Comparison of Technical Efficiency of Rice Mill Systems in Thailand and Taiwan J. Wongkeawchan¹, A. Wiboonpongse², S. Sriboonchitta³, W.T. Huang⁴

Abstract

This study attempts to measure the technical efficiency and to find the sources of inefficiency of rice mill businesses in Thailand and Taiwan. The survey based on cross-sectional data in 2000. Purposive sampling technique was applied to select 36 commercial rice mills in Thailand and 35 in Taiwan. Data Envelopment Analysis (DEA) was used to estimate technical efficiency level. The results showed that the average of total technical efficiency and pure technical efficiency of rice mill in Thailand is less than Taiwan. However, the appropriate scale efficiencies of rice mills in both countries are almost identical. To find the sources of inefficiency, it was found that the experience and educational level of rice miller correlated significantly and positively with the technical efficiency of rice mills in both Thailand and Taiwan. Moreover, year of establishment had an important impact on the efficiency level but was different on rice mills in Thailand. Finally, private rice mills have higher significant affect on technical efficiencies than cooperative rice mills in both Thailand and Taiwan at level $\alpha = 0.05$ and $\alpha = 0.10$, respectively.

1. Introduction

Rice is a significant commodity for both the Thailand and Taiwan economies. It is those countries staple food; and by-products of rice are also important for human and animal consumption. For the 1999/2000 crop, Thailand planted about 64.4 million rais to produce 24.2 million tons of paddy, yielding roughly 16.5 millions tons of milled rice. Of this, approximately 9.7 million tons were used for domestic consumption and about 6.8 million tons were left available for export. (Office of Agricultural Economics, 2001).

The annual rice production in Taiwan was increasing during the early postwar years. It increased steadily from 1.2 million tons in 1964 to 3.4 million tons in 1976. However, since 1977 it had declined sharply to 1.9 million tons in 1999 (Taiwan Food Statistics Book, 2000). Hence, the area harvested for rice production was decreasing from 3.4 million rais in 1946 to 2.2 million rais in 1999. More than 90% of rice in Taiwan is used for food, feed, seed, processing and brewing (Lee, 1996)

A rice mill is an intermediate entity playing two important roles. As a production unit, it coverts paddy into milled rice, and, as a marketing unit, it purchases paddy from farmers and forms part of the total distributive chain of milled rice to consumers, commercial merchants and government agencies. This inevitably has led to the existence of many rice mills with a variety of sizes and technologies in almost every region of those countries. Rice mill businesses are highly competitive businesses in the rice marketing system. Taiwan is seen to be the leading country in this industry given its highly efficient production. This high efficiency was primarily due to the use of high processing technology. Recently, large mills in Thailand are beginning to modify machines for labor saving, i.e., the assembly line, dumpcart, etc.

So far, it remains unknown how this capital intensive technology contribute to improving the efficiency of production in the rice mill industry of Thailand. It is noticeable that the

¹ Agricultural System Program Student, Faculty of Agriculture, Chiang Mai University

² Associate Professor, Dr., Department of Agricultural Economics, Chiang Mai University

³ Lecturer, Dr., School of Economics, Chiang Mai University

⁴ Professor, Dr., Faculty of Business Administration, Taichung Healthcare and Management University

technology might not be appropriate for the labor available in Thailand. Most rice mills in Thailand are still using a lot of labor force for bagging, piling, carrying, loading, etc. On the other hand, given the same production techniques and scale, the firms may operate with different efficiencies. In addition, efficiency is also due to the differences in firm's availability of non-measurable inputs, such as managerial ability, which affects the efficiency of measurable combined inputs such as the quantities of paddy and labor.

Therefore, it is important that a study be conducted to compare the technical efficiencies, and investigate how efficiently the resources are being utilized in the production management process in the rice milling industry (of the two countries) in order to produce the potential output.

This paper is organized into five sections. Following this introduction, Technical efficiency and DEA is introduced and explained. In section 3 the data collection used in the study are described. Next, the various model specifications employed in the empirical analysis are presented. The last two sections cover the empirical results of this study and a summary of the findings.

2. Technical efficiency and DEA

The conventional definitions of efficiency used in the economics literature can be traced back to Farrell (1957). Farrell introduced a simple method of measuring the efficiency of firm directly from observed data, in a single output taking to account of multiple inputs. The efficiency consisted of both technical efficiency and allocative efficiency. The measure of technical efficiency that Farrell introduced is an input orientated measure by how much inputs could be reduced whilst maintaining the existing level of output (Fraser and Cordina, 1999)

Data Envelopment Analysis (DEA) is a non-parametric mathematical programming methodology based upon the work of Farrell. It involves the use of linear programming to construct an efficiency frontier that provide a means by which all firms can be assessed in terms of relative efficiency. DEA approach has two main advantages in estimating efficiency scores. First, it dose not require the assumption of a functional form to specify the relationship between inputs and outputs. Second, it does not require the distributional assumption of the inefficiency term.

The constant returns to scale (CRS) assumption means that average productivity, denoted by output/ input ratio is not dependent on scale of production. However, the most general assumption that can be made in respect of returns to scale is that they are variable. This permits constant but also increasing and decreasing returns to scale for different scale sizes. To allow for this possibility, variable returns to scale (VRS) that measure technical efficiency can be decomposed into pure technical efficiency and scale efficiency (SE). The VRS rating is obtained when control for the scale size of the Decision Making Unit (DMU) and SE measures the impact of scale size on the productivity of a DMU. The technical efficiency score (in both CRS and VRS models) equal one implies full efficiency on the other hand if the score is less than one it indicated technical inefficiency. Similarly SE, if the score equals one then that is scale efficiency or if the score is less than one that is scale inefficiency.

Consider the situation with n firms or decision-making units (DMUs), each producing a single output by using m different inputs. Here, Y_i is the output produced and X_i is the (m×1) vector of inputs used by the ith DMU. Y is the (1×n) vector of outputs and X is the (m×n) matrix of inputs of all n DMUs in the sample.

The technical efficiency (TE) measure under constant returns to scale (CRS) is obtained by solving the following DEA model:

Subject to
$$\begin{array}{l} \min_{\theta_{i}^{CRS},\lambda} \theta_{i}^{CRS} \\ Y_{i} \leq Y\lambda \\ \theta_{i}^{CRS} X_{i} \geq X\lambda \end{array}$$
(1)

 $\lambda \geq 0$

where θ^{CRS} is a TE measure of the *i*th DMU under CRS and λ is an n×1 vector of weights attached to each of the efficient DMUs. A separate linear programming (LP) problem is solved to obtain the TE score for each of the n DMUs in the sample.

If $\theta^{CRS} = 1$, the DMU is on the frontier and is technically efficient under CRS. If $\theta^{CRS} < 1$, then the DMU lies below the frontier and is technically inefficient.

The CRS or 'overall' (TE $_{CRS}$) measure can be decomposed into its 'pure' TE and scale efficiency components by solving a variable returns to scale (VRS) DEA model, which is obtain by imposing additional constrain on equation (1) (Banker et al., 1984) as specified below.

 $\min_{\substack{\theta_i^{CRS}, \lambda}} \theta_i^{CRS}$ Subject to $Y_i \leq Y\lambda$ $\theta_i^{CRS} X_i \geq X\lambda$ $\sum_{j=1}^n \lambda_j = 1$ $\lambda \geq 0$ (2)

Let θ_i^{VRS} denote the TE index of the *i*th DMU under variable returns to scale (TE_{VRS}). Because the VRS analysis is more flexible and envelops the data in a tighter way than the CRS analysis, the VRS TE measure (θ^{VRS}) is equal or greater than the CRS measure(θ^{CRS}). This relationship is used to obtain a measure of scale efficiency (SE) of the *i*th DMU as

$$SE_{i} = \frac{\theta_{i}^{CRS}}{\theta_{i}^{VRS}}$$
(3)

where SE = 1 indicate scale efficiency or CRS and SE < 1 indicates scale inefficiency.

The second stage, regression can be used to explain the efficiency scores for the various firm-specific factors as to identify the factor affecting technical inefficiency from the DEA results.. This analysis can be helpful in targeting extension activities to deal with technical inefficiencies in production. Tobit regression was used to identify possible factors associated with inefficiency.

When dependent variables are discrete, there are other estimation techniques, which provide maximum likelihood estimates such as Logit, Probit and Tobit. In case of Logit and Probit, the dependent variable can take any value between 0 or 1 but in the case of Tobit the dependent variable can take any value between 0 and any arbitrary number. So, for this study the most suitable method is Tobit because in efficiency in percentage which is a dependent variable that lies between 0 and 100 (Llewelyn and William, 1996; Burki and Terrell, 1998; Thiam et. al., 2001).

3. Data collection

Stratified and purposive sampling techniques were used to select the rice mills based on cross sectional data in 2000. The rice mills to be chosen as representatives of the rice mill industry of Thailand are in the Northeastern, Central and Northern regions as rice planting area. Surin, Phitsanulok and Chiang Mai provinces were selected to represent these areas respectively. The 11 samples were chosen from the name list of the Provincial Commercial Office, which classified commercial mill s in medium and large-scale businesses. In addition, one cooperative with a rice mill firm in each province was chosen for comparison with private rice mills.

There are more than 1,300 rice mills in Taiwan. However, most of them are located in Central and Southwestern regions, as they constitute the largest proportion of rice growing areas in

the country. Therefore, rice mills in the two regions were selected for the study. However, the samples to be covered by the study were drawn only from the 135 rice mills that have been registered as members of Taiwan Rice and Cereals Industry Association. The 30 samples are selected as representative of private rice mill. Moreover, five farmer associations were chosen to compare with private rice mill operation.

4. Model specification

The procedures are two-dimensional in order to carry the purpose of this study. Data Envelopment Analysis (DEA), the analytical method, was employed to analyze and compare the level of technical efficiency for rice millers by combining all rice mills in both Thailand and Taiwan. An input oriented measure, output is aggregated into one category and inputs are aggregated into four categories, namely, paddy, land, labor, and value of machine, as variables to be included in the model specification in equation 1 to 3 in section two. The variables are adjusted to account for such exchange rate differences between Thailand and Taiwan. These output and input variables are described below.

Output (Y) represents the total quantity of rice after processing (ton).

Paddy (X_1) represents the total quantity of annual paddy (ton).

Land (X_2) represents the total quantity of land (rai).

Labor (X_3) represents the total amount of family labor and hired labor (person).

Machine (X_4) represents the initial value of machine in mill operation (baht).

The survey data was given that rice processing was the dominant activity of the sample firms. Therefore, the output is total quantity of head rice produced by individual rice mills. The various inputs used in the analysis were adjusted. Paddy is only one raw material of processing. It was measured by ton per year of total quantity paddy used in 2000. Next, land was the total number of rai that the rice mill possessed as their processing area, warehouse and rice mill yard. Labor input was measured in number of persons. Each person was defined as the one man working 8 hours a day in the rice processing activity. Labor was measured by skilled and unskilled labors. Most rice mills are the family businesses, family labor ranging at 2-5 people per mill, was assumed to be skilled labor. Except for hired managers, hired labor was unskilled labor to perform bagging, pilling, carrying, and loading for example. Hence, disparity of labor was the quantity of hired labor. Finally, capital investment use for rice mill includes fixed cost and variable cost. Paddy is one variable that can be indicated in the variable cost. This study used value of machine to represent capital.

The variation of technical efficiencies in the rice mill industry is caused by two major reasons. One is the variation in technical aspect with respect to the quality of milling machine i.e. machine capacity and source of power used. The other is the variation in other factors such as managerial skill, labor skill, type of business etc.

Firm specific estimates of pure technical efficiency are used as a dependent variable. Technical efficiency scores are regressed on the explanatory variables which include years of establishment, degree to full capacity of operation, experience, Dummy variables are used for education of entrepreneurs, energy source in operation and dummy variable of business type (i.e. private rice mill and cooperatives rice mill) of each rice mill.

The Tobit regression to estimate an equation of the general form is

$$PTE_{i} = \alpha + \beta_{i}Year_{i} + \beta_{2}Capa_{i} + \beta_{3}Exp_{i} + \beta_{4}Edu_{i} + \beta_{5}Energy_{i} + \beta_{6}Type_{i} + \varepsilon_{i}$$
(4)

Where:

- PTE_i = Pure Technical Efficiency score for rice mill i
- Year_i = Number of years established of rice mill
- $Capa_i$ = Maximum degree to full capacity of machine operating (ton per day)
- Exp_i = Manager's experience (Number of year to engage in rice mill business)
- Edu_i = Education of entrepreneurs (1=Primary schoodl, 2=Secondary school, 3=High school, 4= University)
- Energy_i = Energy source in rice mill operation (1=diesel engine, 2= electronic motor, 3=Stream engine, 4=Automatic machine)
- Type_i = Dummy variable, equals to 1 if rice mill is private, 0 is association or cooperatives
- α, β = Prameters.
- $\varepsilon_i = \text{Error term.}$

5. Empirical findings

Taiwan

When combining rice mills in Thailand and Taiwan, the data showed that there were wide variations in both the input used as paddy and expenditure on machine and rice output data (Table 1). That is, there are large variations in the levels at which inputs were being used. Also note that initial value on machine and paddy has a much larger proportionate variation maximum/minimum than land and labor. This may be a reflection of the increased capital intensification and automation in the rice mill industry. In addition, this shows that the size of Taiwan's rice mill is more uniform and use less land but higher investment.

Table 1 Descriptive statistics for the combined sample of 71 rice mills in Thailand and

Minimum	Maximum	Mean	Standard Deviation
585*	112,320*	8,853.87	14917.14
900*	172,800*	14,101.93	23422.28
0.45	40*	11.86	16.60
4*	67*	18.83	14.75
320,000*	79,500,000	12,364,000	12,336,879.98
	Minimum 585* 900* 0.45 4* 320,000*	MinimumMaximum585*112,320*900*172,800*0.4540*4*67*320,000*79,500,000	MinimumMaximumMean585*112,320*8,853.87900*172,800*14,101.930.4540*11.864*67*18.83320,000*79,500,00012,364,000

Note: * = extreme original from Thai rice mills.

5.1. DEA results

The results are summarized by the frequency in Table 2. The mean of total technical efficiency and pure technical efficiency of rice mills in Thailand is less than Taiwan. The average CRS measure of technical efficiency for rice mills in the samples for Thailand and Taiwan is 0.84 or 84 % and 0.87 or 87 %, respectively. While, the average VRS measure are 0.87 or 87 % in Thailand compared with 0.91 or 91 % in Taiwan.

The first thing to note about these results is that, under the CRS measure of technical efficiency 8.3 % of the sample rice mills in Thailand (3 out of 36 mills) and 11.4 % (4 out of 35 mills) of rice mills sample in Taiwan are identified as technically efficient, i.e. operating at best practice.

		Number of mills						
	Range of efficiency score	CF	CRS		VRS		SE	
		Thailand	Taiwan	Thailand	Taiwan	Thailand	Taiwan	
	Equal to 100%	3	4	7	11	4	4	
	>90 - < 100%	9	8	9	8	21	20	
	80 - < 90%	11	20	12	13	8	6	
	70 - <80%	11	1	6	1	3	4	
	60 - < 70%	2	2	2	2	0	1	
	Mean efficiency	0.841	0.871	0.874	0.910	0.963	0.958	
	Minimum efficiency	0.635	0.625	0.640	0.674	0.870	0.832	
	Maximum efficiency	1.00	1.00	1.00	1.00	1.00	1.00	
ьτ	1 1 0 1			26	701 1 1	1.0.5 .11	····	

 Table 2 Comparison of technical efficiency score of rice mill in Thailand and Taiwan

Note: total number of observation = 71 mills including 36 mills in Thailand and 35 mills in Taiwan

The average level of technical inefficiency in Thailand and Taiwan is 0.16 or 16 % and 0.13 or 13 %, respectively (Table 2). This implies that, by adopting best practices, rice mills can, on average, reduce their inputs combination of land, labor, paddy, and expenditure on machine, by at least 16 % in Thailand and 13 % in Taiwan. However, to decrease the raw material of paddy in some cases could not be done, since the study analyzed the combined data in both countries and the higher percentage of head rice after processing in Taiwan has influence to enhance technical efficiency together extent than in Thai rice mills. The potential reduction in inputs from adopting best practices varies from mill to mill. The best practice or frontier firms cannot reduce their inputs. However the other 91.7% of rice mill in Thailand and 88.6% of rice mills in Taiwan can reduce their inputs according to the DEA results. They can do this by forming benchmarking partnerships with relevant best-practice firms and emulating the best practices of the latter.

The total technical efficiency can be decomposed into pure technical efficiency and scale efficiency. The VRS measure of technical efficiency of 19.4 % and 31.4 % (of the sample of rice mills in Thailand and Taiwan) are identified as technically efficient and operating at best practice. The average VRS measure of technical efficiency for mills in Thailand is 0.87 and 0.91 in Taiwan (Table 2). This means that 3 % and 4% of the difference between VRS technical inefficiency and CRS technical inefficiency identified above are due to rice mills operating at non-optimal scale.

As indicated earlier, the scale efficiency of the rice mills can be measured by the ratio of the constant returns to scale and the variable returns to scale input measures of technical efficiency. A ratio of unity implies that the rice mill is operating at optimal scale. A ratio of below unity implies that the rice mill is experiencing technical inefficiency because it is not operating at its optimal scale.

When technical efficiencies obtained with CRS and VRS models are equal then the operator is running under constant returns to scale (Coelli *et al.*, 1998). The results for scale efficiency suggested that 11.1 and 11.4 % of the rice mills in Thailand and Taiwan are operating at their own optimal scale (constant returns to scale). Since, rice mill scale efficiency in Thailand is a little higher about 96.3 % than 95.8% in Taiwan. Hence, inefficiency due to scale accounts for approximately 4 percentage points of the average technical inefficiency of 16 and 13 % in Thailand and Taiwan. According to the results, therefore, over 80 % of the rice mills in the sample are experiencing some technical inefficiency due to their size.

5.2 Use of DEA results to study inefficiency on individual rice mill

Throughout the DEA modeling approach for efficiency analysis, it is possible to achieve two types of results. First, it is possible to identify the adjustments that can be made in the use of inputs on inefficient mills by comparing then with their 'peer' mills. Second, the factors that can be manipulated to minimize the excessive use of inputs and hence reduce the costs of production can be established.

For example, by using the result of the VRS DEA model to work out what is required by inefficient rice mills to become efficient. Taking the rice mill Decision Making Unit (DMU) 1, with efficiency scores of 0.804 and 0.832 under the CRS and VRS assumptions, respectively. For rice mill, the firms 19 (lambda weight = 0.020), 41 ((lambda weight = 0.159) and 65 ((lambda weight = 0.820) are referents when VRS are assumed.

The production practices of the DMU-1 and its referents are compared in Table 3. The use of input by the DMU-1 is excessive. The above comparison would suggest strategies for the DMU-1 to rationalize the use of its inputs. The lambda values obtained from the DEA solution for this rice mill provide a composite DMU, which would produce the equivalent level of output, however by using lesser levels of input.

A composite DMU result shows that DMU-1 should reduce land and labor to 1.4 rais and approximately 12 men, respectively. In addition, rice mill should increase their machine utility such as expand time in operation, to raise technical efficiency. Nevertheless, paddy could not be decrease from 12,480 tons to 10,388.4 tons as it is restricted by the cracking percentage of milled rice in Thailand.

Variable in DEA	Input used level	Input level of the referent units			Composite
moder	DMU-1	DMU-19	DMU-41	DMU-65	DMU
Lambda values <i>Output</i>		0.020	0.159	0.820	
Rice (ton)	7,488	36,000	25,900	3,200	7,488
Inputs					
Paddy (ton)	12,480	60,000	36,909	4,000	10388.4
Land (rai)	14	33	1.35	0.62	1.4
Labor (people)	26	28	22	8	11.2
Machine (bath)	10,000,000	10,000,000	29,688,000	4,128,000	8,324,059.8

Table 3 Input use levels of the DMU-1 and its referents DMU in the VRS case

The results found in this section are the difference in technical efficiency that exists among rice mills in Thailand and Taiwan in different categories. The interesting issue to investigate is, "what are the factors that influence the difference in technical efficiency level?" The next section is presented with the purpose of answering this question.

5.3 Factor affecting technical inefficiency in rice mill industry

To assess the sources of measured efficiencies, this study uses a Tobit regression model as efficiency scores are truncated (Zheng et al., 1998). Therefore, firm specific estimates of pure efficiency are used as a dependent variable and as information on potential explanatory variables defined in section 4.

The estimated used the Tobit procedure in the LIMDEP software package. The outcomes are presented in table 4. Technical efficiency measures are regressed on number of years established, degree to full capacity of operation, experience, education level of entrepreneurs,

energy source in mill operation and dummy variable of business type (i.e. private rice mill and cooperatives rice mill) of each rice mill.

At level of significance, the results showed that experience and educational level have a significant effect on the efficiency level in both Thailand and Taiwan. The value of the estimated coefficient is positive, indicating that greater specialization in production is associated with higher relative efficiency. It can be concluded that management is probably most important to explain the relative technical efficiency. Even the word management here is not describing unique activity, but rather a complicated one, which comprises many activities within rice mills. This starts with the importance of education and the information of the millers. It was found during the field survey that the millers who were well educated were usually more advanced in managing their organization. In addition, work experience in milling or related fields, including formal training, has contributed to management skill. It was found that most of the millers who are successful in business usually have over ten years of working experience.

In Taiwan, further, the year established has an important impact on the efficiency level, but in contrast, in Thailand it is at 0.10 significant level. Due to in Taiwan, the average age of the rice mill is older than in Thailand and restriction to new entrepreneurs to enter into business. Some of rice mills have transferred into the third generation. Thus, a positive relationship between the age of the firm and technical efficiency can be expected due to learning-by-doing effects in Taiwan.

Additionally, the type of business is found to be related significantly in a positive way with technical efficiency at $\alpha = 0.05$ in Thailand and 0.10 significant level in Taiwan. This is due to commercial rice mills trying to operate at full capacity for maximum profit however cooperative rice mills were setup to help members against the uncertain value of paddy when they purchased it. Therefore, private rice mills could reach higher technical efficiency than cooperative rice mills.

T 7 • 11	Thail	and	Taiwan		
Variable	coefficient	p-value	coefficient	p-value	
Constant	0.8313	.0000	0.8868	.0000	
Year of establish	-0.0427	.2307	0.0391	.0938	
Capacity	-0.00065	.7942	-0.00014	.9415	
Experience	0.0164	.0000	0.0882	.0004	
Education	0.1409	.0000	0.1500	.0000	
Energy source	0.0129	.6981	0.0280	.1900	
Type of business	0.2134	.0477	0.1485	.0981	
Log likelihood	12.6402		10.3133	-	
Number of observation	36		35	-	

Table 4 Tobit regression analysis testing pure technical inefficiency of rice mills in

Thailand and Taiwan

The other variable, capacity and source of energy, are not found to have a significant association with technical efficiency as measured for the sampled mills. It can be denoted that capacity and source of energy may appropriated with their own mill business.

5. Summary and Conclusions

The analysis of technical efficiency for the rice milling industry are conducted using Data Envelopment Analysis model. The results showed that the average of total technical efficiency and pure technical efficiency of rice mill in Thailand is less than Taiwan. The average CRS measure of technical efficiency is 84 % in Thailand and 87 % in Taiwan. The averages VRS measures are 87 % in Thailand, compared to 91 % in Taiwan. This shows that efficiency of rice mills in Taiwan are clustered at the higher level than the rice mills in Thailand

When technical efficiencies obtained with CRS and VRS models are equal then the operator is running under constant returns to scale. Scale efficiency results illustrated that 11.1 % and 11.4 % of the rice mills in Thailand and Taiwan are operating at their optimal scale. Rice mill scale efficiency indices are about 96.3 % and 95.8% in Thailand and Taiwan, respectively. This implies that even if Taiwan has higher technical efficiency but the appropriate scale efficiencies of rice mill in both countries are almost identical. In addition, it can be mentioned that rice mills in Thailand and Taiwan, at least from the sample firms, are producing at an increasing return to scale. Therefore, these rice mills could increase their technical efficiency by continuing to increase their size.

The DEA results for each rice mill are also available to determine whether an individual rice mill can increase its technical efficiency by increasing or decreasing its inputs or whether it is already operating at optimal scale. The adjustments that can be made in the use of inputs by inefficient firms can be found by comparing them with their 'peer' firms. The composite of inputs on each decision making unit (DMU) was suggested how minimizing the use of excessive inputs could produce unchanged output.

Finally, this study attempts to identify factors inducing technical inefficiency of rice mills in both Thailand and Taiwan. The use of Tobit regression model to regress total technical efficiency on explanatory variables, defined as the number of years established, capacity of operation, experience, education level of rice miller, source of power, and dummy variable on type of business. The outcome from the analysis indicated that experience and educational level of rice miller was correlated significantly (and positively at $\alpha = 0.05$) with the technical efficiency of rice mill in both Thailand and Taiwan. Moreover, the age of the rice mill has an important impact on the efficiency level in Taiwan but not in Thailand. Finally, commercial rice mills have more technical efficiencies than cooperatives rice mills in Thailand and Taiwan at level $\alpha = 0.05$ and $\alpha =$ 0.10, respectively.

Reference

- Banker, R.D., A. Charnes and W.W. Cooper. 1984. "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis". *Journal of Productivity Analysis*, 7, 19-27.
- Charnes, A., Cooper, W.W., Rhodes, E., 1978. Measuring the Efficiency of Decision-

Making Units, European Journal of Operational Research 2, 429-444.

- Charnes, A., W.W. Cooper, A.Y. Lewin and L.M. Seiford. 1993. *Data Envelopment Analysis: Theory, Methodology, and Application*. Kluwer Academic Publishers, Boston.
- Coelli, T.J., D.S. Rao, and G.E. Battese. 1998. *An Introduction to Efficiency and Productivity Analysis*. Kluwer Acadamic Publishers, Boston.
- Cooper, W.W., L.M Seiford, and K. Tone, 2000. *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software.* Kluwer Academic Publishers, USA.

- Council of Agriculture. 2000. *Taiwan Food Statistics Book*. Council of Agriculture Executive Yuan.
- Emmanuel, T. 2001. Introduction to the Theory and application of data envelopment analysis: A Foundation Text With Integrated Software. Kluwer Academic Publishers.
- Färe, R., Grosskopf, S., Lovell, C.A.K., 1994. *Production Frontiers*. Cambridge University Press, Cambridge.
- Farrell, M.J. 1957. "The Measurement of Productive Efficiency". *Journal of the Royal Statistical Society*, 120(3), 252-290.
- Fraser, I. and D. Cordina. 1999. "An Application of Data Envelopment Analysis to Irrigated Dairy Farm in Northern Victoria, Australia". Agricultural Systems, 59(3), 267-282.
- Jaforullah, M. and J. Whiteman. 1998. "Scale Efficiency in the New Zealand Dairy Industry: a Non-Parametric Approach". Australian Journal of Agricultural Economics 43(4), 523-541.
- Khem, R. S, P. S. Leung and H. M. Zaleski. 1999. "Technical, Allocative and Economic Efficiencies in Swine Production in Hawaii: a Comparison of Parametric and Nonparametric Approaches", *Agricultural Economics*, 20(1), 23-35.
- Llewelyn R.V. and J.R.Williams. 1996. "Nonparametric Analysis of Technical, Pure Technical, and scale efficiencies for food crop production in East Java, Indonesia". Agricultural Economic, 15(2), 113-126.
- Lee, Y.O. 1996. "Rice Production and Consumption and Rice Policy in Taiwan". *Reprinted from the In dustry of Free China*. Vol 85, No.4. 1999.
- Office of Agricultural Economic, Ministry of Agricultural and Cooperatives, 2001.

Major Rice: Area, Production and Yield by Province, 1995/96 – 1998/99. [Online]. Available: <u>http://oae.go.th/statistic/yearbook/1998-1999</u>/sec3/sec3/sec3table23html. (May 17, 2001).

Shafiq, M. and T. Rehman. 2000. "The Extent of Resource Use Inefficiency in Cotton

Production in Pakistan's Punjab: an application of Data Envelopment Analysis". Agricultural Economics, 22(3), 321-330.

- Thiam, A., E.B.U. Boris and E.R. Teodoro. 2001. "Technical Efficiency in developing country agriculture: a Meta-analysis. Agricultural Economic. 25(2), 235-243.
- Zheng, J., Liu, X. and Bigsten, A.W. "Ownership Structure and Determinants of

Technical Efficiency: An Application of Data Envelopment Analysis to Chinese Enterprises (1986-1990). "*Journal of Comparative Economics* 26(1998): 465-484.