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# An Analysis of Technical Efficiency Variation in Indonesian Rice Farming

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**Abstract**

Rice farming in Indonesia has an important role as a sector producing staple food for almost all of the population and provides a livelihood for millions of people in rural areas. Conditions of rice farming in Indonesia are quite unique because it is scattered in many island with diversity of social and economic characteristics of farmers, environmental conditions, and potential production. This study apply two-stage Data Envelopment Analysis (DEA) to estimate technical efficiency and analyses the determinants of technical efficiency rice farming based on farm level data collected by the Central Bureau of Statistics the Republic of Indonesia. The results showed that the average technical efficiency in all the rice-producing regions in Indonesia is moderate to High. This study suggest that policy to increase the technical efficiency in Indonesian rice farming should be prioritized on the use of certified seeds, control of pests and diseases, government assistance, education and irrigation.

**Keywords:** rice farming, technical efficiency, two-stage DEA, Tobit regression

## 1. Introduction

Efficiency of rice farming in Indonesia has attracted the attention of researchers for a long time. It may be related to its important role as a sector producing the main foodstuffs for almost 95% of Indonesians and providing livelihoods for millions of people in rural areas. Rice is grown by approximately 15 million farmers, or 77% of all farmers in Indonesia (BPS, 2009). The rice producing areas spread in many islands by which the characteristic of farmers, land condition, land size, environmental condition, infrastructure, accessibility to sources of financing are different. Most of the rice farmers are small farmers with agricultural land holdings of less than 0.5 hectares. This situation is commonly found in the densely populated areas such as West Java, Central Java, East Java, Bali and West Nusa Tenggara (BPS, 2009).

Based on previous studies [such as Esparon and Sturgess (1989) in West Java, Squires and Tabor (1991) for Java and off Java, Trewin et al. (1995) in West Java, Llewelyn and Williams (1996) in Madiun Regency of East Java, Fabiosa et al. (2004), Margono et al. (2011), Maryono (2006), Brazdik (2006), Kusnadi et al. (2011), Makki et al. (2012) in South Kalimantan, and Suharyanto et al. (2013) in Bali], the average technical efficiency of rice farming in Indonesia is about 0.70 to 0.8. In addition, according to Saptana (2012) the technical efficiency for some food-crop farming in Indonesia is moderate to high (0.50–0.80). These suggest that there is still room for rice farming in Indonesia to increase output by using the existing technology without changing the use of inputs.

Most references to the concept of efficiency is based directly or indirectly on Farrell (1957) which states that the efficiency can be measured in relative terms as a deviation from best practices of producers compared with producer groups. The production process is technically efficient if and only if the maximum quantity of output can be achieved for a given quantities of input and technologies. In addition, Farrell suggested to measure technical efficiency by estimating frontier production function.

There are studies of technical efficiency using parametric approach with a two-stage procedure [see for example Pitt and Lee (1981); Kalirajan (1981, 1990); Ali and Flinn (1989); Squires and Tabor (1991); Parikh et al. (1995); Bravo-Ureta and Pinheiro (1997); Xu and Jeffry (1998); Tian and Wan (2000); Khai and Yabe (2011); and Piya et al. (2012)]. However, this estimation procedure has been criticized can produce biased conclusion because it ignores the assumption independently and identically distributed (i.i.d) of error term in the second stage estimation

(Coelli et al., 2005; Kumbakar et al., 1991; Wang & Schmidt, 2002; Kumbakar & Lovell, 2000). Another technique to measure the technical efficiency is by using non-parametric Data Envelopment Analysis (DEA). Literature survey on the application of DEA (see as example Seiford, 1996, 1997; Gattoufi et al., 2004; Emrouznejad et al., 2008; Zhou et al., 2008; Kalb, 2010; Liu et al., 2013) shows that this approach has been widely applied in the study of efficiency in various fields.

Technical efficiency in the DEA can be measured by using an input-based method or output-based method. Input-based method identifies technical efficiency as a proportional reduction in the quantity of input use without causing a change in the quantity of output. In contrast, output-based method identifies technical efficiency as an increase in the quantity of output with a given quantity of inputs use. However, according Fare and Lovell in Coelli et al. (2005) both methods would generate the same technical efficiency if the production function has the characteristic of constant returns to scale.

In DEA, effects of specific factors of the firm (say $z_i$ variables) on technical efficiency cannot be estimated simultaneously with the estimation of frontier production function. It means that one stage further after estimation of technical efficiency use DEA is required, that is, an estimation of the efficiency effect model by which the score of technical efficiency based on DEA estimation as dependent variable regressed by independent $z_i$ variables. Because of technical efficiency score is limited in the interval 0 and 1, then the regression techniques of limited dependent variable such as Tobit is most used in the second stage DEA.

Empirically, both approaches either parametric or nonparametric DEA has been used widely in studies of efficiency in agriculture. However, the choice of which one is the best between the two is not clear. Some studies have applied both approaches to the same sets of data [such as Reinhard et al. (2000); Wadud and White (2000); Iráizoz et al. (2003); Latruffe et al. (2004); Alene et al. (2006); Ghorbani et al. (2010); Theodoridis and Anwar (2011)] and found that the estimation result of both approaches is not much different. This evidence shows that the choice of which approach to be used is somewhat arbitrary (Dhungana et al., 2004; Watkins et al., 2014).

This study used the DEA approach because it does not impose parametric restrictions on the underlying technology (Chavas & Aliber, 1993; Featherstone et al., 1997; Fletschner & Zepeda, 2002; Wu & Prato, 2006; Watkins et al., 2014). Framework of the discussion in this paper is followed sequentially by methodology, results and discussion, and conclusion.

## 2. Methodology

### *2.1 Study Areas and Data Source*

The study area covered of Sumatera, Java, Bali & West Nusa Tenggara, Kalimantan and Sulawesi. Data used in this study is taken from the rice farming cost structure survey data conducted by the Central Bureau of Statistics, the Republic of Indonesia in 2008. Total number of observation is 5537 farmers consist of Sumatera (1259), Java (3273), Bali & West Nusa Tenggara (243), Kalimantan (287), and Sulawesi (475).

### *2.2 DEA Models to Estimate Technical Efficiency*

An output-oriented DEA models with variable returns to scale assumption (DEA-VRS) was used to estimate the technical efficiency. The model is adopted from O'Donnell et al. (2008) as follows:

$$\begin{aligned} &\max_{\phi_i \lambda_i} \quad \phi_i \\ &s.t. \quad \phi_i y_i - Y\lambda_i \le 0, \\ &\qquad X\lambda_i - x_i \le 0, \\ &\qquad j'\lambda = 1, \\ &\qquad \lambda_i \ge 0 \end{aligned} \tag{1}$$

Where $y_i$ = the quantity (in kilogram) of dry rice harvest by the $i$th farmers; $x_i = N \times 1$ is a vector of input quantity used by the $i$th farmers which consist of harvested land size (in square meters), seeds (in kilogram), fertilizer (in kilogram), and the number of workers (in person days); $Y = L_k \times 1$ is a vector of output quantity for all $L_k$ farmers; $X = N \times L_k$ is a vector of input quantity for all $L_k$ farmers; $j = L_k \times 1$ vector of ones; $\lambda = L_k \times 1$ is a weighted vector; $\phi_i$ is a scalar in which the value is greater than or equal to 1. The value of $\phi_i - 1$ shows proportion of the increase in output that can be achieved by the ith farmers with the same quantity of input. Technical efficiency is defined as $1/\phi_i$ in which the value has interval range between 0 and 1.

### *2.3 Model of Technical Efficiency Determinants*

Tobit model was used to examine the relationship between the efficiency measures and farm characteristics. According to Banker and Natarajan (2008) Tobit regression produces a consistent estimator of the effect of contextual variables. Further, Hoff (2007) showed that in many cases the Tobit model is adequate to represent the model of efficiency effects. A two-limit Tobit models will be used in the analysis (Maddala, 1983), because of the efficiency indices are bounded between zero and one. General form of the model as follow:

$$\begin{aligned} TE_i^* &= \beta' z_i + u_i \\ TE_i &= L_{1i} && \text{if } TE_i^* \leq L_{1i} \\ &= TE_i^* && \text{if } L_{1i} < TE_i^* < L_{2i} \\ &= L_{2i} && \text{if } TE_i^* \leq 1 \end{aligned} \quad (2)$$

Where $TE_i^*$ is the latent variable representing of technical efficiency indices; $TE_i$ is the observed dependent variable; $z_i$ is a vector of explanatory variables representing of farm characteristics; $\beta$ is vector of unknown parameter to be estimated; $u_i$ is error term distributed ~ N (0, $\sigma^2$); $L_{1i}$ dan $L_{2i}$ are, respectively, the lower and upper limit. Empirical model specification is written as follow:

$$TE_i = \beta_0 + \beta_1 z_{1i} + \beta_2 z_{2i} + \beta_3 z_{3i} + \beta_4 z_{4i} + \beta_5 z_{5i} + \beta_6 z_{6i} + \beta_7 z_{7i} + \beta_8 z_{8i} + \beta_9 z_{9i} + \beta_{10} z_{10i} + \beta_{11} z_{11i} + u_i \quad (3)$$

Where $TE_i$ is the technical efficiency indices based on DEA estimation; $z_1$ = net income from rice farming (in log); $z_2$ = Age (in year); $z_3$ = formal education (D = 1 for high school education and tertiary education level, otherwise D = 0); $z_4$ = off-farm job (D = 1 for farmers who also work outside the farm, otherwise D = 0); $z_5$ = land size (in log); $z_6$ = types of seed (D = 1 for certified seed, otherwise D = 0); $z_7$ = irrigation (D = 1 for irrigated rice fields, otherwise D = 0); $z_8$ = pests/diseases (D = 1 if there is attacks of pests/diseases, otherwise D = 0); $z_9$ = season constraints (D = 1 for drought, otherwise D = 0); $z_{10}$ = Government assistance (D = 1 for farmers who accept assistance of production inputs for free from the government, otherwise D = 0); $z_{11}$ = credit (D = 1 for farmers who have constraint to access credit, otherwise D = 0); The models is estimated using Maximum Likelihood Method.

## 3. Results and Discussion

### *3.1 Descriptive Statistics of Variables*

Table 1 represents the descriptive statistics of variables used in the DEA and Tobit model. Rice cultivated by most farmers in Indonesia is lowland rice. Most farmers cultivate rice in technical irrigated rice field because of lowland rice will grow well if it gets enough water. The average of rice production is 2004 kilograms harvested from average land area of 3662 square meter (or 0.3 hectare).

Table 1a. Descriptive statistics of the variables used in the DEA and Tobit models for Sumatera, Java, Bali and West Nusa Tenggara Island

| Variable | Sumatera (n = 1259) | | Java (n = 3273) | | Bali & West Nusa Tenggara (n = 243) | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| Rice (kg) | 2514 | 1949 | 1603 | 1144 | 2532 | 1872 |
| Harvested area ($m^2$) | 4833 | 3665 | 2823 | 1938 | 4043 | 2827 |
| Seed (kg) | 27 | 25 | 13 | 9 | 24 | 19 |
| Fertilizer (Kg) | 176 | 148 | 148 | 111 | 215 | 161 |
| Labor (person days) | 48 | 40 | 44 | 28 | 56 | 38 |
| Net income (000 rupiahs) | 3927 | 3519 | 2052 | 1702 | 3502 | 2859 |
| Age (years) | 49 | 12 | 51 | 12 | 48 | 12 |
| Education (dummy) | 0.37 | 0.48 | 0.31 | 0.46 | 0.33 | 0.47 |
| Off-farm job (dummy) | 0.36 | 0.48 | 0.36 | 0.48 | 0.36 | 0.48 |
| Land size ($m^2$) | 5897 | 5037 | 3167 | 2179 | 4844 | 4080 |
| Type of seed (dummy) | 0.50 | 0.50 | 0.56 | 0.50 | 0.48 | 0.50 |
| Irrigation (dummy) | 0.50 | 0.50 | 0.57 | 0.50 | 0.70 | 0.46 |
| Pests/dieses (dummy) | 0.57 | 0.50 | 0.50 | 0.50 | 0.39 | 0.49 |
| Season (dummy) | 0.37 | 0.48 | 0.38 | 0.49 | 0.41 | 0.49 |
| Government assistance (dummy) | 0.38 | 0.49 | 0.33 | 0.47 | 0.45 | 0.50 |
| Credit (dummy) | 0.56 | 0.50 | 0.54 | 0.50 | 0.53 | 0.50 |

Source: Author's tabulation based on BPS data.

Table 1b. Descriptive statistics of the variables used in the DEA and Tobit models for Kalimantan, Sulawesi, and Indonesia as a total

| Variable | Kalimantan (n = 287) | | Sulawesi (n = 475) | | Indonesia (n = 5537) | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| Rice (kg) | 2112 | 1194 | 3084 | 2635 | 2004 | 1651 |
| Harvested area ($m^2$) | 4582 | 2597 | 5589 | 4927 | 3662 | 3024 |
| Seed (kg) | 22 | 14 | 29 | 29 | 19 | 18 |
| Fertilizer (Kg) | 118 | 74 | 200 | 204 | 160 | 133 |
| Labor (person days) | 68 | 50 | 50 | 27 | 47 | 33 |
| Net income (000 rupiahs) | 3679 | 2286 | 3583 | 3469 | 2757 | 2630 |
| Age (years) | 46 | 12 | 47 | 12 | 50 | 12 |
| Education (dummy) | 0.33 | 0.47 | 0.37 | 0.48 | 0.33 | 0.47 |
| Off-farm job (dummy) | 0.29 | 0.45 | 0.37 | 0.48 | 0.36 | 0.48 |
| Land size ($m^2$) | 6181 | 3950 | 8262 | 7052 | 4455 | 4150 |
| Type of seed (dummy) | 0.41 | 0.49 | 0.55 | 0.50 | 0.54 | 0.50 |
| Irrigation (dummy) | 0.40 | 0.49 | 0.51 | 0.50 | 0.54 | 0.50 |
| Pests/dieses (dummy) | 0.39 | 0.49 | 0.59 | 0.49 | 0.51 | 0.50 |
| Season (dummy) | 0.37 | 0.48 | 0.39 | 0.49 | 0.38 | 0.49 |
| Government assistance (dummy) | 0.40 | 0.49 | 0.28 | 0.45 | 0.35 | 0.48 |
| Credit (dummy) | 0.31 | 0.46 | 0.47 | 0.50 | 0.53 | 0.50 |

Source: Author's tabulation based on BPS data.

Seed varieties that cultivated by approximately 50 percent of farmers are the certified high-yielding varieties. In terms of financial aspect, more than 50 percent of farmers still find it difficult to access credit because they do not have collateral, lack of information, difficulties in credit procedures, and the distance between the location of farmers with financial institutions is quite far (BPS, 2008). Average use of labor in the cultivation of rice in Java is lower than outside Java, and even at the national level. The high cost of labor, and economic development which is still concentrated in Java may cause farmers find it difficult to hire labor for rice cultivation.

### *3.2 Technical Efficiency Estimation*

The estimation results of production frontier using DEA-VRS showed that the average technical efficiency of rice farming in Indonesia is 0.773 in the interval 0.270 to 1.000 with a standard deviation of 0.144 (Table 2). This means that the maximum output of all rice-producing regions using the existing inputs and technologies on average is only about 77 percent of its potential. In other words, the gap of output achievement between the best farmers and the other farmers is about 23 percent. This suggests that rice production in Indonesia still has the prospect to increase about 23 percent by using the same input.

Table 2. Descriptive statistics of technical efficiency

| Region | Number Observation | Mean | Min. | Max. | SD | Analysis of Variance (ANOVA) |
|---|---|---|---|---|---|---|
| Sumatera | 1259 | 0.768 | 0.270 | 1.000 | 0.167 | |
| Java | 3273 | 0.767 | 0.270 | 1.000 | 0.139 | $F_{(4;5532)}=10.277$ |
| Bali & West Nusa Tenggara | 243 | 0.807 | 0.519 | 1.000 | 0.136 | *P-value = 0.000* |
| Kalimantan | 287 | 0.787 | 0.445 | 1.000 | 0.138 | *F-crit = 2.374* |
| Sulawesi | 475 | 0.801 | 0.444 | 1.000 | 0.114 | |
| Indonesia | 5537 | 0.773 | 0.270 | 1.000 | 0.144 | |

However, the average of technical efficiency for each rice-producing region is varied between 0.767 in Java and 0.807 in Bali & West Nusa Tenggara. This shows that the performance of rice production for each rice-producing region is also varied between 77% in Java and 81% in Bali & West Nusa Tenggara. Based on the analysis of variance in Table 3, the value of F statistic (10.277) is greater than the critical value of F (2.374). Furthermore, the *p*-value (0.000) is less than the level of significance ($\alpha$) 0.01. Thus, it can be concluded that there are significant differences in the average level of technical efficiency among the group of rice farmers in all rice-producing regions.

Table 3 represents the distribution of technical efficiency among farmers across the rice-producing region in Indonesia. The proportion of farmers who reached fully technical efficiency is only about 9 percent. Furthermore, about 35 percent of farmers achieve technical efficiency of 0.800 to 0.999, or in other words closer to the frontier output. This indicates that the opportunities to increase rice production in Indonesia is still quite large because there are still more than 50 percent of farmers in which their output achievement is far below the frontier output.

Table 3. Distribution of technical efficiency

| | Sumatera | Java | Bali & West Nusa Tenggara | Kalimantan | Sulawesi | Indonesia |
|---|---|---|---|---|---|---|
| 0.000–0.099 | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| 0.100–0.199 | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| 0.200–0.299 | 6 (0.48) | 1 (0.03) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 7 (0.13) |
| 0.300–0.399 | 30 (2.38) | 1 (0.03) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 31 (0.56) |
| 0.400–0.499 | 51 (4.05) | 11 (0.34) | 0 (0.00) | 8 (2.79) | 1 (0.21) | 71 (1.28) |
| 0.500–0.599 | 118 (9.37) | 357 (10.91) | 19 (7.82) | 15 (5.23) | 9 (1.89) | 518 (9.36) |
| 0.600–0.699 | 219 (17.39) | 915 (27.96) | 36 (14.81) | 55 (19.16) | 83 (17.47) | 1308 (23.62) |
| 0.700–0.799 | 288 (22.88) | 555 (16.96) | 66 (27.16) | 82 (28.57) | 166 (34.95) | 1157 (20.90) |
| 0.800–0.899 | 214 (17.00) | 721 (22.03) | 54 (22.22) | 57 (19.86) | 116 (24.42) | 1162 (20.99) |
| 0.900–0.999 | 190 (15.09) | 490 (14.97) | 27 (11.11) | 33 (11.50) | 40 (8.42) | 780 (14.09) |
| 1.000 | 143 (11.36) | 222 (6.78) | 41 (16.87) | 37 (12.89) | 60 (12.63) | 503 (9.08) |
| Total | 1259 (100.00) | 3273(100.00) | 243 (100.00) | 287 (100.00) | 475 (100.00) | 5537 (100.00) |

*Note*. Numbers in parentheses () show the percentage.

In terms of scale efficiency, rice cultivation of most the farmers in Sumatra, Java and Kalimantan show decreasing returns to scale (DRS). In contrast, the production of rice by most farmers in Bali and West Nusa Tenggara, Sulawesi shows that increasing returns to scale (IRS). Based on scale efficiency, the increased in rice production need to be prioritized in both of the rice-producing regions. Returns to scale distribution of rice farming in Indonesia is presented in Table 4.

Table 4. Distribution of returns to scale

| | CRS | | IRS | | DRS | | DMU | |
|---|---|---|---|---|---|---|---|---|
| Sumatera | 129 | (10.25) | 529 | (42.02) | 601 | (47.74) | 1259 | (100.00) |
| Java | 889 | (27.16) | 1076 | (32.88) | 1308 | (39.96) | 3273 | (100.00) |
| Bali & West Nusa Tenggara | 35 | (14.40) | 108 | (44.44) | 100 | (41.15) | 243 | (100.00) |
| Kalimantan | 25 | (8.71) | 113 | (39.37) | 149 | (51.92) | 287 | (100.00) |
| Sulawesi | 60 | (12.63) | 242 | (50.95) | 173 | (36.42) | 475 | (100.00) |
| Indonesia | 1138 | (20.55) | 2068 | (37.35) | 2331 | (42.10) | 5537 | (100.00) |

*Note*. Numbers in parentheses () show the percentage; DMU = decision making unit.

### *3.3 The Determinants of Technical Efficiency*

The maximum likelihood estimation result for Tobit regression is presented in Table 5. The estimation for Indonesia used the data of all regions (pooled data). We also add four regional dummy variables into the models which consist of SUMATERA (D1 = 1 for Sumatera, otherwise D = 0); JAVA (D = 1 for Java, otherwise D = 0); KALIMANTAN (D = 1 for Kalimantan, otherwise D = 0); and BALI & WEST NUSA TENGGARA (D = 1 for Bali & West Nusa Tenggara, otherwise D = 0). Regional dummy variable is used in the models for Indonesia to catch variation/ differences of the average technical efficiency between regions. Conceptually, four of five regions covered in the study are used as regional dummy variables to avoid the dummy variable trap. In this context, region which is not included (Sulawesi) would be a benchmark for other regions.

The result estimation for Indonesia shows that all variables used in the models have significant effect on the technical efficiency of rice farming as expected. Net Income, age, education, type of seed use, irrigation, and government assistance individually has a positive and significant effect on the technical efficiency. In contrast, off-farm job, pest/diseases, season and constraint to access credit have a negative and significant effect on the technical efficiency. In addition, all the coefficient of region dummy variables showed negative sign which mean that the average of technical efficiency of rice farming in Sumatera, Java, Bali & West Nusa Tenggara, and Kalimantan is less than average of technical efficiency of rice farming in Sulawesi.

However, the effect of all variables hypothesized on technical efficiency may vary across rice-producing region. Net income from rice farming in Sumatera, Java and Bali & West Nusa Tenggara has a positive and significant effect on technical, but it doesn't have a significant effect on technical efficiency in Kalimantan and Sulawesi. The age of farmers has a positive and significant effect on technical efficiency in almost all rice-producing regions, except in Sumatera. Coefficient of formal education is positive and significant for all rice-producing region showed that farmers with senior high school education and tertiary education have an average technical efficiency greater than farmers with junior school education level and lower. In almost all rice-producing region (except in Bali & West Nusa Tenggara), the average technical efficiency of rice farming will be lower if the farmers also work outside the agricultural sector.

Coefficient of land size is negative and significant in Sumatera, Java, Bali & West Nusa Tenggara, and Sulawesi showed that technical efficiency of rice farming in these regions decrease as land holding increase. While in Kalimantan, the coefficient is positive but not significant. Coefficient of seed are positive an significant in all rice-producing regions, meaning that the use of certified high-yielding seed leads to average technical efficiency higher than the use of non-certified high-yielding seed. Coefficient of irrigation is also positive, means that the cultivation of rice in irrigated rice fields gives the average of technical efficiency greater than rice cultivation in non-irrigated rice fields.

The presence of pests/diseases determines the technical efficiency of rice farming achieved by farmers. The coefficient of pests/diseases is negative and significant in all rice-producing regions showed that the average technical efficiency of rice farming that attacked by pests/diseases is less than the average technical efficiency of rice farming that is not attacked by pests/diseases. Coefficient of season is negative, indicating that the average technical efficiency of rice farming during a drought is lower than the average technical efficiency during a flood.

Coefficient of government assistance is positive, showing that farmers who receive assistance of production inputs for free from government have an average technical efficiency higher than other farmers who do not receive government assistance. Furthermore, the coefficient of credit in Sumatra, Java, Kalimantan and Sulawesi are negative, indicating that the average technical efficiency of farmers who have problems accessing credit is lower than other farmers who do not have problems accessing credit. However, constraint to accessing credit is not significantly affecting the technical efficiency of rice farming in Bali & West Nusa Tenggara. This is because most rice farmers in this region have self-financing capability of the operating cost in the rice cultivation.

Table 5. Maximum likelihood estimation for Tobit models

| Variable | Sumatera | Java | Bali & West Nusa Tenggara | Kalimantan | Sulawesi | Indonesia |
|---|---|---|---|---|---|---|
| | n=1259 | n= 3273 | n=243 | n=287 | n=475 | N=5537 |
| Constant | 0.405*** | 0.778*** | 0.620*** | 0.667*** | 0.770*** | 0.740*** |
| | (0.049) | (0.031) | (0.066) | (0.065) | (0.051) | (0.024) |
| Net income | 0.081*** | 0.010** | 0.023** | 0.002 | 0.005 | 0.029*** |
| | (0.007) | (0.005) | (0.012) | (0.008) | (0.006) | (0.003) |
| Age | -3.45E-05 | 0.001*** | 0.001** | 0.001*** | 0.001** | 0.001*** |
| | (0.0003) | (0.0002) | (0.0004) | (0.0004) | (0.0004) | (0.0001) |
| Education | 0.080*** | 0.038*** | 0.038*** | 0.046*** | 0.043*** | 0.049*** |
| | (0.008) | (0.005) | (0.011) | (0.010 | (0.009) | (0.004) |
| Off-farm job | -0.026*** | -0.026*** | 0.004 | -0.032*** | -0.022*** | -0.025*** |
| | (0.007) | (0.005) | (0.011) | (0.009) | (0.008) | (0.003) |
| Land size | -0.036*** | -0.019*** | -0.018* | 0.005 | -0.010* | -0.024*** |
| | (0.008) | (0.005) | (0.010) | (0.009) | (0.006) | (0.003) |
| Seed | 0.064*** | 0.074*** | 0.098*** | 0.031*** | 0.070*** | 0.076*** |
| | (0.008) | (0.005) | (0.016) | (0.012) | (0.009) | (0.004) |
| Irrigation | 0.056*** | 0.046*** | 0.112*** | 0.036*** | 0.040*** | 0.047*** |
| | (0.007) | (0.005) | (0.015) | (0.012) | (0.009) | (0.003) |
| Pests/dieses | -0.089*** | -0.054*** | -0.061*** | -0.049*** | -0.043*** | -0.060*** |
| | (0.008) | (0.004) | (0.012) | (0.009) | (0.009) | (0.003) |
| Season | -0.033*** | -0.034*** | -0.063*** | -0.076*** | -0.038*** | -0.036*** |
| | (0.007) | (0.005) | (0.013) | (0.011) | (0.007) | (0.003) |
| Gov. assistance | 0.080*** | 0.050*** | 0.030** | 0.075*** | 0.058*** | 0.058*** |
| | (0.007) | (0.005) | (0.013) | (0.012) | (0.010) | (0.004) |
| Credit | -0.032*** | -0.038*** | 0.019 | -0.043*** | -0.023*** | -0.036*** |
| | (0.007) | (0.004) | (0.012) | (0.010) | (0.009) | (0.003) |
| SUMATERA | | | | | | -0.046*** |
| | | | | | | (0.005) |
| JAVA | | | | | | -0.055*** |
| | | | | | | (0.005) |
| BALI & WEST NUSA TENGGARA | | | | | | -0.024*** |
| | | | | | | (0.008) |
| KALIMANTAN | | | | | | -0.031*** |
| | | | | | | (0.006) |
| Log likelihood | 727.123 | 1791.234 | 196.839 | 280.509 | 429.930 | 3125.225 |
| LR test | 1183.704*** | 1146.744*** | 321.154*** | 431.278*** | 489.344*** | 3063.268*** |

*Note*. ***; **; * indicate significance at 1, 5 and 10 % level, respectively; number in parentheses () indicates standard error; Likelihood ratio (LR) = $2(L_r - L_{ur})$ where $L_r$ is restricted log likelihood function and $L_{ur}$ is unrestricted log likelihood function.

## 4. Conclusions

The average technical efficiency of rice farming in Indonesia based on DEA-VRS is about 0.77, indicating that rice production in Indonesia still has the opportunity to be increased to reach its maximum potential. In general, rice production in all the rice-producing region in Indonesia has the potential to be improved. However, based on the scale of efficiency, the production of rice in Bali and West Nusa Tenggara, and Sulawesi should be prioritized as most of the rice farming region showed increasing returns to scale.

Based on the results Tobit regression, policies to increase rice production can be prioritized on several factors. Firstly, increase the use of certified seeds. In this context, government can provide a favorable climate for private rice seed breeding industry to grow and develop, so that they can also take part in the provision of the seed.

Second, pests and diseases control. In this context, the concept of integrated pest management which has been carried out should be maintained and disseminated among farmers. The field school for controlling plant pests and diseases should be maintained and developed to accelerate the spread controlling technology of pest and diseases to farmers. Third, the government assistance in the form of inputs (such as seeds, fertilizers, and agricultural machineries) free of charge to farmers should be maintained.

Fourth, improved education for farmers is necessary for increasing farmers' knowledge on various information and technology relating to agricultural practices. Finally, irrigated rice field is shown to have an important role to improve the productivity of rice farming. Therefore, damaged irrigation infrastructure should be rehabilitated and constructed, so that adequate water supply for rice farming can be maintained during drought and excess supply of water during the flood can be avoided.

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