agriculture, and a smaller household size has led to an increasing use of hired labor. The rapid expansion in the rice farming area followed by an expanded irrigation service and higher cropping intensity increased the demand for farm labor. However, labor migration from the agricultural sector to other economic sectors had created a shortage in agricultural labor. This raised wage rates, which drove farmers to adopt labor-saving machinery and practices. Mechanization was applied in land preparation, harvesting and threshing, and labor-saving practices included broadcasting pre-germinated seed and use of herbicides. The labor use for rice production dramatically declined that is in irrigated area of Suphan Buri Province it decreased from 7.87 man-days per rai in wet season 1987/88 crop year to 1.19 man-day per rai in 2007/08 crop year. At the same time, machinery use sharply increased from 0.57 to 7.27 h per rai in 2007/08 crop year. This phenomenon was observed in all the other rice production environments.

Furthermore, as land rent is usually paid in kind that is rice, the rental price has been increasing following increases in the price of rice. This was clearly shown by the survey data from six villages across different production environments. As for the cost of rice production, in Suphan Buri Province, the irrigated SP1 village recorded an increase in production cost from 2,813.9 baht per rai in the wet season of 1987/88 crop year to 5,224.6 baht per rai in the 2007/08 crop year, or 85.67% increase. The costs of machinery, fertilizer and land use increased significantly. The impact of a fixed rent in kind is that when the paddy price rose, the cost of land use increased as well. Between farming environments, farmers in rainfed and flood-prone areas in this province had higher costs in both wet and dry seasons. Comparing the cost per unit of rice production between 1987/88 and 2007/08 crop years, it was found that farmers in the irrigated SP1 village had incurred higher cost, from 4.8 baht per kg in wet season 1987/88 crop year to 6.86 baht per kg in 2007/08 crop year. As to the dry season crop, the cost per rai and cost per kg also increased. In rainfed area, the cost per kilogram was higher than in irrigated and flood-prone areas. This was the result of long periods of drought; the rainfed rice farming village (SP2) suffered losses over two consecutive crop years covered by the study.

In the same period, the paddy price in 2007/08 crop year was much higher than the price in 1987/88 crop year. However, the higher increase in the production cost than in the output price reduced profits in the irrigated areas whereas the farmers in the rainfed rice farming village suffered production loss. Nonetheless, the cash cost of rice production was still greater than zero because most farmers cultivated rice in their own land. The net return from dry season crop was higher than the wet season crop. The benefits from a higher cropping intensity had been the driver for farmers in irrigated area to continue producing rice despite the steady decline in profitability of rice farming. On the other hand, rice production in rainfed area was more for household food security than profitability. Evidence to support this point was found in the rainfed area in Khon Kaen Province; KK2 and KK3. The cost of rice production per kg rose from 6.23 and 6.94 baht per kg in KK2 and KK3, respectively, in 1987/88 crop year, to 10.34 and 10.41 baht per kg, respectively, in 2007/08 crop year.

The aforementioned changes have affected efficiency of rice production. To reiterate, these include the changes in the rice farming households, adoption of new production technology, changes in rice cropping patterns, and changes in cost structures as well as returns.

Changes in rice production efficiency and their determinants

The estimated parameters of the time-varying production frontier model by maximum likelihood technique are presented in Table 3. The stochastic frontier with time-varying technical inefficiency following the model developed by Battese and Coelli (1992) are reflected in the Table. This model includes the effect of production environment and technological change, and the estimates of all parameters show their consistency with economic theory, it can fully explain time-varying production frontier in this study. The Cobb-Douglas production function was applied because it is easy to convert into the log linear form. The exponent for any input term in a Cobb-Douglas function represents the productive elasticity of that input, and the sum of exponent terms in the Cobb-Douglas function which implies returns to scale of production.

On the other hand, the translog model is more flexible than the Cobb-Douglas model but it may not be globally well-behaved. The estimated sign of these variables show that the relations between yield and all inputs are positive. All estimated parameters are also significant except the value of chemical input. Among the statistically significant factors (excluding dummy variable), seed whose coefficient is 0.54, has the largest influence on rice yield. The next is machinery use; the coefficient of machinery hours is 0.28. The statistically insignificant μ

Table 3. Maximum likelihood estimates of time-varying production frontier model.

Parameter	Coeff.	S.E.
Constant	3.5895**	0.1931
Ln(SEED)	0.5420**	0.0356
Ln(FERT)	0.0104*	0.0043
Ln(HLAB)	0.0322**	0.0051
Ln(FLAB)	0.0630**	0.0226
Ln(MACH)	0.2746**	0.0255
Ln(CHEM)	0.0008	0.0032
SP1	1.1386**	0.0894
SP3	0.7489**	0.0939
KK1	0.8915**	0.0952
KK2	0.6494**	0.1081
KK3	0.4694**	0.1035
YEAR07	0.3917**	0.0614
μ	-496.24	619.46
η	-0.1022	0.0250
σ_v^2	0.1520	0.0126
σ_u^2	182.61	228.22
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	182.76	228.22
$\gamma = \sigma_u^2 / \left(\sigma_u^2 + \sigma_v^2\right)$	0.9992	0.0010
Log likelihood	-343.38	

Coeff. = Coefficient of parameter; S.E. = Standard Error; * and ** Its average is greater at 5 and 1% levels of significance. Source: By author’s calculation.

indicates that the distribution of efficiency error term (u_{it}) was a half-normal distribution. However, there are very small variations in the parameters that arise with these models. These have implications on the estimated values of the error term u_{it} approximated by $E(u_{it}/\varepsilon)$. Based on half-normal distribution, it is found that variance of u(σ_u^2) accounts for 99.56% of the estimated variance of ε. Estimate of the variance parameter, γ, which captures the effect of technical efficiency is 0.9992. These γ estimates are very close to 1 and very high t-statistics significance. This indicates that most of the total variation in output from the production frontier is attributable to technical efficiency. The finding makes the study of inefficiency highly relevant. The technical inefficiency changes through time can be determined as well. If η=0, the time-varying production frontier model reduces to time-invariant model.

From Table 3, the η≠0, shows a negative sign. This indicates that technical inefficiency decreases with time, which means that the technical efficiency of rice production in Thailand was decreasing between 1987/88 and 2007/08 crop year. The mean comparison test on technical efficiency scores indicated that the efficiency scores in

Table 4. Technical efficiency score obtained by time-varying production frontier model.

Year/TE score	SP1	SP2	SP3	KK1	KK2	KK3	Mean
1987/88 crop year	0.9043	0.8584	0.8008	0.9279	0.9053	0.8947	0.8832
2007/08 crop year	0.7508	0.5217	0.8045	0.7014	0.7745	0.7583	0.7263

Source: By author calculation.

the 2007/08 crop year are significantly lower than the 1987/88 crop year. The mean technical efficiency score is 88.32% in 1987/88 crop year, decreasing to 72.63% in 2007/08 crop year. It means that on the average rice production in 1987/88 crop year is closer to production frontier than 2007/08 crop year, implying that the farmers in 1987/88 crop year used their available resources more effectively than the farmers in 2007/08 crop year (Table 4). The main reason may be an increasing in the input factors use and cropping many times on the same land.

However, several studies have not agreed with this result. They indicated that the rice production efficiency was increased over time period, which was mainly due to the development of production technology and quality of the irrigation system (Young et al., 1996; Richard and Shively, 2007). The model utilizes the time-varying production frontier model of Battese and Coelli (1992) with the additional assumption of time-specific intercepts to represent the index of technological change. The maximum likelihood estimates indicate statistically significant and positive sign of time-trend variable (YEAR07), which means there are technological changes in rice production over time. However, while the study was able to indicate technological change of rice production over time, it was unable to test between biased or neutral technological change; a longer period of panel data for rice production would enable this test.

An in-depth study and explanation of the dynamic changes in rice production in Thailand would require longitudinal data base. If long term data for rice production and farm household were available, a clearer picture of rice production in transition and the effect on farm households would emerge.

The cost of rice production in all areas in Thailand has been increasing during the past two decades (Isvilanonda, 2009) while the return on factor inputs with respect to yield steadily decreased. The total elasticities of six inputs with respect to output (or return to scale) fell from 0.98 in 1987/88 to 0.91 in 2007/08 crop year. This result is consistent with earlier studies indicating decreasing returns to scale as well as in Thailand's rice production (Patmasiriwat and Isvilanonda, 1990; Pochatan, 2005; Songsrirod, 2007). Increasing the amount of input use cannot improve yield performance because the marginal product (MP) of rice production is less than the average product (AP). Therefore, rather than increasing the amount of each input, the efficiency of its use should be increased in order to improve yield performance.

Determinants of technical efficiency

The different socio-economic characteristics of each farmer may have an effect on the technical efficiency and capacity of each farmer to use technology. The study results highlight that the coefficient for age of household head is negative and statistically significant. This signifies that households headed by younger and more physically able farmers could provide more family labor than those headed by older farmers. With household size, the results indicate that the bigger households tend to show better technical efficiency. As for the variables that explain farm characteristics, the coefficient for land ownership and cropping intensity indicated no relation to efficiency improvement. As to farm size, the results showed that larger farm sizes have attained higher technical efficiency than those smaller ones as predicted by economies of scale.

Interestingly, the study also indicated that formal education may not be related to the technical efficiency improvements in rice production in Thailand. Similarly, the same condition holds for training in agricultural practices. There was no significant relation found between training in agricultural practices and technical efficiency. This result seems counterintuitive. It was noted however that the training programs considered in these study were of very short duration and probably insufficient to enable a deeper understanding of the concepts and practices for effective farm application.

On the ratio of hired labor to total labor, the result suggests that hired labor did not contribute to improved technical efficiency in rice production in the 1987/88 crop year. This has changed in the current production year. Hired labor now plays a significant role in improving efficiency in rice farming. This is because most processes in rice production at present depend on hired labor. In machinery adoption, the use of combine harvester improves technical efficiency but in the other rice production activities, using more machinery reduces technical efficiency. On household financial status, the key factor to technical efficiency improvement is the ratio of farm income to total household income; the result indicates that the household with a higher farm income tends to be more efficient. The last factor is credit access. The loan results in inefficiency if the farmer did not use the borrowed money for rice production. But the efficiency of farmers who obtained credit for rice production improved (Table 5).

Table 5. Tobit regression estimates of factors affecting technical efficiency in rice production.

Variable	1987/88 Crop year		2007/08 Crop year	
	Coeff.	**S.E.**	**Coeff.**	**S.E.**
CONS	0.6915***	0.0613	0.9238***	0.0827
AGE	-0.0009*	0.0005	-0.0017*	0.0009
HHS	0.0049**	0.0026	-0.0125	0.0051
LOWNER	0.0242	0.0183	-0.0329	0.0294
FSIZE	0.0004	0.0003	0.0006**	0.0003
CINTEN	0.0651***	0.0155	-0.0063	0.0221
EDU	0.0020	0.0050	0.0008	0.0040
ATCHEM	-	-	-0.0004	0.0325
ATVARIE	-	-	0.0218	0.0400
ATOTHER	-	-	0.0003	0.0453
RHLAB	-0.0552	0.0292	0.0673*	0.0379
RMACH	0.0627	0.0393	-0.2124***	0.0680
ADCBHARV	-	-	0.0928***	0.0303
ADTP	0.0426***	0.0160	0.0175	0.0249
RFINCOM	0.0728***	0.0203	0.0556*	0.0318
CREDIT	-	-	-0.1705***	0.0350
RRCRE	-	-	0.0017***	0.0005
Log likelihood	- 238.95		- 124.94	

Coeff. = Coefficient of parameter; S.E. = Standard Error. *, ** ,* ** are represented a significant at 10, 5 and 1%, respectively.

CONCLUSIONS AND RECOMMENDATIONS

The adoption of Modern Rice Varieties (MVs) has induced great changes in the rice production sector in Thailand. The application of new technologies, greater use of chemical fertilizers, and the adoption of new rice varieties that are non-photoperiodic led to a higher average rice yield performance in Thailand over the past few decades. The average rice yield per rai in Thailand has almost reached the maximum under the present technology of production. Increasing rice yield per rai under the present technology could be achieved by improving the socio-economic characteristics and production management of farmers (Songsrirod, 2007). In other words, technical efficiency of rice production can be increased by improvements in farmer characteristics, farm characteristics, environmental condition and agricultural practices (Alviar, 1979). Improvement in these factors would increase the technical efficiency of farmers as well as productivity.

Technical efficiency of rice production in Thailand has been a priority research issue. Earlier studies found that Thai farmers had been producing rice below their ultimate potential output (Sriboonchitta and Wiboonpongse, 2000; Wiboonpongse et al., 2005; Pochatan, 2005; Songsrirod, 2007). It was reflected that Thai farmers still had opportunities to increase their production efficiency. This study introduces the time-varying production frontier model, which allows technical efficiency improvement through time. Technical efficiency of rice production between 1987/88 and 2007/08 crop year, as well as the different impacts of production environment on farm technical efficiency through time were analyzed. The Cobb-Douglas production function and maximum likelihood estimates for parameters of the time-varying production frontier model were employed. The result shows that seed and machinery hour have the largest influence on rice yield. It can be explained by the adoption of labor-saving machinery for rice production in all processes to compensate for the scarcity of manual labor. Machinery power thus had an important role in increasing rice yield.

The adoption of labor saving technology and machinery over the last two decades did little to improve the technical efficiency of rice production in Thailand; it is still lower than the maximum potential and it even showed further decline. This reflects that on the average, rice production in 1987/88 was closer to the production frontier than in 2007/08. Logically, the farmers in 1987/88 crop year used their resources more effectively than the farmers in 2007/08 crop year. Moreover, the technical efficiency score is different between production environments. When comparing the technical efficiency score of rice production among the production environment, the study result indicated that the farmer in irrigated rice area have higher technical efficiency score than other area.

Therefore, it is implied that the irrigation system is the key factor for technical efficiency improvement.

The changes of technical efficiency of rice production employed during the 1987/88 to 2007/08 crop year showed a decreasing trend and indicated the significant role of irrigation development on efficiency improvement. It is pertinent to suggest that the way to raise production without changes in the quantity of input is to use a given technology. The larger rice farm is more technically efficient than the small one because they have the advantage of economy of scale. However, expanding farm size for rice production is now difficult or impossible because of the increasing population and limited areas for expansion. Economy of scale however can be achieved by small farmers being associated, which suggests a development program to enhance the formation of farmer associations or to encourage farmers to cooperate. This would strengthen their bargaining power with suppliers of inputs and buyers of products, as well as reduce transaction costs when purchasing supplies, transporting and marketing farm produce. Being associated also tends to improve the adoption of innovation and acquisition of new knowledge.

The households with a higher farm income have been shown to be more efficient. This suggests that improving farm income can also improve rice production efficiency. Therefore, a policy to raise or guarantee the price of agriculture commodities is an alternative option; this would stabilize or improve farm household income, which would thus make them more efficient rice producers. The negative sign between credit access and technical efficiency, and the positive relation between credit for rice and technical efficiency suggest that the farmer who borrows more money is less efficient if the money was not used for rice production. The farmers who borrowed money specifically for rice improved their efficiency. This strongly suggests a program of supervised credit to ensure that loans are used for production inputs such as chemical fertilizer and seed.

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