Rice harvesting in the Mekong Delta

Scale Efficiency and Technical Efficiency Analysis of Rice Producing Households in the Mekong Delta

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Abstract

This paper aims at analyzing scale efficiency and technical efficiency of rice producing families in the Mekong Delta by employing data envelopment analysis and stochastic frontier analysis methods. Results of analyses show that the technical efficiency of rice production surpasses 75% whether the income is based on a fixed or variable scale. Factors affecting the technical efficiency comprise farming area, investment, expense on fertilizer and agrochemical while technical inefficiency depends on expertise, experience and ability to apply new techniques by peasants.

Keywords: technical efficiency, technical inefficiency, rice producing household, DEA, SFA.

1. The problem raised

Studying the efficiency of rice production has been an interesting subject to scientists and policy makers in Asia because the rice production has a close relation with the food safety of this continent (Richard T. Yao and Gerald E. Shively, 2007). Of methods used for estimating the scale and technical efficiencies, data envelopment analysis (DEA) and stochastic frontier analysis (SFA) are the most common and applied by such authors as R. D. Banker, A. Charnes, và W. W. Cooper (1978), Linh H.V (2007), Y. Chen and A.I. Ali (2002), Hiền N.T.M (2003), and Nhựt Q.M (2007), etc. Therefore, the analysis of technical and scale efficiencies of rice production is necessary to the effort to help peasants realize interactive relation between output, value and inputs. This paper comprises four parts: (1) data gathered; (2) detailed description of DEA and SFA; (3) results of analyses of scale and technical efficiencies of the rice production; and (4) some important result of the paper.

2. Data gathered

a. Choosing locales for study:

The research is carried out in Cần Thơ and Sóc Trăng – two provinces that could be considered as typical of rice producing provinces in the Mekong Delta because they have many similarities (rice productivity and farming area per household, etc.) and both of them are affected by some research centers, such as Mekong Delta Rice Institute, Cần Thơ University, and Sóc Trăng Seed Center, etc.

b. Sampling method:

There are 261 rice farming households (161 in Cần Thơ and 100 in Sóc Trăng) included in the research during the 2006 winter-spring crop. The selection is based on representative characteristics: farming area, years of experience and rice farming pattern. Of these households, 209 have applied some technical advances and 52 do traditional farming. Such selection allows the research to compare efficiencies of different farming patterns.

Table 1: Characteristics of data gathered

Privince	Locale	Sample	As% of total
Cần Thơ	Thới Lai Commune	65	24.90
	Thới Long Ward	96	36.78
Sóc Trăng	Phú Tâm Commune	60	19.54
	Hồ Đắc Kiện Commune	40	15.33
Total		261	100.00

Source: Data gathered in June 2006

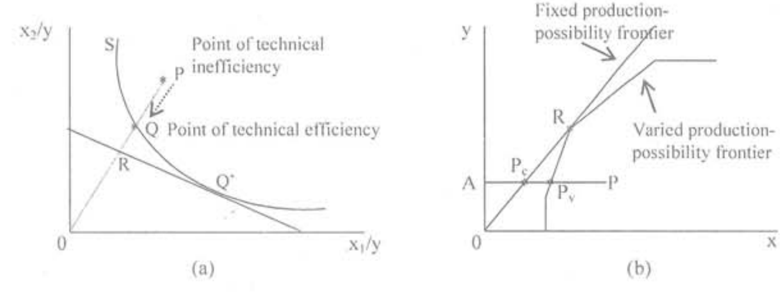
3. Researching method

Production frontiers analyses have been used under various forms for 40 years, and the most basic ones used for measuring scale and technical efficiencies are DEA and SFA, because the DEA involves the use of linear programming while the SFA applies econometrics (T.Coelli, D.S. Prasada Rao, G.G. Battese, 1998). The two methods are combined to measure the scale and technical efficiencies and determine parameters of the function of technical efficiency and check hypothesis of the SFA model.

a. DEA: It is one of nonparametric methods for the estimation of production efficiency of the household. This method was introduced by Farrell (1957) and it became common in 1978 with contributions from Charnes. That is why it is used widely in most researches of production efficiency. Such authors as A. Charnes, W.W. Cooper, E. Rhodes (1978), R.D. Banker, A. Charnes, W.W. Cooper (1984), Yao Chen, Agha Iqbal Ali (2002), and Tim Collie in particular have succeeded in turning this method into a software program called DEAP version 2.1 that allows simple measurement of scale and technical efficiencies.

The DEA method has two basic forms: input-orientated measures and output-orientated measures. This research, however, only measures inputs because the technical efficiency of rice farming households is determined by the relation between one product (value) and inputs. Moreover, as T.Coelli, D.S. Prasada Rao, G.G. Battese (1998) pointed out, results of two measures are similar.

Figure 1: Scale and technical efficiencies



Source: Tim Coelli, 1998

The input-orientated technical efficiency is determined by factors (xi) used by the household to produce the production value (y). In the Figure 1a, the curve S shows points of technical efficiency of the farming household, that is, if the household uses an amount of factor inputs equaling the point Q shown on the curve S, it can gain the maximum technical efficiency. And any other amount of inputs outside the curve S, like the point P, prevents the farming household from achieving the technical efficiency. The amount of inputs the household cut and ensure the same technical efficiency equals the distance from Q to P without changing the value of production.

Precisely, the technical efficiency of the household is defined as:

TEi = OQ/OP (Figure 1a)

Coefficient of the technical efficiency varies from 0 to 1, and at the same time, it points out the coefficient of technical inefficiency. If the TEi = 1, the household achieves the maximum technical efficiency because the point B is on the curve S as shown in the Figure 1a.

However, to calculate the technical efficiency under the assumption of constant returns to scale (CRS), first of all, we should make clear some indicators: there are K inputs and M value of production of each household among N surveyed households. Therefore, the household i is represented by corresponding axial vectors xi and yi. The K*N matrix of inputs, the M*N matrix of value of production and Y express data about N households. Thus, the technical efficiency of the household i among N households can be determined by an objective function and limited to:

$$
\begin{aligned}
& \text{Min}_{\theta,\lambda}\theta, \\
\text{st} \quad & -yi + Y\lambda \geq 0, \\
& \theta xi - X\lambda \geq 0, \\
& \lambda \geq 0,
\end{aligned}
$$

in which, θ is the coefficient of technical efficiency of the household i and θ ≤ 1. If θ = 1, the household i gains the maximum technical efficiency. Meanwhile, the linear programming should be implemented N times for N surveyed households and a value of θ is given to each household.

We can also identify the technical efficiency with variable returns to scale (VRS) by adding to the CRS model the vector N1'λ = 1. More precisely, it is as follows:

$$
\begin{aligned}
& \text{Min}_{\theta,\lambda}\theta, \\
\text{st} \quad & -yi + Y\lambda \geq 0, \\
& \theta xi - X\lambda \geq 0, \\
& N1'\lambda = 1, \\
& \lambda \geq 0,
\end{aligned}
$$

in which, N1 is the vector Nx1 with a value of 1, therefore, the coefficient of technical efficiency under VRS assumption will be equal to or bigger than the coefficient of technical efficiency under the CRS assumption.

For that reason, the technical efficiency under both CRS and VRS assumption will be worked out in this paper because only if the optimal scale is ensured can the CRS technical efficiency be really appropriate while this condition couldn't be fulfilled in developing countries due to limited resources (T.Coelli, D.S. Prasada Rao, G.G. Battese, 1998).

As for the scale efficiency (SE), it is in fact determined by using the ratio of two coefficients of CRS technical efficiency (TECRS) and VRS technical efficiency (TEVRS). This means that any difference between the two coefficients of technical efficiency by the household i also proves a failure to achieve the SE (T.Coelli, D.S. Prasada Rao, G.G. Battese, 1998). The SE worked out from the Figure 1b is as follows:

$TE_{CRS} = APc/AP$

$TE_{VRS} = APv/AP$

$SE = APc/APv$

The coefficient of SE varies from 0 to 1, and any household that is at the point R (Figure 1b) gains the maximum SE.

In short, coefficients of scale and technical efficiencies can be determined using DEAP version 2.1 introduced by Tim Collie.

b. SFA: SFA is a method of economic modeling introduced by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977), who first suggested production frontier function with random error. The SFA model can be written as:

$\ln(yi) = x_i\beta + v_i - u_{i,i} = 1,2,\ldots, n$

in which $\ln(y_i)$ is the log value of output of the producer i;

x_i is a vector of N inputs used by the producer i, the first factor equals 1 and the rest is in form of logarithm of K outputs employed by the producer i;

β is a axial vector (K + 1) of technology parameters to be estimated;

u_i is the non-negative technical inefficiency component;

v_i is the random error comprising natural factors such as weather, disease, etc.

Checking the hypothesis is an indispensable task when analyzing the production frontier function, in which the hypothesis H_0 is free from effects of technical inefficiency factors and vise versa for the hypothesis H_1.

H_0: ($\gamma = 0$): without effects of factors of technical inefficiency, ui,

H_1: ($\gamma > 0$): with effects of factors of technical inefficiency.

$$\gamma = \sigma_u^2 / \sigma^2 = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$$

According to Coelli, the one-sided generalized likelihood-ratio (or LR) is defined as:

$LR = -2\{\ln[L(H_0) - \ln[L(H_1)]\}$

in which, $L(H_0)$ and $L(H_1)$ are approximate values in hypotheses H_0 and H_1. The critical value of LR to be considered corresponds to the value of $\chi2(2\alpha)$.

For example, if the critical value $\alpha = 5\%$, looking at the table $\chi2(2\alpha)$, the value 2.71 ($2\alpha = 2*5\%$) is selected instead of 3.84.

Thus, the SFA model in this research is defined in detail as:

$$\ln(y_i) = x_i\beta + v_i - u_i, i = 1,2,..., n$$

where:

y_i = Value of the winer-spring rice crop (VND)

x_1 = Labor (person)

x_2 = Farming area (1,000m^2)

x_3 = Investment (VND/crop)

x_4 = Expense on hired labor (VND/crop)

x_5 = Seed (VND/crop)

x_6 = Fertilizer (VND/crop)

x_7 = Agrochemical (VND/crop)

x_8 = Other expenses (VND/crop)

Meanwhile, random effects of technical inefficient factors, ui, as variables are represented as:

$|ui| = \delta0 + \delta1Z1 + \delta2Z2 + \delta3Z3 + \delta4Z4$

where:

Z1 = Peasants' education (level)

Z2 = Experience (year)

Z3 = Role in agricultural organizations (1 = yes, 0 = no)

Z4 = Application of technical advances (1 = yes; 0 = no)

In short, the SFA model allows us to determine parameters, standard deviation and values used for checking the hypotheses using Frontier 4.1 introduced by Tim Collie.

4. Results and discussion

a. Scale and technical efficiencies:

Results of measurement of coefficients of production efficiency produced by the DEAP version 2.1 and presented in the Table 2 show that the technical efficiency of rice farming models scores over 75% on average while the scale efficiency scores some 97%. Generally, most rice farming households, or 91.19% of 261 surveyed households to be precise, fail to reach the optimal technical efficiency and only 23 households gain the optimal score. Statistically, this means that they can cut some 25% (1 – 0.75) of factor inputs and gain the optimal technical efficiency without damaging the value of production. Coefficients of technical efficiency in this research are relatively appropriate to previous researches by other authors, such as Bình T.V. (2007); Linh H.V. (2007); and Hiền N.T.M. (2003), etc.

Table 2: Scale and technical efficiencies of rice farming households

	TE_{CRS}	TE_{VRS}	SE	Rank
Average coefficient	0.753	0.777	0.969	-
Number (and %) of households gaining the optimal efficiency	23 (8.81%)	23 (8.81%)	25 (9.58%)	-
Coefficients of technical efficiency by models				
- Rice – vegetable	0.886	0.906	0.978	1
- Rice – fish	0.797	0.895	0.891	2
- New rice strain	0.766	0.809	0.948	3
- IPM	0.784	0.830	0.943	4
- 3 decreases – 3 increases	0.872	0.823	0.940	5
- Sowing seed in rows	0.826	0.888	0.931	6

Sources: Authors' calculations using the DEAP 2.1.

Note:

TE_{CRS} = CRS technical efficiency

TE_{VRS} = VRS technical efficiency

SE = Scale efficiency

Of 261 rice farming households, only 25 ones, or 9.58%, gain the optimal scale efficiency; and 230 households produce rice at an increasing scale. This means that most of them have a chance to increase the inputs to gain the scale efficiency. This approach is different from making decreases in the inputs to gain the technical efficiency mentioned above. In terms of the scale efficiency, the highest efficiency gained by producing rice in combination with another product comes from decreases in such inputs as fertilizer and agrochemicals. The following results produced by the SFA model can allow us to identify factors that affect the technical efficiency.

b. Results of the SFA model:

Estimated results from the SFA model are presented in the Table 3. First of all, we should examine meanings of this model to decide whether we can accept the hypothesis H0 or not; and whether the technical efficiency is affected by the random error (vi) or technical inefficient factors (ui).

We see that LR = 13.19, higher than the accepted value (α= 5%) of 9.23 presented in the distribution table $\chi 2(2\alpha)$, which allows us to accept the hypothesis H_0 and reject the H_1. In other words, effect of technical inefficient factors has a meaning level of 5%. However, we see that $\gamma = \sigma_u^2 / \sigma^2 = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$ = 0,03 and coefficient $\sigma^2 = \sigma_v^2 + \sigma_u^2 = 0{,}003$ (very close to 0), which allow us to work out $\sigma_v^2 = 0{,}02991; \sigma_u^2 = 0{,}00009$. So we can conclude that the effect of technical inefficient factors comes mostly from the random error σ_v^2.

The following Table 3 explains parameters of the SFA model, and estimation sign of parameters in the model is rather appropriate to results found in researches by Tom. K (2002), Hiền N.T.M. (2003), A.A. Tijani (2006), and Linh H.V. (2007). Such variables as farming area and investment have a positive correlation to the technical efficiency of the producer because the producer who wants to improve the farming techniques should make investment bigger than the one required by traditional techniques. On the other hand, marginal productivity of such inputs as fertilizer and agrochemical has a negative correlation with the technical efficiency. This is appro-

Table 3: Estimated results of the SFA model

Model	Meaning	Parameter	Coefficient	Standard deviation	Ratio t
Constant		β_0	06.0892***	0.2209	27.5606
Loglaodong	Family labor	β_1	0.0118	0.0158	0.7518
logdientich	Area	β_2	0.9727***	0.0461	21.1040
Logvon	Investment	β_3	0.0609***	0.0160	3.8086
Logcplaodong	Labor cost	β_4	0.0155	0.0271	0.5717
Loggiong	Expense on seed	β_5	-0.0029	0.0261	-0.1101
Logphanbon	Expense on fertilizer	β_6	-0,0471**	0,0243	-1,9326
Lognongduoc	Expense on agrochemical	β_7	-0,0524***	0,0174	-3,0130
Logkhac	Other expenses	β_8	0,0371	0,0404	0,9178
Technical inefficient model					
Education		δ_1	-0.0142*	0.0092	-1.5427
Experience		δ_2	0.0015***	0.0004	3.5491
Role in organization		δ_3	0.0174	0.0148	1.1736
Application of technical advances		δ_4	-0.0553**	0.0260	-2.1274
Sigma-squared $\sigma^2 = \sigma_v^2 + \sigma_u^2$		Σ	0.0030***	0.0003	10.7147
Gamma $\gamma = \sigma_u^2 / \sigma^2 = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$		Γ	0.0377	0.0267	1.4128
Estimated approximate value = 0.37578039E+03					
Checked value LR = 13.19					

Sources: Authors' calculations using the DEAP 2.1.
*,**,*** correspond to meaning levels of 10%, 5% and 1%.

priate to theories and expectations of the producer when applying technical advances, such as reduction in agricultural materials for lower cost and less damage to the environment.

As for the technical inefficiency model, the negative sign of parameters has a meaning of positive impact on the technical efficiency. Namely, peasant's education and readiness to apply technical advances lead to a higher technical efficiency because the education is considered as an important factor to decisions in business and household income (Minot, 2003). In addition, application of technical advances aims at improving the productivity or reducing the production cost, therefore, results of the above explanatory variables are appropriate to theories and previous researches. Meanwhile, the experience has a negative effect on the technical efficiency although its marginal value is small. This allows us to affirm that producers should follow process of applying technical advances, instead of their experience, to gain higher efficiency.

5. Conclusion

The research shows that the average coefficients of technical and scale efficiencies of rice farming households in the surveyed communes in the Mekong Delta are rather high although most of them fail to gain the optimal technical efficiency. Of various farming models surveyed, the production of rice in combination with another product is more efficient than the rice monoculture.

The technical efficiency has close relations with such factors as farming area and investment. In addition, peasants' education and readiness to apply technical advances affect positively the technical efficiency.

In short, the SFA is a suitable method to identify the technical efficiency of agricultural production, especially in developing countries, because data gathered from farming households are usually affected by random error and natural conditions (Tim Collie, 1998) ■

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