Production and Cost Efficiency Analysis Using Frontier Stochastic Approach, A Case on Paddy Farming System With Integrated Plant and Resource Management (IPRM) Approach In Buru District Maluku Province Indonesia

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Abstract

The purpose of this study was to determine the level of production and cost efficiency on paddy farming system with integrated plant and resource management (IPRM) approach in Buru District Maluku Province. Maximum Likelihood Estimation (MLE) method was used to estimate parameters in both frontier stochastic models. 120 respondents was determined by using simple random sampling method. The empirical finding shows that the varies of the error term in both models are mostly influence by inefficiency factors (γ production= 0.933; γ cost = 0.948) rather than stochastic factors. The average technical efficiency is 0.855 and 75.83% respondent already operates in this level of efficiency. The average cost efficiency is 0.86 and 80% of respondent already achieve this level of cost efficiency. These findings indicate that rice farming system with integrated plant and resource management approach in the research area are efficient and profitable.

Keyword: *Rice, Production efficiency, Cost efficiency, IPRM approach, Indonesia, Stochastic frontier*

1. Introduction

Rice is the staple food for Indonesia diet. 94% of the energy consumption are based on vegetable food with the highest proportion are cereals (Purwantini and Ariani, 2008). According to the ASEAN Food Security Information and Training Center (2009), the minimum food security ratio must be 20% of the domestic need to achieve steady food security. While, the current food security ratio of Indonesia is only 4.38% (Hanani, 2009). Therefore, it needs more effort to increase the national production of rice to achieve the food security.

Since the domestic production still not optimal yet, the production optimization of rice farm is one of the strategy to increase the national rice production. Beside, the introduction of new technology will gives a larger opportunity for farmers to increase their income. Integrated plant and resource management is one of the well-known approach which is considered capable to increase the productivity. The implication of this approach will be adapted with the specific condition of the location. This method is one of the solution to increase the farmers income through sustainable agriculture system (Kartaatmaja and Fagi, 2000).

In order to accelerate the application of this program, government launched the field school named to improve farmer's knowledge and skill to maintain all available resources (plant varieties, land, water and production tools) integrated based on the location characteristic to reach the efficiency of farming system.

The efficiency of farming system are including the technology management which is related to the farmer's capacity and capability to manage it. When farmer's managerial capacity and capability increase, the ability to manage the input of production will improve and affect the increasing of production efficiency. As the result, the production will increase to the maximum level. Factors that influence the farming system efficiency can be distinguished as controlled (farmer's managerial skill) and uncontrolled factors (natural factors, price, and agriculture institution). The integration of all of the variables together, will create the level of efficiency that can be achieved.

The productivity of rice in the lowland in Waeapo District are varies between 2 to 5 ton/ha with the average production are 4.23 ton/ha. Comparing with the result of the research and assessment held by the Agriculture Institution, the real average rice production that can be achieved are 6.76 ton/ha. This result shows that farmers still could not achieve the maximum productivity which is caused by the inefficiency of production.

One of the government programs to optimize the production of rice in the low land is by organize field school to introduce the integrated plant and resource management approach which had been launched in 2009. The goal of field school is to increase the farmer's knowledge and managerial skill to apply an integrated plant and resource management approach in order to increase their production efficiency.

In order to measure the production efficiency of low land rice in Waeapo district after the extensive of field school, this research aim to estimate the stochastic production and cost frontier model, to estimate the production and cost efficiency of rice farming system in Buru District.

2. Method

2.1 Theoretical Framework

The measurement of production (technical) and cost efficiency can be done by estimating the stochastic frontier function of both models. The comparison from the actual and the frontier function will represent the farmer's efficiency.

The stochastic production frontier firstly introduced separate by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Brooeck (1977) separately. Further, this models develop by Kumbhakar *et al.,* (1991); Bettese and Coelli (1992 and 1995); Coelli *et al.,* (1999); Kumbhakar and Lovell (2003); Coelli *et al.,* (2005) and Ghosh and Raychaudhuri (2010).

A single equation for stochastic production frontier function represent by equation 1

$$Y_i = X_i \beta + (V_i - U_i) \quad (1)$$

The transformation of equation 1 to the natural logarithm function shows by equation 2.

$$\ln y_i = \beta_0 + \beta_i \ln X_i + (V - U_i) \quad (2)$$

A single equation for stochastic cost frontier function represent by equation 3

$$C_i = C(Y_i, P_i; \beta) + V_i + U_i \quad (3)$$

The transformation of equation 1 to the natural logarithm function shows by equation 4.

$$\ln(C_i) = \ln C\ (Y_i, P_i; \beta) + V_i + U_i \quad (4)$$

According to the equation 1 to 4, we can see that the error term consist of two components, U_i dan V_i. . The first component U_i represent the unmeasured variables such as weather, walkout, epidemic, and other variables which is undefined in the production function. The second component V_i. is the random shock variable which is identically normal distributed with the value of mean *(μ_i)* is 0; the variance is constant or $N(0, \sigma_v^2)$; symmetry; and there is no U_i intervention. U_i is a non-negative variable and assumed normally distributed with one of the distribution pattern such as eksponensial, truncated normal,and half-normal. U_i also define how far did firm operated above the frontier, especially for the frontier cost function.

The important of Maximum Likelihood Estimation (MLE) is not only to estimated parameters β_0, β_i and μ, but also the two variances of V_i.and U_i. The value of variances can be used to measure the value of γ which is the contribution of the technical and cost efficiency of the total residual effect. Therefore the value of γ are between zero and one ($0 \leq \gamma \geq 1$).

Technical efficiency define as the ratio between observe production and the production output from the frontier production function. The formula of technical efficiency define by equation 5

$$TE_i = \frac{y_i}{\exp(x_i\beta + v_i)} = \frac{\exp(x_i\beta + v_i - u_i)}{\exp(x_i\beta + v_i)} = \exp(-u_i) \quad (5)$$

where $0 < TEi < 1$

The measurement of cost efficiency explain by equation 6

$$CE_i = \frac{C(Y_i, P_i; \beta).\exp\{U_i\}}{C_i} \quad (6)$$

where CE_i is the possible minimum cost ratio with specific inefficiency level toward actual total cost. When the $C_i = C\ (P_i\ Y_i;\beta).exp(U_i)$, the CE_i will equal to 1 which is mean firm/farming system in the full efficiency condition in the time *i*. In the other hand, when the actual cost bigger than the minimum estimated cost ($0 \leq CE_i < 1$) the farming system are inefficient.

2.2 Location Determination

This research held in the Waeapo Sub District, Buru District, Maluku Province with the consideration that Buru district is the biggest rice producer in Maluku province. Besides that, the integrated plant and resource management program already introduced to the farmers since 2004 by Counseling Agency for Agricultural Technology. Furthermore, the implication of field school program already held since 2009 till now with total area 5.500 ha which covered 16 villages, and applied by 220 farmer groups.

2.3 Sampling Techniques and Data Collection

The sampling technique used Simple Random Sampling. Sample farmers as the primary data source was 120 respondents. Secondary data also gathered from any related department such as Agriculture Department, National Bureau of Statistic, and Local Government Institution. Primary data was collected from April to June 2012 by using the interview technique.

2.4 Empirical Model

The empirical model used in this research is Cobb-Douglas stochastic frontier model. The production stochastic frontier function and the cost stochastic frontier function will be explained by equation 7 and 8.

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + ... + \beta_{8i} \ln X_{8i} + (V_i - U_i) \quad (7)$$

where Y is rice production (kg/ha), X_1 is the total seed (kg/ha), X_2 is total of fertilizer N (kg/ha), X_3 is total of fertilizer P (kg/ha), X_4 is total of fertilizer K (kg/ha), X_5 is total of pesticide (liter/ha), X_6 = is total of herbicide (liter/ha), X_7 = total labor including family, worker, animal husbandry, and machine (working hours/day/ha), dan X_8 = is total of organic fertilizer (kg/ha).

$$\ln(C_i / w_i) = \alpha_0 + \alpha_1 \ln(Px_{1_i} / w_i) + ... + \alpha_6 \ln(Px_{6i} / w_i) + \alpha_7 \ln Y_i + (V_i + U_i) \quad (8)$$

where C is Total production cost (IDR), Px_1 is seed price (IDR/kg), Px_2 is fertilizer N (Urea) price (IDR/kg), Px_3 is fertilizer P price (IDR/kg), Px_4 is fertilizer K price (IDR/kg), Px_5 adalah is pesticide price (IDR/litter), Px_6 is herbicide price (IDR/liter), W is wage (IDR/HOK) and Y is production output (kg). Both production and cost stochastic frontier models are estimated by using Frontier 4.1 software which is the most appropriate tools to estimate the stochastic frontier function.

3. Empirical Result

3.1. The Analysis of Stochastic Production Frontier Function and Production Efficiency

According to Table 1, most of coefficients have positive value except herbicide under both OLS and MLE estimation. The value of R-square is 0.667, indicating that all input variables simultaneously influence the varies of production as much as 66,7%, while 33.3% influence by variables exclude in the model. Partially, there are only four variables that significantly influence the production, such as fertilizer N, fertilizer K, labor and organic fertilizer. The implication of this result is the increasing use of fertilizer N, fertilizer K, labor and organic fertilizer by 10% will increase the rice production each 0.9%, 2.26%, 7.0% and 0.2%, *ceteris paribus.*

Table 1. The statistical result of average production and stochastic production frontier function

Parameter	OLS estimation		ML estimation	
	Coefficient	Standard error	Coefficient	Standard error
β_0	3.4193***	0.5020	3.5223***	0.3693
β_1	0.0318	0.0284	0.0319	0.0257
β_2	0.0958*	0.0497	0.1697***	0.0497
β_3	0.0009	0.0504	0.0460	0.0532
β_4	0.2260**	0.0704	0.1620**	0.0653
β_5	0.0976	0.0559	0.0423	0.0493
β_6	-0.0384	0.0277	-0.0297	0.0263
β_7	0.7046***	0.1150	0.6688***	0.0916
β_8	0.0162**	0.0068	0.0144***	0.0054
sigma-squared(σ^2)	0.0218	-	0.0499***	0.0099
Gamma(γ)	-	-	0.9335***	0.0515
Coefficient function	1.13		1.11	
R^2	0.66		-	
F-statistic	27.80***		-	
log likelihood function	64.05		70.817	
LR test			13.516	

Note: ***Significant at α=1%, ** Significant at α=5%, * Significant at α=10%

According to Table 1, coefficient function of MLE estimation is 1.11 which explain that the stochastic production frontier function has the characteristic of increasing return to scale. It means that the increasing use of inputs proportionally will increase the output production to achieve the maximum profit.

The value of γ is 0.933 and significant at the level of 1%. This value shows that 93% of the random error varies are mostly influence by and inefficient factor, nor the stochastic variables which is not considered in the model. Therefore the production frontier possible to achieve through the improving on farming system management. The value of γ which approaching 1 also remain one side error, where U_i dominated the symmetry error distribution from V_i. The explanation of one side error also strengthen by the value of likelihood ratio. According to the table 1, we can see that the value of observe LR is 13.516 which is greater than the given LR ($\chi_1^2 = 3.841$). Since the observe LR are greater than the given LR, we can conclude that the assumption that all of the rice farming system which held by farmers in Buru district 100% efficient, is unproven.

Okoruwa and Ogundele (2006) whose research about stochastic production frontier of local rice varieties in Negeria also found the value of γ are 0.930 and 0.830. Another researches held by Abedullah *et al*. (2007), Minh & Long (2009), Ojogho and Alufohai (2010) also observe the value of γ which approaching 1. This implies that most of researches on stochastic production frontier are one side error.

According to Table 2, we can see that the average technical efficiency of stochastic production frontier model is 0.855, with the minimum value is 0.505 and maximum value is 0.977. The minimum value shows the most inefficient farmers and *vice versa*. If the inefficient farmers (minimum) enable to achieve the the maximum level of efficiency, the cost they may save are up to 41.05% (1-0.504/0.977). With the similar formulas, the normal farmers will enable to save 12.49% of their usual production cost (1-0.855/0.977).

Table 2. Technical Efficiency Distribution of Rice Farming System in Buru District

Efficiency range	Technical Efficiency (TE)		Efficiency Level	
	Frequency	Relative Frequency (%)	Statistical Descriptive	Value
0.30 - 0.39	0	0.00	Mean	0.855
0.40 - 0.49	0	0.00	Min	0.504
0.50 - 0.59	2	1.67	Max	0.977
0.60 - 0.69	7	5.83	Standard Deviation	0.092
0.70 - 0.79	20	16.67		
0.80 - 0.89	43	35.83		
0.90 - 0.99	48	40.00		
Total	120	100.00		

Based on the technical efficiency distribution according to Table 2, we can see that 75.38% farmers in the research area already operate in the efficient level of production. The value of standard deviation also quite small indicating the efficiency gap among farmers is quite small. This result implies that integrated plant and resource management approach successfully increase the technical efficiency of farming system in Buru District.

3.2 The Analysis of Stochastic Cost Frontier Function and Cost Efficiency

According to Table 3, we can see that four variables, such as production, price of fertilizer N, price of fertilizer K and price of pesticide are significant through Maximum Likelihood Estimation, which is indicate the increasing of those variables will increase the total cost of production. This condition reflects that the rice farming system in the research area is very sensitive with the switch in production and input price. The value of α_1 is 0.8795, indicating that the increasing 1% in production will caused the increasing 0.8% of total cost. Since the increasing of production are bigger than the increasing of total cost, the unit cost will be decrease as the result of increasing in total output produce.

Table 3. The statistical result of average cost and stochastic cost frontier function

Variable	OLS estimate		ML estimate	
	Coefficient	Standard error	Coefficient	Standard error
α_0	-1.3983***	0.3127	-1.4136***	0.2413
α_1	0.8680***	0.0204	0.8795***	0.0177
α_2	0.0481	0.0555	0.0342	0.0389
α_3	0.1576***	0.0547	0.2722***	0.0567
α_4	-0.1160	0.0976	-0.1409	0.0714
α_5	0.1766	0.1091	0.1952**	0.0840
α_6	0.1285***	0.0479	0.1142***	0.0417
α_7	-0.0071	0.1019	0.0062	0.0774
sigma-squared	0.0158	-	0.0378***	0.0065
Gamma	-	-	0.9480***	0.0315
log likelihood function	82.6101		89.9426	
LR test			14.6649	

Note: ***Significant at α=1%, ** Significant at α=5%, * Significant at α=10%

According to Table 3, the value of parameter γ is 0.948 and significant at the level of 1%, which is imply that the varies of random error are 94.8% influence by an inefficiency factors. This statistical result means that the different between the real cost and the minimum stochastic cost frontier caused by the different of cost efficiency. The result of observe LR also bigger than the given LR ($14{,}6649 > \chi_1^2 = 3{,}84146$) which is imply that the assumption that all of the rice farming system which held by farmers in Buru district 100% efficient, is unproven.

According to Table 4, the result of efficiency analysis shows that the cost efficiency index is 0.86, with the minimum efficiency is 0.53 and maximum efficiency is 0.98. If inefficient farmers (minimum efficiency) could achieve the maximum efficiency, the additional profit they can earn is 46% (1-[0.53/0.98]). As well as the minimum efficient farmers, the average efficient farmers can earn additional profit up to 12.2% if they can achieve the maximum efficiency. Therefore, farmers should improve their farming skill in managing the use of input to achieve the minimum cost efficiency.

Table 4. Cost Efficiency Distribution of Rice Farming System in Buru District

Efficiency range	Cost Efficiency (CE)		Efficiency Level	
	Frequency	Relative Frequency (%)	Statistical Descriptive	Frequency
0.30 - 0.39	0	0.00	Mean	0.8660
0.40 - 0.49	0	0.00	Minimum	0.5379
0.50 - 0.59	2	1.67	Maximum	0.9816
0.60 - 0.69	5	4.17	Standard deviation	0.1374
0.70 - 0.79	17	14.17		
0.80 - 0.89	41	34.17		
0.90 - 0.99	55	45.83		
Total	120.00	100.00		

According to Table 4 the distribution of the cost efficiency, 80% off farmers in the research area have been operate in the efficient level (> 0.80) while the rest are between 0.50 to 0.80. This result shows that the lowland rice farming system in Waeapo Distric with integrated plant and resource management approach are efficient in cost. Further, we can conclude that integrated plant and recourse management approach enable to increase farmer's profit.

4. Conclusion and Suggestion

4.1 Conclusion

Rice farming system in Buru District are in the condition increasing return to scale (RTS > 1) where the increasing use of input proportionally will increase the output until it can achieve an optimal level of output. According to the production and cost efficiency, the rice farming system efficient in technical and cost. this is supported by the results which showed 75.83 percent and 80 percent of rice farmers study area operate at efficiency levels of production (technical) and cost above 0.80.

This result indicates that the performance of field school to introduce integrated plant and resource management program successfully transfer knowledge and skill to the farmers. As the result, farmers in the research area enable to increase their productivity and profit.

4.2 Suggestion

Managerial fixes farm according integrated plant and resource management approach will improve productivity further improve technical efficiency, development of farmers through field school need to continue and improve the effectiveness of learning in a group.

Selection and use of inputs in proportion as recommended (based on need) on the integrated plant and resource management approach will boost profit due to cost savings.

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