CHAPTER 7

ESTIMATION OF PRODUCTION FRONTIER AND DETERMINANTS OF TECHNICAL INEFFICIENCY

The purpose of this chapter is to explain the estimated results of production frontiers for both conventional rice and hybrid rice. Furthermore, the inefficiency models were modeled to identify factors affecting technical inefficiency of hybrid rice and conventional rice production. In addition, the allocative efficiency was concerned in order to get better recommendations for rice growers.

7.1 Model specification

The following section presents the empirical model of Cobb-Douglas production frontier and the empirical model for assessing determinants of technical inefficiency.

7.1.1 Cobb-Douglas production frontier

The stochastic frontier method with Cobb-Douglas production function was used in the study. The empirical Cobb-Douglas production frontier for a given variety (hybrid rice or conventional rice) is modeled as follows:

$$\ln Y = a_0 + \sum a_i \ln X_i + bD_j + v - u \qquad (7.1)$$

where:

i = 1,2,3…7

j = 1,2

Y = rice yield of farm (kg/ha)

X_i = input variables, where X_i:

MANU = quantity of pure manure (kg/ha)

NITRO = nitrogen active amount (kg/ha)

PHOS = phosphorus active amount (kg/ha)
POTAS = potassium active amount (kg/ha)
PEST = pesticide expenditure (thousand VND/ha)
LABOR = number of labors employed (man-days/ha)
SEED = quantity of seed used (kg/ha)
D_1 = 1 if Quocoai district, and = 0 otherwise (Phuxuyen district).
D_2 = 1 if spring season, and =0 otherwise (summer season).
This variable is applicable only to conventional rice
$\alpha_0, \alpha_i, \beta$ = parameters to be estimated
v, u = error terms as mentioned above

It gives the same result either to identify factors affecting technical efficiency or technical inefficiency, except the sign of variables in technical efficiency equation are opposite with those in technical inefficiency equation. In this study, technical inefficiency equation was constructed to estimate determinants of technical inefficiency.

7.1.2 Model for assessing determinants of technical inefficiency

The determinants of inefficiency need to be specified in the empirical model. Most of the authors agree with Wilson *et al*. (1998), who pointed out that inefficiency should be related to non-physical inputs or management practices which are not captured by the aggregated input quantities X_i. In this study, the personal characteristics of household head included the year of schooling, age of household head, and dummy variables for gender and access to technical information. Moreover, land size variable was included to examine the influence of farm size on technical inefficiency through the managerial ability of farmers.

Technical inefficiency equation of any rice variety is given in equation 7.2

$$TI = a_0 + a_1 GEND + a_2 EXP + a_3 AGE + a_4 EDU + a_5 IFO + a_6 LAND + e \quad (7.2)$$

where

TI = technical inefficiency of farm
GEND = 1 if head of household is female, and =0 otherwise
EXP = experience (year)
AGE = age of household head (year)
EDU = number of years in school of household head (year)
IFO =1 if household has access to technical information, = 0 otherwise
LAND = total of rice land area (ha)

7.1.3 Description of variables and expected results

Y (yield)

Yield is the total rice output harvested and calculated per hectare. Rice yield is a depended variable in Cobb-Douglas production frontier.

MANU (manure)

Manure is an important input, providing nutrient to rice plant that has bearing on rice yield. In this study, measurement of manure application based on estimation of pure manure as reported by the sample households and local persons. The proportion of pure manure in the actual amount of manure application is 30 percent.

NITRO (nitrogen), PHOS (phosphorous), and POTAS (potassium)

Nitrogen, phosphorus, and potassium are the important inputs, which directly affect rice yield. The amount of actual nitrogen, phosphorous, and potassium use were converted to active amount based on the nutrient composition of these fertilizers. The proportion of pure nitrogen (N), phosphorous (P_2O_5), and potassium (K_2O) are 46 percent, 18 percent, and 66 percent, respectively.

PEST (pesticide)

The measurement of pesticide was rather cumbersome because farmers used many types of pesticides. Also actual quantities used were not easily recalled. They were only able to give information on the total expenditure on pesticides. In this study, however, it was observed that pesticide price and pesticide quality were rather uniform. Majority of the sample households bought pesticide from local cooperatives. Therefore, one possible aggregation was to use the value of expenditure on pesticides as a proxy. This kind of aggregation was also used by many researchers (Rawlins, 1989; Wiboonpongse, 1983, and Wilson *et al*., 2001).

LABOR (labor)

The included total labor used from land preparation to harvesting, measured in man-days. Some farmers also hired labor or exchanged labor (with their neighbor or related people). All types of hired and exchanged labor were not significantly different according to quality. Therefore all types of labor added up without weighing.

SEED (seed)

Seed rate reflects the density of rice plant. Given the same rice variety, the difference in seed rate may also cause the variation in rice yield. Therefore, this variable was included in the production frontier function.

D_1 (location dummy) and D_2 (season dummy)

Different location normally has different topography, weather, and soil characteristics. The survey was conducted in two districts of Hatay province, thus location dummy variable was used to investigate the difference in rice yield between two districts. Furthermore, the season dummy variable is only included in production frontier model of conventional rice to find out the influence of seasonal factor on conventional rice yield.

AGE (age), EDU (education), GEND (gender of household head)

Age variable was included in technical inefficiency equation to estimate the influence of age on the technical inefficiency. It is believed that age can serve as a proxy for decision making on production process.

The education was measured as the number of year of schooling achieved by household head, which was used as a proxy for managerial ability. Increasing literacy may help farmers acquire and understand agricultural technology and to calculate appropriate input quantities.

Gender of household head may be attributed to the ability of decision making on resource allocation or resource utilization. Therefore, gender of household head was also included in the technical inefficiency equation to identify its influence on technical inefficiency. Age, education, and gender of household head are considered as factors affecting the managerial capacity of household head. Therefore, they were simultaneously included in the technical inefficiency equation. It was suggested by some previous studies by Lin (1994) and Song (1997).

EXP (experience)

Experience is measured by the number of year that farmers grow the specific rice variety. More farming experience coupled with higher level of educational achievement may lead to better assessment of the importance and understanding the complexities involved in making good decisions in farming.

IFO (information)

The access to technical information about the available technologies on rice production may play a crucial role in determining the technical inefficiency because of the exposure and better understanding of these technologies. Thus, access to technical information was included in the technical inefficiency equation to evaluate the influence of technical information on technical inefficiency. Household, who had access to technical information of rice production was given 1 or otherwise given 0.

LAND (land size)

Land size (or total land area) variable was included in technical inefficiency equation to examine the land size economy in the study site. The existence of land size economy could reflect the good managerial ability of farmers.

The expected signs of coefficients of explanatory variables in production frontier model and technical inefficiency equation are shown in Table 7.1.

Table 7.1: Expected signs for estimated variables

Production frontier model		*Technical inefficiency equation*	
Variable	Sign	Variable	Sign
MANU	Positive	GEND	Positive or Negative
NITRO	Positive or Negative	EXP	Negative
PHOS	Positive	AGE	Negative
POTA	Positive	EDU	Negative
PEST	Positive or Negative	IFO	Negative
LABOR	Positive	LAND	Positive or Negative
SEED	Positive		
D_1	Negative		
D_2	Positive		

7.2 Estimated result of production frontiers

The following section is to present the estimated production frontiers for hybrid rice and conventional rice and the discussion on estimated results

7.2.1 Estimated result of production frontier for hybrid rice

The correlation matrix for the logarithm of the yield and variables affecting hybrid rice yield was presented in Table 7.2. It shows that the correlation coefficients of explanatory variables are low. Therefore, the multi-collinearity problem did not exist in the stochastic Cobb-Douglas production frontier.

Table 7.2: Correlation matrix for the logarithm of the yield and variables affecting the hybrid rice yield

	ln(Y)	ln(x_1)	ln(x_2)	ln(x_3)	ln(x_4)	ln(x_5)	ln(x_6)	ln(x_7)	D_1
ln(Y)	1.0000								
ln(x_1)	0.5233	1.0000							
ln(x_2)	-0.4909	-0.3304	1.0000						
ln(x_3)	0.4620	0.3678	-0.2792	1.0000					
ln(x_4)	0.6661	0.4900	-0.2930	0.3567	1.0000				
ln(x_5)	-0.3704	-0.2734	0.1729	-0.0935	-0.3090	1.0000			
ln(x_6)	-0.1900	0.0890	0.2876	-0.1412	-0.1338	0.1494	1.0000		
ln(x_7)	0.3482	0.2988	-0.2242	0.2073	0.2441	-0.1760	0.0340	1.0000	
D_1	-0.4168	-0.1656	0.0306	-0.0563	-0.1671	0.0321	-0.2195	-0.1711	1.0000

Source: Calculation

Note:

Y= YIELD
x_1= MANU
x_2= NITRO
x_3= PHOS
x_4= POTA
x_5= PEST
x_6= LABOR
x_7= SEED
D_1= LOCATION

Consider γ in Table 7.3 that is statistically significant from zero. This implies that the production frontier for hybrid rice do exist. The significant variables explaining the variation in hybrid rice yield were nitrogen, phosphorus, pesticide, and location dummy.

Table 7.3: Estimates of stochastic Cobb-Douglas production frontier for hybrid rice

Variable	Coefficient	t-ratio
Stochastic Production Frontier		
Constant	9.415	23.90^{***}
ln (MANU)	-0.007	-0.28
ln(NITRO)	-0.089	-1.95^{*}
ln(PHOS)	0.035	2.68^{**}
ln(POTAS)	0.052	2.34^{**}
ln(PEST)	-0.025	-1.84^{*}
ln(LABOR)	-0.093	-1.00
ln(SEED)	0.017	0.69
D_1	-0.045	-3.88^{***}
Variance parameters		
σ^2_ε	0.002	6.50^{***}
γ	0.999	11.29^{***}
Log likelihood function	172.77	

Source: Estimated by using Frontier 4.1

Note: ***, **, and * are significant at 1%, 5 % and 10%, respectively.

$$s_e^2 = s_v^2 + s_u^2 \quad g = \frac{s_u^2}{s_v^2 + s_u^2}$$

The coefficient of manure has negative sign. However, it is insignificant. This means that the amount of manure application ranging from 900 to 3,600 kg/ha did not affect the hybrid rice yield.

Nitrogen is a crucial factor largely contributing to increase in rice yield, especially that of hybrid rice. However, the coefficient of nitrogen is negative and statistically significant. The production elasticity of hybrid rice yield with respect to nitrogen is -0.89. It implies that an increase in amount of nitrogen use by 1 percent led to reduction in hybrid yield by 0.89 percent. The survey found that average amount of nitrogen application of sample farms was quite high (about 101 kg/ha) and the maximum amount was 130 kg/ha (Table 6.5). Rice plants were supplied with nitrogen not only from chemical fertilizer, but also from manure. When compared to the recommended rate of nitrogen (page 60), it showed that many sample farms used excessive amount. Farmers indicated that during production process, if rice leaf was not very green, they added more nitrogen to get higher yield. As the result, rice leaf grown very fast, creating favorable conditions for pest and disease. According to Cuong (2000), the bacterial leaf bright is a common disease occurring when nitrogen is inappropriately applied and in excess. Thuan and Bo (2001) also concluded that nitrogen is an important element for rice, however, the over application of nitrogen easily leads to negative consequences. The negative effect of nitrogen use on hybrid rice yield can be explained by either over use of nitrogen or application of nitrogen in inappropriate time. For this reason, it is suggested that farmers should reduce amount of nitrogen application. Meanwhile, farmers should pay more attention to timeliness of nitrogen application.

The coefficient of phosphorus is positive and statistically significant as expected. The production elasticity of hybrid rice yield with respect to phosphorus is 0.035, i.e., one percent of increase in amount of phosphorus use increased hybrid rice yield by 0.035 percent. Thuan and Bo (2001) confirmed that application of phosphorus in rice production significantly accelerates the use of nitrogen. It was found that, the average amount of phosphorus use for hybrid rice of sample farms was 68 kg/ha (Table 6.5), which was considerably lower than the recommended amount.

It was argued that potassium not only plays an important role in strengthening straw, but also reduces the bacterial leaf bright in hybrid rice (Cuong, 2000). The production elasticity of hybrid rice yield with respect to potassium is 0.052 and statistically significant at 1 percent. This reflects that one percent of increase in potassium application increased hybrid rice yield by 0.052 percent.

Hybrid rice could obtain high yield, however hybrid rice requires high level of fertilizer application. For this reason, this variety is highly susceptible to bacterial leaf bright, rice blast, and brown plant hopper (Cuong, 2000). The estimated result of stochastic production frontier shows that coefficient of pesticide variable is negative (-0.025) and statistically significant at 10 percent. It implies that hybrid rice yield was negatively affected by the use of pesticide. One percent of an increase in pesticide expense reduced hybrid rice yield by 0.025 percent. It was observed that, there were two reasons leading to this consequence. Firstly, due to excessive use of nitrogen, serious bacterial leaf bright occurred and the intervention by pesticide use did not yield good result (Cuong, 2000). Secondly, farmers sprayed pesticide before and after the pest was observed, thus pesticide spray might be ineffective. Therefore, farmers are recommended that they should reduce the amount of nitrogen application and apply it timely. By doing so, the rice yield may be higher and the cost of pesticide will be reduced. Furthermore, reduction in pesticide use will contribute to the environmental protection as well as farmer's health.

The coefficient of labor variable is negative (-0.093) and insignificant. The possible reason leading to insignificance of labor variable was due to small variation in labor use among sample farms (CV is 6.56).

In addition, the coefficient of seed variable is positive and statistically insignificant. The small variation in seed use among sample farms (CV is 19.39) might result in the significance of seed variable (Table 6.5). Therefore, the amount of seed use ranging from 27 to 54 kg/ha did not have influence on hybrid rice yield.

For location dummy variable, the coefficient of this variable is negative (-0.044) and statistically significant at 1 percent level. This means that average rice yield in Quocoai district was lower (1.05 percent) as compared with that of Phuxuyen district. The major factor leading to this difference is the soil quality. Hatay province can be divided into two distinct zones: the eastern delta zone and the western mountainous-hilly zone. Phuxuyen district belongs to the first zone. Soil of Phuxuuen district is alluvial soil, which is more suitable for rice production than that of Quocoai (belonging to the second zone). In this study, the statistical data for rice collected by Hatay Statistical Office were used to verify the comparison of rice yield between two districts. It was showed that rice yield of Phuxuyen was higher than that of Quocoai, and this situation is consistent over the time. Therefore, it can be concluded that soil fertility is one factor affecting rice yield.

The coefficient of g is 0.99 and highly significant at 1 percent level, meaning that 99 percent of the total variation of hybrid rice yield explained by the model is attributed to technical inefficiency and only 1 percent to random shocks.

In summary, manure, labor, and seed variables were not significantly explained by the estimated frontier production function of hybrid rice. On the contrary, the nitrogen, phosphorus, potassium, pesticide, and location were very crucial variables leading to variation in hybrid rice yield. Therefore, the improvement on the use of nitrogen, phosphorus, and pesticide could increase hybrid rice yield.

7.2.2 Estimated result of production frontier for conventional rice

The correlation matrix for the logarithm of the yield and variables affecting the conventional rice yield is showed in Table 7.4. In addition, the estimated of stochastic Cobb-Douglas production frontier for conventional rice is presented in Table 7.5. The coefficient of g is statistically significant from zero. This implies that the production frontier for conventional rice do exist. In addition, the significant variables explaining the variation in conventional rice yield were nitrogen, phosphorus, pesticide, location dummy, and season dummy.

As shown in Table 7.5, the coefficient of manure variable is positive as expected. The production elasticity of conventional rice yield with respect to manure is 0.023 and insignificant. One possible reason leading to the insignificance of this variable was that conventional rice yield might not be directly affected by the use of manure in the same cropping season. The influence of manure on conventional rice yield may be accumulated over the year.

Table 7.4: Correlation matrix for the logarithm of the yield and variables affecting the conventional rice yield

	ln(Y)	ln(x_1)	ln(x_2)	ln(x_3)	ln(x_4)	ln(x_5)	ln(x_6)	ln(x_7)	D_1	D2
ln(Y)	1.000									
ln(x_1)	0.427	1.000								
ln(x_2)	-0.063	-0.215	1.000							
ln(x_3)	0.304	0.344	-0.258	1.000						
ln(x_4)	0.401	0.425	-0.144	0.361	1.000					
ln(x_5)	-0.290	-0.211	0.091	-0.175	-0.276	1.000				
ln(x_6)	0.008	0.1435	-0.004	-0.019	0.052	-0.012	1.000			
ln(x_7)	0.292	-0.052	0.119	-0.166	0.048	-0.084	0.085	1.000		
D_1	-0.249	-0.242	0.060	-0.006	-0.245	0.223	-0.248	-0.053	1.00	
D2	0.628	0.070	0.333	-0.251	0.059	0.018	0.0005	0.045	-0.010	1.000

Source: Calculation

Note:

Y= YIELD
X_1= MANU
X_2= NITRO
X_3= PHOS
X_4= POTA
X_5= PEST
X_6= LABOR
X_7= SEED
D_1= LOCATION
D_2 = SEASON

The coefficient of nitrogen variable is negative (-0.062) and significant at 1 percent level. Conventional rice yield was negatively affected by the use of nitrogen. This could be explained by excessive use of nitrogen and inappropriate time. Hence, farmers should apply nitrogen appropriately. Thereby, they may achieve higher conventional rice yield.

Another crucial factor affecting conventional rice yield was phosphorus. The coefficient of phosphorus variable is positive (0.05) and significant at 1 percent level. One percent of increase in amount of phosphorus use increased conventional rice yield by 0.05 percent. This means that farmers accrue benefits from the use of phosphorus

Table 7.5: Estimates of stochastic Cobb-Douglas production frontier for conventional rice

Variable	Coefficient	t-ratio
Stochastic Production Frontier		
Constant	8.692	28.12^{***}
ln (MANU)	0.023	1.58
ln(NITRO)	-0.062	-3.11^{***}
ln(PHOS)	0.050	4.17^{***}
ln(POTAS)	-0.003	-0.33
ln(PEST)	-0.062	-3.01^{***}
ln(LABOR)	0.017	0.40
ln(SEED)	0.010	0.40
D_1	-0.022	-3.38^{***}
D_2	0.130	19.11^{***}
Variance parameters		
σ^2_ε	0.0011	8.84^{***}
γ	0.9999	5.22^{***}
Log likelihood function	378.96	

Source: Estimated by using Frontier 4.1

Note: ***, **, and * are significant at 1%, 5 % and 10%, respectively.

$$s_e^2 = s_v^2 + s_u^2 \qquad g = \frac{s_u^2}{s_v^2 + s_u^2}$$

The estimated coefficient of potassium variable is negative (-0.003) and insignificant. The correlation between pesticide variable and potassium variable (Table 7.5) might lead to multi-collinearity, which suppressed the significance of potassium variable. When pesticide variable were not included in the production frontier model, the influence of remaining variables on conventional rice yield did not change (Appendix Table 8). It means that this multi-collinearity problem was not severe. Therefore, the pesticide variable should be modeled in the frontier production model in order to get the better estimation of production frontier for conventional rice.

Furthermore, the production elasticity of conventional rice yield subjected to pesticide is negative and statistically significant. This result also could be explained as same as the influence pesticide use on hybrid rice yield.

On the other hand, the production elasticity of conventional rice yield with respect to labor is positive and small (0.017). Nevertheless, this variable was not statistically insignificant. Low and insignificant elasticity of labor might be due to some constraints. One factor was that, farmers could have different working efficiency. Some farmers might allow more break time than others, resulting in differences in working time spending. Another reason could be the small variation of labor use among farms (CV is 6.56).

The coefficient of location dummy variable is negative (0.022) and statistically significant. This indicates that conventional rice yield of Quocoai district achieved lower yield (1.02 percent) as compared to that of Phuxuyen district. The explanation of this result was exactly as same as the result of location dummy variable in hybrid rice production frontier.

As expected, the coefficient of season dummy variable is positive (0.13) and significant at 1 percent level, meaning that the spring conventional rice obtained higher rice yield (1.14 percent) than that of the summer conventional rice. In spring season, weather cool and favorable for rice cultivation, while in summer season, rice suffers from hot weather and storm causing substantial damage to rice yield.

Briefly, it was found that the important variables explaining the variation in conventional rice yield were nitrogen, phosphorus, pesticide, location, and season. It is relevant to state that location (reflected by soil quality) and season (reflected by climate condition) are uncontrollable factors. Therefore, the improvement on the use of nitrogen, phosphorus, pesticide will substantially contribute to the increase in conventional rice yield. However, the amounts of manure, seed, and labor use were not statistically significant in the estimated production frontier. Potassium variable also did not meet the expected result.

7.3 Measurement of technical efficiency

The technical efficiency of individual farm was calculated with the support of Frontier 4.1 software and was shown in Appendix Tables 4 and 5. Tables 7.6 and 7.7 show the range of technical efficiency for hybrid rice production and conventional rice production.

Table 7.6: Technical efficiency of farm households in producing hybrid rice

Level	Technical efficiency	Number of observation	% of total observation
Low	0.01-0.69	0	0
Medium	0.70-0.75	6	6
	0.76-0.80	3	3
High	0.81-0.85	23	23
	0.86-0.90	41	41
Very high	0.91-0.95	18	18
	0.96-1.00	9	9
Total		100	100
Average	0.87*		
Maximum	0.99		
Minimum	0.73		

Source: Calculation

Note: * simple average of the total observation

As shown in Table 7.6, the average technical efficiency of sample households was 0.87. It means that farmers obtained 87 percent of the maximum level of technical efficiency and they could increase rice yield by making better use of the existing technology. In addition, the technical efficiencies ranged from 0.73 to 0.99. Numbers of farms achieving the technical efficiency from 0.86 to 0.90 and from 0.81 to 0.85 were 41 percent and 23 percent, respectively. The distribution of technical efficiency for hybrid rice was presented in Figure 7.1.

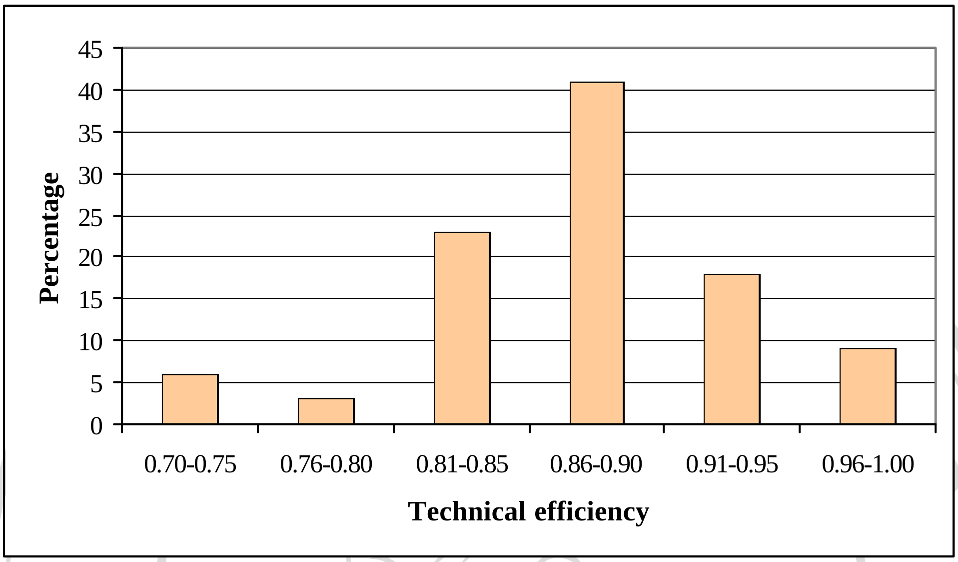

Figure 7.1: Distribution of technical efficiency for hybrid rice

Table 7.7 shows the technical efficiency of farm households in producing conventional rice

Table 7.7: Technical efficiency of farm households in producing conventional rice

Level	Technical efficiency	Number of observation	% of total observation
Low	0.01-0.69	0	0
Medium	0.70-0.75	7	3.60
	0.76-0.80	16	8.24
High	0.81-0.85	55	28.35
	0.86-0.90	75	38.65
Very high	0.91-0.95	38	19.65
	0.96-1.00	3	1.54
Total		194	100.00
Average	0.85*		
Maximum	0.97		
Minimum	0.72		

Source: Calculation

Note: * simple average of the total observation

The average technical efficiency of conventional rice production was 0.85 (Table 7.7), implying that improvement on technical efficiency of conventional rice production in the study site is still possible (remaining 15 percent). The distribution of technical efficiency for conventional rice was presented in Figure 7.2.

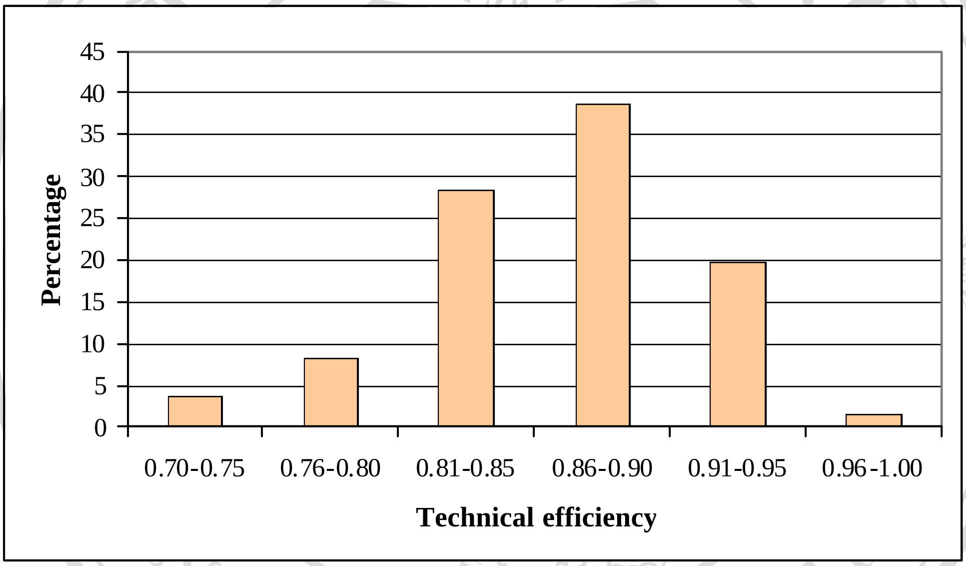

Figure 7.2: Distribution of technical efficiency for conventional rice

Briefly, the technical efficiencies of both hybrid rice production and conventional rice production were almost identical (0.87 and 0.85). This means that farmers have the same pattern of technical efficiency.

7.4 Estimated result of models for assessing the determinants of technical inefficiency

As mentioned in the part of research methods, 100 farms were randomly selected to collect the information on both hybrid and conventional rice production (in spring season and summer season). The descriptive statistics of variables affecting the technical inefficiency of hybrid rice and conventional rice were the same, since the same information about human characteristics of farm household was used (except the mean of TI was different).

The descriptive statistics of technical inefficiency and variables affecting the technical inefficiency of hybrid rice and conventional rice production were presented in Tables 7.8 and 7.9, respectively.

Table 7.8: Descriptive statistics for technical inefficiency and variables affecting the technical inefficiency of hybrid rice

Variable	Mean	SD	Min.	Max.
Technical inefficiency	0.125	0.058	0.001	0.27
Gender (dummy)	0.49	0.50	0.0	1.0
Experience (year)	3.81	0.88	2.0	5.0
Age (year)	46.51	8.94	27.0	73.0
Education (year)	7.56	2.40	3.0	12.0
Information (dummy)	0.74	0.44	0.0	1.0
Land size (year)	0.018	0.047	0.10	0.31

Source: Survey, 2002

Table 7.9: Descriptive statistics for technical inefficiency and variables affecting the technical inefficiency of conventional rice

Variable	Mean	SD	Min.	Max.
Technical inefficiency	0.156	0.047	0.01	0.28
Gender (dummy)	0.464	0.499	0.00	1.00
Experience (year)	6.930	0.765	5.00	8.00
Age (year)	46.20	8.855	27.0	73.0
Education (year)	7.600	2.400	3.00	12.0
Information (dummy)	0.752	0.432	0.00	1.00
Land size (ha)	0.018	0.047	0.10	0.314

Source: Survey, 2002

Tables 7.10 and 7.11 present the correlation matrixes for technical inefficiency and variables affecting the technical inefficiency of hybrid rice and conventional rice.

Table 7.10: Correlation matrix for technical inefficiency and variables affecting the technical inefficiency of hybrid rice

	TI	GEND	EXP	AGE	EDU	IFO	LAND
TI	1.000						
GEND	0.126	1.000					
EXP	-0.671	0.052	1.000				
AGE	0.523	0.215	-0.443	1.000			
EDU	-0.424	-0.095	0.448	-0.580	1.000		
IFO	-0.640	-0.103	0.623	-0.447	0.309	1.000	
LAND	-0.013	-0.109	0.030	0.106	-0.187	0.096	1.000

Source: Calculation

Table 7.11: Correlation matrix for technical inefficiency and variables affecting the technical inefficiency of conventional rice

	TI	GEND	EXP	AGE	EDU	IFO	LAND
TI	1.000						
GEND	-0.021	1.000					
EXP	-0.737	-0.006	1.000				
AGE	0.3302	0.210	-0.417	1.000			
EDU	-0.349	-0.083	0.406	-0.580	1.000		
IFO	-0.623	-0.089	0.571	-0.297	0.328	1.000	
LAND	-0.007	-0.031	-0.040	0.237	-0.235	0.029	1.000

Source: Calculation

Table 7.12 shows the estimates of inefficiency equation for hybrid rice. It indicates that the important factors affecting the technical efficiency of hybrid rice were gender, experience and access to technical information. The coefficient of gender dummy variable is positive (0.011), but statistically insignificant. This can be explained that in Vietnam, female farmers have equal rights as male farmers in the family as well as in the society, especially in access to education and information systems.

Table 7.12: Estimates of inefficiency equation for hybrid rice

Variable	Coefficient	t-ratio
Constant	0.200	2.74^{***}
GEND	0.011	1.07
EXP	-0.033	-4.32^{***}
AGE	0.0016	1.86^{**}
EDU	-0.00025	-0.08
IFO	-0.043	-2.45^{***}
LAND	0.032	0.32

Source: Estimated by using Frontier 4.1

Since, hybrid rice has been introduced to farmers in recent years, farming experience is considered as important factor determining the ability of understanding of good cultivation practice. As hypothesized, the coefficient of experience is negative (-0.033) and statistically significant at 1 percent level. This means that farmers with longer experience of hybrid rice cultivation had lower technical inefficiency (0.033 percent) than those with less experience. This also points out that there is a room for government to help farmers increase the farm’s technical efficiency through government policies such as agricultural extension and development of support system for technical information.

Other factor also caused the variation in technical inefficiency that was age of household head. It was found that the coefficient of age variable is positive (0.0016) and significant at 5 percent. This expresses that the technical efficiency of old household heads is higher than those young household heads.

The coefficient of education variable is positive (0.00025) and insignificant. The correlation between education and age variables might lead to the insignificance of education variable.

An important variable affecting technical inefficiency is the access to technical information dummy variable. Its coefficient is negative (-0.043) and statistically significant. This indicates that farmers having access to technical information got lower technical inefficiency than those of the other farmers who did not access to technical information. Access to technical information reflects the higher ability to understand techniques of rice cultivation, including fertilizer application, pest management, and water management. This suggests that extension service should be widely expanded, so farmers could have easier access to technical information.

The coefficient of land size variable is positive (0.032) and insignificant. As the result, land size economy did not exist. In case, land size variable was substituted by land area per head in technical inefficiency equation, the estimated result showed that the coefficient of this variable was positive and insignificant.

In short, experience, age of household head, and access to technical information were the very important factors affecting the technical inefficiency of hybrid rice production.

The estimated inefficiency equation for conventional rice is illustrated in Table 7.13. It indicates that the crucial variables causing the variation in technical efficiency of conventional rice production were gender and access to technical information.

The coefficient of gender dummy variable is negative (-0.006) and insignificant. The coefficient of this variable is insignificant in both technical inefficiency equation for hybrid rice production and technical inefficiency equation for conventional rice production. Therefore, the influence of gender factor on the technical inefficiency of rice production of sample households did not exist. In other words, gender factor did not show the difference in managerial skill in rice production in the study site.

Table 7.13: Estimates of inefficiency equation for conventional rice

Variable	Coefficient	t-ratio
Constant	0.485	7.96^{***}
GEND	-0.006	-0.96
EXP	-0.040	-8.86^{***}
AGE	0.00002	0.03
EDU	-0.0007	-0.38
IFO	-0.0411	-5.28^{***}
LAND	-0.017	-0.30

Source: Estimated by using Frontier 4.1

The coefficient of experience variable is negative (-0.04) and statistically significant. Therefore, the experience of rice cultivation plays the crucial factors on increasing the technical efficiency of rice production. This also suggests that apart from learning technical knowledge of rice production from the extension works, learning from neighbors, who had longer experience, is also very useful to farmers.

Furthermore, the coefficient of age variable is positive (0.00002). However, this variable is insignificant, meaning that the managerial skill of conventional rice production was not represented by the age of household head.

It is expected that farmers get benefits from education or farmers with higher level of education could reduce technical inefficiency through management of available resource in order to achieve the high output. The coefficient of education variable is negative (-0.0007) and insignificant. The correlation between education and age variable might cause the insignificance of education variable. Overall, education levels of old farmers are lower than those of young farmers in Vietnam. The multi-collinearity might exist, leading to insignificance of this variable.

According to Studenmund and Cassidy (1992), it is quite often that doing nothing is the best remedy for multi-collinearity. The major reason for considering doing nothing is that multi-collinearity in an equation will not always reduce the t-scores enough to make them insignificant or change estimate coefficient of explanatory variables enough to make them differ significantly from expectations. In other words, the mere existence of the multi-collinearity does not necessarily mean anything. A remedy for multi-collinearity should only be concerned if and when the consequences cause insignificant t-scores or unreliable estimated coefficients. In technical inefficiency equation for conventional rice there were two variables (experience and access to technical information) that were significant and their coefficients had the expected signs. This means that multi-collinearity was not severe and a remedy for it was not necessary. Therefore, the estimated results are accepted.

The coefficient of access to technical information dummy variable is negative (-0.041) and statistically significant. The estimated result for this variable reveals the importance of technical information in reducing the technical inefficiency. Therefore, facilitating the availability of extension for farmers can be importantly regarded with policy implication in increasing agricultural productivity.

In short, the coefficients of land size variables have positive and negative signs in hybrid rice technical inefficiency equation and conventional rice technical inefficiency equation, respectively and both of them are insignificant. One possible reason was that irrespective of large-size farm or small-sized farm, each household owned many plots of land with small area per plot. This probably is considered as the constraint to existence of economy of land size. One recommendation for land tenure is that local government should help farmers to exchange small land plots among them to consolidate land into large area per plot.

In summary, it was found that crucial factors affecting technical inefficiency of conventional rice production were experience and access to technical information. Age and education variables had the expected signs, but both of them were insignificant.

7.5 Evaluation of allocative efficiency

As mentioned above, economic efficiency refers to two components: technical efficiency and allocative efficiency. Technical efficiency can be defined as the ability to achieve a higher level of output, given a similar level of production inputs. Technical efficiency does not refer to the two important factors affecting the profit, i.e., input price and output price. Technical and allocative efficiency occurring together are sufficient conditions for achieving economic efficiency. This reason leads to a question whether the sample farmers with their estimated level of technical efficiencies were able to obtain the optimum level of input use in achieving its economic efficiency. Therefore, the investigation of allocative efficiency should be done to answer this question and to obtain better recommendations of the study.

7.5.1 Method of evaluation

Allocative efficiency was initially proposed be Farrell (1957) and according to Adesina and Djato(1996) allocative efficiency was interpreted as the extent to which farmers make efficient decisions by using inputs up to the level at which their marginal contribution to output value is equal to the factor cost.

Since MVP_{xi} represents the return generated by the additional increment of an input Xi, this should just cover the unit price of that output. Thus, the MVP_{xi} value is referred for determining the profitability of the last additional unit of any input used by farmer. Farmer would attain the allocative efficiency since

$$MVP_{X_i} = P_{X_i} \quad \text{or} \quad \frac{MVP_{X_i}}{P_{X_i}} = 1 \tag{7.3}$$

where P_{X_i} is the price of input X_i

Let $$\frac{MVP_{X_i}}{P_{X_i}} = r_{X_i} \tag{7.4}$$

is the ratio of marginal value product of input X_i and the price of that input. The hypothesis should be carried, that is

$H_0 : r_{X_i} = 1$ (Farmer achieved the allocative efficiency)

$H_1 : r_{X_i} \; \zeta \; 1$ (Farmer did not achieve the allocative efficiency)

As mentioned in Chapter 6, farmers could buy production inputs at the same average price irrespective of suppliers. Therefore, in this study average price of each input and average rice price were used to calculate the r_{Xi} ratios.

7.5.2 Allocative efficiency of hybrid rice

The result of estimated production frontier of hybrid rice shows that, the amounts of manure, labor, and seed use did not affect hybrid rice yield. On the contrary, the difference in amounts of nitrogen, phosphorus, potassium and pesticide use among the sample farms caused the variation in hybrid rice yield. For this reason, it is relevant to identify the allocative efficiencies of nitrogen, phosphorus, potassium, and pesticide input.

Table 7.14: Descriptive statistics of r_{Xi} (MVPxi /Pxi) ratio for hybrid rice

r_{Xi} ratio of	Mean	SD	Minimum	Maximum
Nitrogen	-8.32	1.54	-13.22	-5.00
Phosphorus	0.83	0.33	0.40	2.00
Potassium	8.95	2.98	5.60	17.70
Pesticide	-0.42	0.15	-1.01	-0.17

Source: Calculation

The hypothesis $H_{o,}$ which assumed that the farmers obtained the allocative efficiency of each input use (nitrogen, phosphorus, potassium, and pesticide), was rejected (Appendix Table 11). As shown in Table 7.14, ***r*** ratio of nitrogen input is -8.32. This implies that an increase in 1 VND for nitrogen expense led to reduction in marginal value product (MVP) relating to nitrogen expense by 8.32 VND. In addition, the explanation of ***r*** ratio of pesticide input (-0.42) is that an increase in 1 VND for pesticide expense reduced MVP with respect to pesticide expense by 0.42 VND. Actually, farmers want to avoid the risk of production, thus they applied higher amount of nitrogen and pesticide than actually recommended. As the result, it led to the allocative inefficiencies of nitrogen and pesticide inputs. In order to achieve allocative efficiency and higher rice yield as well, farmers should reduce the amounts of nitrogen and pesticide application.

Furthermore, the ***r*** ratio of phosphorus input was 0.83, meaning that an increase in 1 VND for phosphorus expense reduced the MVP with respect to phosphorus expense by 0.83 VND. Since, farmers always want to maximize their profit, they should try to reduce the amount of phosphorous application to achieve allocative efficiency.

The last factor, which needs to be analyzed, is potassium use. The ***r*** ratio of potassium input was 8.95, indicating that an increase in 1 VND for potassium expense increased MVP with respect to potassium expense by 8.95 VND. On the average, the actual amount of potassium application was lower than recommended amount. For this reason, farmers also should increase amount of potassium application in order to achieve higher hybrid rice yield and allocative efficiency as well.

7.5.3 Allocative efficiency of conventional rice

The estimated frontier production function showed that nitrogen, phosphorus, and pesticide variables were the important variables (except dummy variables) explaining the variation in conventional rice yield. As the result, it was necessary to evaluate the allocative efficiencies of nitrogen, phosphorus and pesticide inputs.

Table 7.15: Descriptive statistics of r_{Xi} (MVPxi /Pxi) ratio for conventional rice

r_{Xi} ratio of	Mean	SD	Minimum	Maximum
Nitrogen	-11.38	2.05	-16.74	-6.94
Phosphorus	1.24	0.38	0.66	2.72
Pesticide	-0.78	0.15	-1.24	0.05

Source: Calculation

None of the inputs was used at allocative efficiency level (Appendix Table 12). The hypothesis H_0 (farmers attaining allocative efficiency of input use) with respect to each input was rejected. The ***r*** ratios of nitrogen and pesticide inputs were -11.38 and -0.78, respectively. The explanations of these results are similar to those in evaluation of allocative efficiency of hybrid rice. Therefore, farmers are recommended to reduce application level of nitrogen and pesticide in order to obtain higher conventional rice yield and allocative efficiency.

Moreover, the ***r*** ratio of phosphorus input was 1.24, reflecting that an increase in 1 VND for phosphors expense increased the MVP with respect to potassium expense by 1.24 VND. On the average, amount of potassium application was lower than recommended amount. Therefore, it is appropriate to advise farmers to increase amount of potassium application to increase conventional rice yield and allocative efficiency.