Changes in the Efficiency of Rice Production in Thailand

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ABSTRACT

By applying the time-varying Cobb-Douglass production frontier model with unbalanced panel data between the crop year (CY) 1987/88 and CY 2007/08, it was discovered that the returns to scale from rice production in Thailand have been decreasing. This is a sign that an increase in the amount of inputs may not improve rice yield performance. Even with the adoption of labor-saving technology and machinery over the last two decades, the efficiency of rice production in terms of yield increase has been less than the maximum potential yield. Instead, there has been a declining trend. The empirical study showed that the mean technical efficiency score was 88.32 percent in CY 1987/88 and this decreased to 72.63 percent in CY 2007/08, which indicates that the farmers in CY 1987/88 utilized their resources more effectively than the farmers in CY 2007/08. Moreover, the technical efficiency score of rice production in irrigated areas was higher than that in other areas, which implied that irrigation development was the key factor for improvements in technical efficiency.

Keywords: rice, time-varying model, stochastic frontier, technical efficiency

บทคัดย่อ

การศึกษาครั้งนี้ใช้แบบจำลองขอบเขตเชิงเฟ้นสุ่มของการผลิตข้าวที่ผันแปรตามเวลา โดยใช้ฟังก์ชั่นการผลิตแบบ Cobb-Douglas กับข้อมูลในลักษณะ panel data ระหว่างช่วงปีการผลิต 2530/31 และ 2550/51 ผลการศึกษา พบว่าการผลิตข้าวในประเทศไทยเป็นการผลิตที่มีผลตอบแทนต่อขนาดลดลง การเพิ่มการใช้ปัจจัยการผลิตจะไม่สามารถเพิ่มผลผลิตข้าวของเกษตรกรได้ และแม้ว่าการผลิตข้าวในปัจจุบันมีการใช้เทคโนโลยีที่ประหยัดแรงงานอย่างแพร่หลาย แต่ผลการวิเคราะห์ประสิทธิภาพเชิงเทคนิค พบว่า ระดับประสิทธิภาพเชิงเทคนิคของเกษตรกรยังต่ำกว่าระดับประสิทธิภาพการผลิตสูงสุดและอยู่ในระดับที่ต่ำกว่าการผลิตในอดีต คือ เท่ากับร้อยละ 88.32 ในปีการผลิต 2530/31 ลดลงเหลือร้อยละ 72.63 ในปีการผลิต 2550/51 นั่นคือเกษตรกรในปีการผลิต 2530/31 ใช้ทรัพยากรในการผลิตข้าวได้มีประสิทธิภาพมากกว่าเกษตรกรในปีการผลิต 2550/51 ผลการศึกษายังระบุว่าสภาพแวดล้อมการผลิตเป็นปัจจัยที่ทำให้ระดับประสิทธิภาพการผลิตข้าวของเกษตรกรแตกต่างกัน โดยที่เกษตรกรในพื้นที่ชลประทานมีระดับประสิทธิภาพสูงกว่าพื้นที่อื่นๆ แสดงให้เห็นว่าการพัฒนาชลประทานเป็นปัจจัยสำคัญในการเพิ่มประสิทธิภาพการผลิตข้าวในประเทศไทย

คำสำคัญ: ข้าว, แบบจำลองที่ผันแปรตามเวลา, ขอบเขตเชิงเฟ้นสุ่ม, ประสิทธิภาพเชิงเทคนิค

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INTRODUCTION

Rice production efficiency has been of longstanding interest to economists. One of the first studies on this topic was the seminal work of Barker *et al.* (1985), which reviewed the trends and changes in the Asian rice economy, beginning in the early 1940s. Several related empirical studies from Thailand applied a stochastic frontier to analyze rice production. Early attempts to measure the farm-specific technical efficiency of rice farms in Thailand include Patmasiriwat and Isvilanonda (1990) and Pitipunya (1995). More recent studies have been carried out by Sriboonchitta and Wiboonpongse (2000), Pochatan (2005), and Songsrirod (2007), using cross-sectional data to construct a production frontier. Unlike the previous studies, these later studies used panel data to indicate improvements in efficiency through time and to fill the knowledge gap. The panel data can explain the change in technical efficiency between CY 1987/88 and 2007/08. It can be used to explain systematically and clearly, the changes in rice production in Thailand, especially in the pattern of rice production and input productivity, including labor productivity. This information would be useful for planning and policy making, for solving the problems of rice production and for improving the well-being of Thai farmers.

This paper aimed to analyze and compare the production efficiency of rice farming between CY 1987/88 and CY 2007/08, by employing panel data from six rice villages across the production environment. Three villages in Suphan Buri province were selected to represent the three rice production environments, namely, Wang Yang (SP1) for an irrigated environment, Sra Ka Jom (SP2) for a rainfed and drought-prone environment, and Jorakhe Yai (SP3) for a flood-prone environment. Another three villages in Khon Kaen province were selected, namely, Khokna-ngam (KK1) for an irrigated environment; Kai Na (KK2) for a rainfed environment, and Ban Meng (KK3) for a drought-prone environment. The repeat survey taken in 2008 found that of the 295 rice farming households in CY 1987/88, only 228 (76%) of the households remained in rice farming in CY 2007/08.

The current paper is organized into four sections. After the introduction, the analytical framework is discussed. The results and related discussion provide the third section. The final section presents the conclusions and recommendations.

ANALYTICAL FRAMEWORK

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 categorized generally under the distinctly opposing techniques of either a non-parametric or a 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). Stochastic Frontier Analysis (SFA) acknowledges the random noise around the estimated production frontier. In the simple case of a single output and multiple inputs, the approach predicts the output from the inputs by the functional relationships $y_i = f(x_i, \beta) + \varepsilon_i$, where i denotes the efficient observation being evaluated and values of β are the parameters to be estimated. The residual ε_i is composed of a random error v_i (the effect of uncontrolled variables, such as weather) and an inefficiency component u_i.

Often, earlier research has estimated the technical efficiency of rice production using cross-sectional data. However, it cannot explain clearly the change of rice production over a time period. In order to solve this weakness, the current study used panel data in a production frontier model to avoid the limitations of a cross-sectional model, as the panel data contains more information than a single cross section. Consequently, it is to be expected that access to panel data will either enable some of the strong distribution assumptions used with cross-sectional data to be relaxed, or produce estimates of technical efficiency with more desirable statistical properties. Moreover, the efficiency change though time will be determined.

By utilizing panel data, the production frontier model must choose between two concepts. The first is the time-invariant concept, which considers a 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 models can be adapted to the problem of estimating technical efficiency. However, the assumption of time invariance for technical efficiency may be considered slightly, particularly in long panel. The second concept involves a 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:

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

where, $u_{it} = \beta_t * u_i$, $\varepsilon_{it} = v_{it} - u_{it} = v_{it} - \beta_t * u$ *and* $\varepsilon_i = (\varepsilon_i 1,...,\varepsilon_{it}) * \beta_{ot}$ 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 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 Equation 2:

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

where, $u_{*i} = -\dfrac{(\sum_t \beta_t * \varepsilon_{it})\sigma_v^2}{(\sigma \int_v^2 + \sigma_u^2 \sum_t \beta_t^2)}$ 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 Equation 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:

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

The current study applied the time-varying production frontier model to measure the technical efficiency of rice production in CY 1987/88 and CY 2007/08. Farm-level Cobb-Douglas production frontier equations were estimated for rice farming, both in the wet and dry seasons. The estimating equation for the production frontier is shown in Equation 5:

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

Except for the intercept parameters β_0, the variables in Equation 5 are indexed by i and t; these represent the i^{th} farm (i=1,2,3,...,295 in CY 1987/88 and i=1,2,3,…,228 in CY 2007/08) in the t^{th} period (t=1 and 2). The dependent variable $PROD_{it}$ is the 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 CY 1987/88 and CY 2007/08, the maximum likelihood estimate for u_i can be obtained from the mean or mode of u_i / ε_i, which are given by the production frontier Equation 5.

RESULTS AND DISCUSSION

The estimated parameters obtained from the

Table 1 Variables, definitions and measurement units used in the time-varying frontier model

Variable	Definition	Measurement unit
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	hour
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

Note: SP1, SP3, KK1, KK2 and KK3 are dummy variables representing the differential of the production environment; SP2 is the base area.

time-varying production frontier model using the maximum likelihood technique are presented in Table 2, which provides three different models for the stochastic frontier with time-varying technical inefficiency, following the model developed by Battese and Coelli (1992). Model 1 is the basic time-varying production frontier model. Model 2 adds the dummy variable of villages, in order to capture the impact of the production environment on technical inefficiency. Model 3 adds the dummy variable and the time trend variable, in order to determine the technological changes through time.

The Cobb-Douglas production function was applied, because it is easily converted 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 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 well-behaved globally.

The estimated results of the models indicated that all point estimates of the three models exhibited a sign for each coefficient that was consistent with economic theory, except for the coefficient for family labor in models 1 and 2, which may have been caused by the overuse of this input (Battese and Coelli, 1992). Because model 3 included the effect of production environment and technological change, and the estimates of all parameters are consistent with economic theory, it can fully explain the time-varying production frontier in the current study.

In model 3, the estimated sign of the variables in the equation all show a positive relationship between yield and all inputs. In addition, all estimated parameters are significant, except for the value of chemical input. Among the statistically significant factors (excluding the dummy variables), seed, with a coefficient of 0.54, had the largest influence on rice yield, with the next highest being machinery use, with the coefficient for machinery hours being 0.27.

In all models, μ was statistically insignificant, which indicated that the efficiency error term (u_{it}) had a half-normal distribution. However, there were very small variations in the parameters arising from these models that have implications on the estimated values of the error term u_{it} approximated by $E(u_{it} / \varepsilon)$. For models 1 and 2, based on a half-normal

Table 2 Maximum likelihood estimates of time-varying production frontier model

Variable	Model 1		Model 2		Model 3	
	(Parameter)	Coeff.	S.E.	Coeff.	S.E.	Coeff.
S.E.						
Constant	4.4389**	0.1352	3.3672**	0.1974	3.5895**	0.1931
Ln(SEED)	0.6518**	0.0249	0.6268**	0.0347	0.5420**	0.0356
Ln(FERT)	0.0375**	0.0044	0.0149**	0.0045	0.0104*	0.0043
Ln(HLAB)	0.0327**	0.0055	0.0357**	0.0055	0.0322**	0.0051
Ln(FLAB)	-0.0274	0.0231	-0.0054	0.0222	0.0630**	0.0226
Ln(MACH)	0.2193**	0.0263	0.2823**	0.0268	0.2746**	0.0255
Ln(CHEM)	0.0040	0.0035	0.0045	0.0033	0.0008	0.0032
SP1	-	-	1.1162**	0.0942	1.1386**	0.0894
SP3	-	-	0.7132**	0.0976	0.7489**	0.0939
KK1	-	-	1.0155**	0.0983	0.8915**	0.0952
KK2	-	-	0.8786**	0.1072	0.6494**	0.1081
KK3	-	-	0.6715**	0.1039	0.4694**	0.1035
YEAR07	-	-	-	-	0.3917**	0.0614
μ	-457.37	4428.92	-390.92	446.39	-496.24	619.46
η	-0.0418	0.0062	-0.0615	0.0152	-0.1022	0.0250
σ_v^2	0.1867	0.0153	0.1822	0.0146	0.1520	0.0126
σ_u^2	220.23	2126.32	119.24	136.54	182.61	228.22
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	220.42	2126.32	119.42	136.54	182.76	228.22
$\gamma = \sigma_u^2 / \left(\sigma_u^2 + \sigma_v^2\right)$	0.9992	0.0082	0.9985	0.0018	0.9992	0.0010
Log likelihood	-426.42		-363.03		-343.38	

Note: Coeff. = Coefficient of parameter; S.E. = Standard error.
* significant at the 5% level.
** significant at the 1% level.
Source: author calculation.

distribution, it was found that the variance of u (σ_u^2) accounted for 99.95 and 99.89 percent of the estimated variance of ε, respectively. For model 3, the variance of u (σ_u^2) accounted for nearly the same amount (99.56%) as in the other two models.

The estimate of the variance parameter, γ, which captures the effect of technical efficiency, in models 2 and 3 was 0.9985 and 0.9992, respectively. These γ estimates are very close to 1 and both were very highly significant using a t-test. This indicates that most of the total variation in output from the production frontier was 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 $\eta=0$, the time-varying production frontier model reduces to a time-invariant model. From Table 1, $\eta \neq 0$ has a negative sign. This fact, in combination with the statistical significance of all three models, indicates that technical inefficiency decreases with time, which means that the technical efficiency of rice production in Thailand was decreasing between CY 1987/88 and CY 2007/08 (Table 4). The time-varying production frontier model was suitable for explaining the technical efficiency of rice production in the current study, so this model was used to calculate the technical efficiency score.

Model 3 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 were statistically significant and had a positive sign for the time-trend variable (YEAR07), which means there are technological changes in rice production over time. However, while the study was able to indicate there had been technological change of rice production over time, it was not possible to test between biased or neutral technological change; a longer period of panel data for rice production would enable this test to be performed.

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

Production elasticities and returns to scale

Production elasticities and the return to scale for each year were calculated (Table 3), based on the production parameter estimates in Table 2. In CY 1987/88, the production elasticity indicated that all input factors were important for rice production in Thailand; a positive relationship between the input factors and yield was found. Seed and labor were important factors to increase rice yield. Rice production in 2007/08 differed from the past, with the major causes of the change being the expansion of the non-agricultural sector and the higher wage rate in the non-agricultural sector. Labor migration from the agricultural sector resulted in a shortage of labor for rice production that was compensated for by farmers adopting machinery and labor-saving practices, such as four-wheeled tractors for land preparation, chemical sprayers and combine harvesters for harvesting and threshing. Thus, mechanization played an important role in increasing rice yields, as reflected in CY 2007/08; the mean elasticities of machinery hours, with respect to output increased from 0.0936 in CY 1987/88 to 0.1422 in CY 2007/08. The mean elasticities of seed, with respect to output also increased over time from 0.3141 in 1987/88 to 0.5171 in CY 2007/08. This showed that the quantity of seed use was an important factor in increasing yield. On the other hand, the importance of labor decreased over time; the mean elasticities of hired and family labor with respect to output decreased from 0.2196 and 0.0147 in CY 1987/88 to 0.0801 and 0.01 in CY 2007/08, respectively (Table 3).

The cost of rice production in all areas in Thailand with respect to yield has been increasing during the past two decades (Isvilanonda, 2009), while the return on factor inputs has steadily decreased. The total elasticity of six inputs with respect to output (or return to scale) fell from 0.98

Table 3 Production elasticities and returns to scale of rice production in CY 1987/88 and CY 2007/08

Input variables	CY 1987/88	CY 2007/08	Panel data (CY 1987/88 and CY 2007/08)
Elasticity of SEED	0.3141	0.5171	0.5420
Elasticity of FERT	0.2412	0.0957	0.0104
Elasticity of HLAB	0.2196	0.0801	0.0322
Elasticity of FLAB	0.0147	0.0100	0.0630
Elasticity of MACH	0.0936	0.1422	0.2746
Elasticity of CHEM	0.0934	0.0688	0.0008
Returns to scale	0.9766	0.9139	0.9230

Source: author calculation

in CY 1987/88 to 0.91 in CY 2007/08. This result was consistent with earlier studies, which indicated decreasing returns to scale with rice production in Thailand (Patmasiriwat and Isvilanonda, 1990; Pochatan, 2005; Songsrirod, 2007). Increasing the amount of inputs could not improve yield performance, because the marginal product (MP) of rice production was 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.

Technical efficiency improvement through time

The results of a mean comparison test on the technical efficiency scores indicated that the efficiency scores in CY 2007/08 were significantly lower than those in CY 1987/88. This result was not consistent with the average yield, where rice yield performance in CY 2007/08 was significantly higher than CY 1987/88. The intensive use of major inputs, such as seed, fertilizer and machinery in CY 2007/08 may have caused the technical efficiency score to decline dramatically. The mean technical efficiency score in models 1, 2 and 3 was 76.96, 86.22 and 88.32 percent in CY 1987/88, which decreased in CY 2007/08 to 69.02, 76.49 and 72.63 percent, respectively. This indicated that, on average, rice production in CY 1987/88 was closer to the production frontier than in CY 2007/08, or that the farmers in CY 1987/88 managed their resources more effectively than the farmers in CY 2007/08.

The impact of production environment on technical efficiency

The production environment is the key factor affecting production efficiency (Patmasiriwat and Isvilanonda, 1990). The efficiency scores obtained from the time-varying production frontier model are shown in Table 4. The technical efficiency score in model 1 is less than that in model 2, in both crop years, in all villages. The technical efficiency score of the rainfed and drought-prone village (SP2) that was found to be at a very low level (0.31) in model 1, does not consider the impact of the production

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

Villages	Model 1		Model 2		Model 3	
	1987/88	2007/08	1987/88	2007/08	1987/88	2007/08
SP1	0.8605	0.7913	0.8858	0.7966	0.9043	0.7508
SP2	0.5723	0.3056	0.8240	0.6022	0.8584	0.5217
SP3	0.7158	0.7665	0.7985	0.8337	0.8008	0.8045
KK1	0.8560	0.7494	0.8987	0.7766	0.9219	0.7084
KK2	0.8258	0.7492	0.8835	0.8081	0.9053	0.7745
KK3	0.7803	0.6754	0.8726	0.7956	0.8947	0.7583
Mean	0.7696	0.6902	0.8622	0.7749	0.8832	0.7263

Source: author calculation

[3] The decrease in water levels in the flood-prone areas in the past enabled the farmers to adopt a new pattern of rice cultivation. The yearly rice cultivation could not be continued when runoff from the mountains and forests inundated the fields. The farmers had to wait until August to November to plant a crop. The lower incidence of flooding gave the farmers the opportunity to grow non-photoperiod rice twice a year, both crops in the dry season. This resulted in rice no longer being cultivated in the wet season in village SP3.

[4] Urban expansion drove up the price of the land in the suburban area and induced farmers in KK2 to sell their land; some used the proceeds from land sales to buy rice land in the irrigated area. Thus, most rice land in KK2 changed to irrigated rice production land in CY 2007/08.

environment. However, the score was better in model 2 (0.60) when the production environment factor was included in the model. This indicated that the effects of the production environment on technical efficiency score vary; technical efficiency scores differed between production environments. In CY 2007/08, the highest mean technical efficiency score (83%) was for the flood-prone area in Suphan Buri province (SP3)[3], in which the land undergoes rehabilitation during the flooding period. Continuous use of irrigated land requires occasional soil rehabilitation. The next highest technical efficiency scores were those of villages KK2[4] and SP1 at 81 and 78 percent, respectively.

CONCLUSIONS AND RECOMMENDATION

The 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). This suggested that Thai farmers still had room to increase their production efficiency. The current study introduced the time-varying production frontier model, which allows technical efficiency improvement through time. The technical efficiency of rice production between CY 1987/88 and CY 2007/08 was analyzed, as well as the different impacts of the production environment on farm technical efficiency through time.

The Cobb-Douglas production function and maximum likelihood estimates for parameters of the time-varying production frontier model were used to show positive relationships between yield and all input factors. There were statistically significant differences seen in all parameters, except for the cost of chemical input. Seed and machinery hours had the largest influence on rice yield. This result can be explained by the adoption of labor-saving machinery for rice production in all processes to compensate for the scarcity of manual labor. Thus, machinery power played an important role in increasing rice yield. The total elasticities of six inputs with respect to output (or return to scale) decreased from 0.98 in CY 1987/88 to 0.91 in CY 2007/08, indicating that the return to scale of rice production in Thailand was decreasing. Thus, increasing the amount of inputs may not improve rice yield performance.

The adoption of labor-saving technology and machinery over the last two decades has done little to improve the technical efficiency of rice production in Thailand; it is still lower than the maximum potential and even has shown further decline. The mean technical efficiency score was 88.32 percent in CY 1987/88, decreasing to 72.63 percent in CY 2007/08. This suggests that the average rice production in 1987/88 was closer to the production frontier than in CY 2007/08. Logically, the farmers in CY 1987/88 used their resources more effectively than the farmers in CY 2007/08. Moreover, the technical efficiency score was different between the production environments. When comparing the technical efficiency score of rice production among the production environments, the study results indicated that a farmer in the irrigated rice area had a higher technical efficiency score than those farmers in other areas. Therefore, this implied that the irrigation system was the key factor for technical efficiency improvement.

The changes in the technical efficiency of rice production employed from CY 1987/88 to CY 2007/08 showed a decreasing trend and indicated the significant role of irrigation development on efficiency improvement. However, factors that contributed to technical efficiency should be considered in a future study, to suggest ways to raise production without changing the quantity of input use and the technology.

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