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Technical efficiency of rice farm under risk of uncertainty weather in Yogyakarta, Indonesia

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Abstract. One of the climate change phenomenon is uncertainty weather condition. This study aims to understand the technical efficiency of rice farm in Yogyakarta included the factors that influence them in uncertainty weather condition. We survey for sampling has been done in Sleman and Bantul Regency based on about 8 of water irrigation resources and about 25 locations of water irrigation area. The sampling method is simple random sampling to take 125 samples. Cobb Douglas translog frontier production function model has been used to analyze the factors that influence rice production and technical efficiency. The result of the production function shows that the factors that influence the rice production are land, labour, organic fertilizer, N fertilizer, irrigation pollution, irrigation type, season and location. The rice farm has not efficient. The study result gives the implication that the rice farm efficiency for sustainable agriculture, it needs using optimal input, peasant skill encouragement, and infrastructure development of irrigation.

1. Introduction

The development of the food crops sector, especially rice, is still a top priority in agricultural policy for most countries in the world because rice is the leading food of almost 50% of the world's population and 90% of the people of Asia. In Indonesia, rice production has an essential position in the food system because rice is the leading food of the Indonesian people. The level of consumption of Indonesian rice is quite high. Based on statistical data analysis, the national rice balance in 2018 experienced fluctuations and even deficits at the end of 2018 [1].

Meanwhile, efforts to increase production encountered various obstacles. Efforts to increase rice productivity in Java through technological innovations experience barriers to the decrease in the area of paddy fields and the reduced carrying capacity of the land and the environment due to intensive use of chemicals causing pollution of soil, water, the environment, as well as human health itself. Therefore the intensification program is necessary for increasing production. Intensification is intended to increase productivity, which can be achieved through increased efficiency or technological breakthroughs. Under fixed technical conditions, increasing efficiency is the right effort to increase productivity.

Rice production and productivity in the Special Region of Yogyakarta experienced fluctuations in the period of 2011 - 2015. Significant increase in production in 2012 amounted to 12.25%. The increase in production occurred due to increased productivity and increased harvested area. However, in 2014-2015 rice production and productivity experienced a significant decrease despite an increase in harvested area. Meanwhile, the latest data shows that the cropped area fell to 92 thousand hectares with the production of 498 thousand tons of milled unhusked rice or productivity of 5.4 tons/ha [2]. This happens because the rainy season and the dry season are uncertain from year to year. Base on the weather



statistical [3], sometimes rainfall occurs almost all year long or vice versa the long dry season which impacts on irrigation management difficulties in lowland rice farming. These conditions will affect the efficiency and sustainability of rice farming in the Special Region of Yogyakarta.

Table 1. Harvest area, production and productivity of rice in the Special Region of Yogyakarta in 2011-2015

Year	Harvest Area (Ha)	Productivity (Ku/Ha)	Production (Ton)
2011	150,827	55.89	842,934
2012	152,912	61.88	946,224
2013	159,266	57.88	921,824
2014	158,903	57.87	919,573
2015	155,838	60.65	945,136

Source : [4]

Research on efficiency has been carried out by several previous researchers. Concerning institutions, Chaovanapoonphol and Somyana [5] analyzed the technical efficiency of corn production under the contract farming system. Meanwhile, Huy and Nguyen [6] evaluates the technical efficiency of agriculture and to determine the effect of the agricultural land rental market on agricultural technical efficiency.

Falavigna et al. [7] evaluated the decision-making unit with several inputs and several outputs, applied to assess economic and environmental factors. Sefeedpari et al. [8] develop and compare eight manure management scenarios throughout its life cycle, excretion for land transportation, taking into account technical, environmental, and economy. Pierrick et al. [9] examined the relationship between the intensity of agricultural production, as biophysical agricultural production per unit of land-use area, and the performance of the agricultural environment. Based on the background and problems above, this study aims to analyze production function and technical efficiency of rice farm.

2. Methods

This research was carried out in the Special Region of Yogyakarta, which is focused on districts that have the largest rice fields, namely Sleman and Bantul that have the widest rice fields with more than 67 percent of the total paddy fields in DI Yogyakarta [10]. From the eight rivers, there are 25 irrigation areas taken by 5 sample farmers by simple random sampling so that the number of samples in this study was 125 farmers.

For analyzing technical efficiency, the Translog Stochastic Frontier Analysis (SFA) model is used. This model is used to estimate the frontier production function. This function explains the maximum output that can be achieved [11]. Doll and Orazem [12] explained that the frontier production function is the maximum production function that can be obtained from some combinations of factors of production at a particular technological level. Thus the frontier production function describes the physical relationship between the factors of production and output whose position is located on the isoquant. Farrell [13] stated that frontier production as "best practice frontier".

The rice production function is assumed to be directly affected by the area of land used, the amount of seeds, the amount of organic and inorganic fertilizers, the amount of pesticides, the amount of labor, irrigation pollution. In this research, environmental detrimental input variables are N (nitrogen) fertilizer and pesticides. In addition there are variables farm structure (location, the distance of irrigation source, type of irrigation and Land Ownership Status), and Managerial Characteristics (age, education, experience, group participation, access to credit, number of family members and income outside farming)

The specifications of the whole model used are:

$$\begin{aligned} \ln Y_{it} = & \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln Z_6 + \beta_7 \ln Z_7 + 0,5\beta_{11} \ln^2 X_1 + 0,5\beta_{22} \ln^2 X_2 \\ & + 0,5\beta_{33} \ln^2 X_3 + 0,5\beta_{44} \ln^2 X_4 + 0,5\beta_{55} \ln^2 X_5 + 0,5\beta_{66} \ln^2 Z_6 + 0,5\beta_{77} \ln^2 Z_7 + \beta_{12} \ln X_1 \ln X_2 + \\ & \beta_{13} \ln X_1 \ln X_3 + \beta_{14} \ln X_1 \ln X_4 + \beta_{15} \ln X_1 \ln X_5 + \beta_{16} \ln X_1 \ln Z_6 + \beta_{17} \ln X_1 \ln Z_7 + \beta_{23} \ln X_2 \ln X_3 + \\ & \beta_{24} \ln X_2 \ln X_4 + \beta_{25} \ln X_2 \ln X_5 + \beta_{26} \ln X_2 \ln Z_6 + \beta_{27} \ln X_2 \ln Z_7 + \beta_{34} \ln X_3 \ln X_4 + \beta_{35} \ln X_3 \ln X_5 + \\ & \beta_{36} \ln X_3 \ln Z_6 + \beta_{37} \ln X_3 \ln Z_7 + \beta_{45} \ln X_4 \ln X_5 + \beta_{46} \ln X_4 \ln Z_6 + \beta_{47} \ln X_4 \ln Z_7 + \beta_{56} \ln X_5 \ln Z_6 + \\ & \beta_{57} \ln X_5 \ln Z_7 + \beta_{67} \ln Z_6 \ln Z_7 + d_1 D_{PIRS} + d_2 D_{PIRb} + d_3 D_{IR} + \delta_0 + \delta_1 Q_1 + \delta_2 Q_2 + \delta_3 Q_3 + \delta_4 Q_4 + \\ & \delta_5 Q_5 + \delta_6 Q_6 + \delta_7 Q_7 + d_4 D_{LOK} + d_5 D_{MILIK} + d_6 D_{KREDIT} + v_i - u_i \dots \dots \dots (1) \end{aligned}$$

with :

- Y = Total production of rice (kg)
- X₁ = land (ha)
- X₂ = Seed (kg)
- X₃ = Labour
- X₄ = Phospor fertilizer (kg)
- X₅ = Organic fertilizer (kg)
- Z₆ = Nitorgen fertilizer (kg)
- Z₇ = Pesticide (liter)
- D_{PIRS} = Dummy irrigation pollution (D_{PIRS} = 1 bila sedang; D_{PIRS} = 0 if other)
- D_{PIRb} = Dummy irrigation pollution (D_{PIRb} = 1 bila berat; D_{PIRb} = 0 if other)
- D_{IR} = Dummy irrigation (D_{IR} = 1 if technical; D_{IR} = 0 if other)
- vit = Random error of the model, events beyond the farmer's control
- uit = Random variable that represents technical inefficiency
- Q₁ = Age (years)
- Q₂ = Education (years)
- Q₃ = Experience (years)
- Q₄ = Family (person)
- Q₅ = Irrigation source distance (meters)
- Q₆ = Off-farm income (Rp)
- D_{LOK} = Location (dummy) D_{LOK} = 1 if rural; D_{LOK} = 0 if suburban
- D_{MILIK} = Dummy land ownership status (D_{MILIK} = 1 if the land is self-owned; D_{MILIK} = 0 if other)
- D_{KREDIT} = Dummy access to credit (D_{KREDIT} = 1 if access is available, D_{KREDIT} = 0 if not)
- D_{part} = Dummy participation in groups (D_{part} = 1 if active; D_{part} = 0 if not)

The next step is the calculation of the technical efficiency (TE) by using the formula:

$$TE = \frac{y_i}{\exp(x_i\beta)} = \frac{\exp(x_i\beta - u_i)}{\exp(x_i\beta)} = \exp(-u_i) \dots \dots \dots (2)$$

3. Results and discussion

Table 2 shows the results of the analysis including (a) the regression coefficients of the MLE analysis of the translog function that includes the input variables N and pesticides that have the potential to pollute the soil environment (detrimental input) and (b) the estimated value of the variance estimate which shows the contribution of technical efficiency to total residual effect.

The coefficient of the dummy variable in the analysis of the production function shows the influence of irrigation water pollution, type of irrigation, planting season and district location on rice production. In conditions of irrigation with moderate levels of pollution still have no effect on rice production, but in conditions of irrigation with heavy levels of pollution significantly has the potential to reduce rice production.

Table 2. Estimated frontier translog model for stochastic production with TE effect

Variable	Parameter	Expected sign	Coefficient	Std Error	t-ratio
Constanta	β_0	+/-	-1.0837	1.1855	-0.9141
Ln Land	β_1	+	1.0027***	0.3606	2.7808
Ln Seed	β_2	+	-0.1339	0.2404	-0.5568
Ln Labour	β_3	+	0.6179**	0.3267	1.8912
Ln P	β_4	+	-0.0324	0.0930	-0.3478
Ln O	β_5	+	0.1229***	0.0384	3.2003
Ln N	β_6	+/-	0.5270***	0.0999	5.2754
Ln Lan x Ln Seed	β_{12}	+	0.0127	0.0462	0.2750
Ln Land x Ln Labour	β_{13}	+	-0.0727*	0.0502	-1.4491
Ln Land x Ln P	β_{14}	+	-0.0321**	0.0152	-2.1106
Ln Land x Ln O	β_{15}	+	-0.0142***	0.0052	-2.6999
Ln Land x Ln N	β_{16}	+/-	-0.0233	0.0490	-0.4747
Ln Land x Ln Pesticide	β_{17}	+/-	0.0042	0.0066	0.6333
Ln Seed x Ln Labour	β_{23}	+	0.0478***	0.0136	3.5110
Ln Seed x Ln P	β_{24}	+	0.0171	0.0146	1.1685
Ln Seed x Ln O	β_{25}	+	0.0085***	0.0014	6.2557
Ln Seed x Ln N	β_{26}	+/-	0.0109	0.0630	0.1727
Ln Seed x Ln Pesticide	β_{27}	+/-	0.0884*	0.0654	1.3526
Ln Labor x Ln P	β_{34}	+	0.0455***	0.0057	7.9704
Ln Labor x Ln O	β_{35}	+	-0.0022*	0.0018	-1.2421
Ln Labor x Ln N	β_{36}	+/-	-0.0624*	0.0393	-1.5877
Ln Labor x Ln Pesitidie	β_{37}	+/-	0.0041	0.0045	0.9204
Ln P x Ln O	β_{45}	+	0.0012	0.0020	0.5941
Ln P x Ln N	β_{46}	+/-	0.0399***	0.0046	8.6413
Ln P x Ln Pesticidae	β_{47}	+/-	-0.0020**	0.0010	-2.0132
Ln O x Ln N	β_{56}	+/-	-0.0047*	0.0038	-1.2324
Ln O x Ln Pesticidae	β_{57}	+/-	0.0002	0.0005	0.3688
Ln N x Ln Pesticidae	β_{67}	+/-	0.0035	0.0030	1.1350
Dummy moderate pollution	d_1	-	0.0166	0.0411	0.4044
Dummy severe pollution	d_2	-	-0.0825**	0.0420	-1.9636
Dummy Technical irrigation Technic =1; non technic=0	d_3	+	-0.1830***	0.0210	-8.7008
Dummy Season Rainy =1; Dry =0	d_4	+/-	-0.0942***	0.0242	-3.8931
Dummy Districts Sleman=1; Bantul=0	d_5	+/-	-0.1128***	0.0338	-3.3398
Variation Parameters					
sigma-squared	σ^2		0.0590	0.0148	3.9834
gamma	γ		0.9707	0.0599	16.2155
log likelihood function	LLF		61.0563		
LR test of the one-sided error	LR test		52.8090		

Information:*** significant at $\alpha = 1\%$, t-tabel = 2.3443** significant at $\alpha = 5\%$, t-tabel = 1.6521* significant at $\alpha = 10\%$, t-tabel = 1.2858

Dummy coefficient of irrigation type variable shows that in the technical irrigation conditions the production is lower than in the non-technical irrigation conditions. This is because the technical irrigation parameters are only seen from buildings that are permanent, not yet considering other aspects such as environmental pollution — base on observation, most of the irrigation channels crossed residential and factory areas (64.8%). Irrigation canals around settlements and factories are usually mixed with drainage channels from settlements and factories. This condition has the potential to cause irrigation water pollution by household and factory waste, which has the potential to reduce rice production.

The dummy coefficient of the planting season variable shows the difference in rice production between the rainy season and the dry season. In the rainy season, the production is lower than the dry season. This happens because in the rainy season the weather has the potential to breed pests and plant diseases so that the potential for pest attacks is relatively greater than the dry season. In addition, rainfall and strong winds and floods have the potential to damage rice crops. Meanwhile, in the early dry season, irrigation needs can still be fulfilled from water reserves in the previous rainy season. It shows that climate change takes effect the rice production.

4. Technical efficiency of rice farming

Technical efficiency shows the ratio of actual production to frontier (best practice in production). The average value of technical efficiency has only reached 0.725 in the rainy season and 0.722 in the dry season. The difference in the average value of technical efficiency between the rainy and dry seasons shows that the potential production in the dry season is higher than the potential production in the rainy season. Based on the average value of technical efficiency, the technical efficiency of rice farming can be categorized as inefficient because it is less than 0.80 as the efficient limit [11]. Table 3 shows the distribution of the number of farmers based on the achievement of technical efficiency. It appears that the number of farmers who have technical efficiency ranges from 0.800 to 0.999 or technically efficient rice farming, which is 34.40% farmers in the rainy season and 33.60% farmers in the dry season. However, the value of maximum technical efficiency in the dry season is higher than the rainy season.

Table 3. Distribution of technical efficiency of rice farming

Technical Efficiency Group	Rainy season		Dry season	
	Number of Farmers	Percentage (%)	Number of Farmers	Percentage (%)
< 0.40	1	0.80	2	1.60
0.40 –	9	7.20	8	6.40
0.50 –	17	13.60	16	12.80
0.60 –	26	20.80	30	24.00
0.70 –	29	23.20	27	21.60
0.80 –	23	18.40	22	17.60
0.90 –	20	16.00	20	16.00
Total	125	100.00	125	100.00
Average TE		0.725		0.722
Minimum TE		0.353		0.340
Maximum TE		0.973		0.981

Based on the results of the estimation of the technical inefficiency model, it is known that the non-farm income and area dummy variables correlate positively and significantly to the technical inefficiency of rice farming at 95% confidence level, while the education and dummy variables of land ownership status have a negative and significant correlation to the technical inefficiency of rice farming a 90% and 95% confidence level. This means that out-of-farm income has a positive effect on technical inefficiency, where the higher off-farm income then the level of inefficiency will be higher, or the level of technical efficiency of rice farming will be lower. Conversely, if outside farm income is getting lower,

then the efficiency level of rice farming will be higher. Non-farm income is related to the type of work and out-of-farm work time. Jobs that provide high income for farmers will receive attention and an enormous outpouring of work compared to farming activities. This allows farming, not as a priority for work, so management is less efficient.

Meanwhile, the dummy variable coefficient of land tenure status is negative, which means there is a difference in technical licensing between farming on self-owned land and non-owned land (rent and catch). Farming that is carried out on privately owned land will be more efficient than farming on leased land. This shows that the sense of ownership will increase the intensity of farm management so that the production achieved is better

Table 4. Estimation of stochastic frontier production function model of rice farm inefficiency by the MLE method

Variable	Parameter	Expected sign	Coefficient	t-ratio
Constanta	δ_0	+/-	0.1789	0.5763
Age	δ_1	-	-0.0010	-0.1983
Education	δ_2	-	-0.0144*	-1.5363
Exoerience	δ_3	-	0.0004	0.1306
Family	δ_4	+/-	0.0199	1.0452
Irrigation source distance	δ_5	+	0.0082	0.3717
Off Farm Income	δ_6	+	0.0001**	2.2550
Dummy Location Rural=1; Suburban=0	d_1	+/-	0.1957**	1.8680
Dummy access to credit Available =1; not =0	d_2	+/-	0.0490	0.6574
Dummy ownership land Status owner=1; non =0	d_3	+/-	- 0.1464**	-1.9306
Dummy group participation Active=1; not = 0	d_4	+/-	0.1370	1.0723
Information:	** significant at $\alpha = 5\%$, * significant at $\alpha = 10\%$,	t-tabel = 1.6521 t-tabel = 1.2858		

The coefficient of the variable of farmer education is negative, indicating that education has a negative effect on technical inefficiency, i.e. if farmer education is higher the level of inefficiency will be lower, or the level of technical efficiency of rice farming will be higher. Conversely, if the education of farmers gets lower, then the efficiency level of rice farming will be lower too. This finding is consistent with the results of the study [14]. But not in accordance with the findings [15], which states that education increases technical efficiency, while [14] states that education and counselling have a positive effect on technical efficiency. These results support the statement that increasing human capital in rural households can improve farm management and ultimately achieve high productivity. Investment in education can be seen as a strategy to increase agricultural productivity through complementary relationships with the use of fertilizers, pesticides, irrigation, improved varieties, and research and extension. Farmers with higher education can achieve high technical efficiency as well. Furthermore, education has a positive effect on the ability (skills) of farmers so they can manage their farming more efficiently [16]. Education supports the ability of farmers' rationality and insight into the development and adoption of technology in farm management. Therefore farmers with relatively higher education will be more rational in running a farm. Thus, rice farming that is run will be more efficient.

5. Conclusion

The climate change affected unstable production of rice farming and it is not efficient technically. The rainy season production is lower than the dry season. The technical efficiency is not much different between the rainy season and the dry season. It can be concluded that the potential production in the

dry season is higher than the potential production in the rainy season. The technical inefficiency of rice farming is influenced by managerial characteristics; namely education has a negative effect and income outside farming has a positive effect. Meanwhile, in terms of structural characteristics, namely location or area and land ownership status, there are differences in technical inefficiencies caused by farming areas and land ownership status. Farming in peri-urban areas is more technically efficient than farming in rural areas. Likewise farming on one's own land is also more technically efficient than farming on non-owned land.

Increased efficiency is done by increasing the managerial and technical skills of farmers through education and training and research collaboration with universities and research institutions for the development of technological innovations in rice farming as needed.

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