# Technical Efficiency of Smallholder Oil Palm Farmers: An Application of Stochastic Frontier Analysis

W. Welda[#1], H. Hasnah[#2*], Rusda Khairati[#3]
*Agricultural Economics Study Program, Faculty of Agriculture, Universitas Andalas*
*Kampus UNAND Limau Manis, Padang, West Sumatra 25163, Indonesia*

***Abstract***

*This study aims to analyze the production function of oil palm farming, analyze the technical efficiency of smallholder oil palm farmers. The study was conducted in 2019 in Dharmasraya Regency, which is a production center for oil palm plantations in West Sumatra. Data were analyzed using the Cobb-Douglas stochastic frontier production function. The results show that the use of labor, Urea, KCl, NPK, Dolomite, manure, pesticides, seedling variety, and farmers' category have a significant effect on the productivity of oil palm. While variables of labor, KCl, NPK, Dolomite, and seedling variety use have a positive impact on oil palm production, the use of Urea, manure, pesticides, and farmers' category has a negative effect on oil palm production. The average level of technical efficiency of smallholder oil palm farmers is 0.73. Impressive results that individual farmers are more efficient than partnership farmers. Production inputs should be applied appropriately to increase the productivity of oil palm.*

***Keywords:*** *oil palm productivity, technical efficiency, stochastic frontier*

## I. INTRODUCTION

Oil palm ( *Elaeis guineensis* ) is a high emerging plantation commodity. A high price may the main reason for oil palm farming development. The average price growth was 0,24 percent between 2012 and 2016. Besides being consumed as food, oil palm has increasingly become popular as alternative energy, which is biodiesel. Oil palmplantation has an essential role in supporting the Indonesian economy. This role comes from the development of export due tothe increase of national oil palm production, which was about a 77.18% increase in CPO from 2013 to 2016. The growth in domestic oil palm (CPO) production is supported by the development of the area of oil palm plantations, which also tends to increase, ranging from 2.77 percent to 4.70 percent per year (BPS-Statistics Indonesia, 2018).

Although the production of oil palm increased, the productivity of CPO produced by smallholder plantations (3.012 kg/ha) in 2017 was lower than that of private company which reaches 4.065 kg/ha and the productivity of the State-Owned Estates of 3. 349 kg/ha (BPS-Statistics Indonesia, 2018). Thus, it is necessary to increase the production of smallholder oil palm farming.

Productivity is one measurement of success in farming activities of an agricultural commodity. Farming activities that can produce output in frontier production means that it achieves the potential productivity.

Several factors can influence oil palm productivity, namely, environmental factors, genetic factor, and plant cultivation techniques. Environmental factors that affect oil palm productivity, including abiotic factors (rainfall, rainy days, soil, topography) and biotic factors (weeds, pests, plant population/ha). Genetic factors include seeds variety used and the age of oil palm plants. Cultivation techniques include fertilization, soil and water conservation, control of weeds, pests and plant diseases, as well as other maintenance activities. These factors are interrelated and affect one another (Pahan, 2010).

In carrying out farming activities, farmers do not always achieve the highest level of efficiency because many factors contribute. Some factors can be controlled by farmers, while other factors cannot be controlled. Failure to consider these factors will affect production.

The gap in productivity of smallholder oil palm plantations among regions in West Sumatra shows the difference in the level of production efficiency. Dharmasraya Regency is the second-largest production center of oil palm in West Sumatra after the West Pasaman Regency. However, the productivity of smallholder oil palm plantations in the Dharmasraya regency (2,890 kg/ha CPO) was lower than that of in West Pasaman, which reached 2,991 Kg/Ha CPO(BPS-Statistics of Sumatera Barat Province, 2018). This figure is supported by the research of Yulistriani, Paloma, and Hasnah (2017), who found that productivity of smallholders oil palm in the Dharmasraya at an average of 1.6 tons/ha. This low productivity is influenced by the low ability of farmers in making decisions in each stage of management of oil palm farm starting from the selection of seedlings, maintenance management, including fertilization to decision making in marketing production.Kumbhakar (2002) stated that the managerial capacity of farmers, which includes farmers' socio-economic factors, could influence the level of technical efficiency. Efficiency improvement is one of the sources to increase the productivity of a firm (Coelli, Rao, O'Donnell, and Battese, 2005).

Based on the background above, it is required to investigate the technical efficiency of smallholder oil palm farmers. The objectives of this study areto analyze the production function of smallholder oil palmand identify factors affecting the technical efficiency of smallholder oil palm farms.

## III. RESEARCH METHOD

### A. Data

This research was conducted in 2019 in Dharmasyara Regency, West Sumatra Province. The research site was selected purposively as Dharmasraya is an oil palm production center in West Sumatra. Data were collected using a questionnaire by involving 156 sample farmers who were selected using the Multiple Stage Sample approach.

The data collected consists of qualitative data on the characteristics of farmers and cultivation techniques carried out. In contrast, quantitative data are in the form of data about the planting area, production, and the number of inputs used in their farming business.

### B. Data Analysis Method

The Stochastic Frontier production function developed by Coelli et al. (2005) was used in this study. The production of smallholder oil palm farming in this study was analyzed using the Cobb-Douglas production function.

The Cobb-Douglas Stochastic Frontier production function form is shown in the following equation:

$$lnY_i = \beta_0 + \Sigma\beta_k lnX_{ik} + V_i \qquad (1)$$

Where: *ln* represents natural logarithm, Y represents the total quantity of oil palm yield in tons of fresh fruit bunches per hectare per year, $X_k$ is a (1 x k) vector of values ofknown functions of production inputs consisting of quantity of labor used, the use of varies type of fertilizers (Urea, TSP, KCL, NPK, Dolomite, manure), the use of chemicals (herbicide and pesticide), age of trees, seedling variety (superior and non-superior) and farmers category (partnership and independent). Constant is represented by $\beta_0$, and $\beta_k$refers to the regression coefficient of production factors. The subscript i refers to the-i farmer. V is random errors that are assumed to be independent and identically distributed (i.i.d.)N $(0, \sigma_v{}^2)$.

Technical efficiency is analyzed using equation below (Coelli et al., 2005):

$$TE = \frac{y}{y*}$$

$$= \exp(x_i\beta + v_i - u_i) / \exp(x_i\beta + v_i)$$

$$= \exp(-u_i) \qquad (2)$$

Where TE is technical efficiency, $y_i$ is actual production from observation and $y_i^*$ is estimated frontier production obtained from the technical efficiency of stochastic frontier production for farmers ranging between zero and one. The stochastic frontier approach produces two conditions simultaneously, namely the magnitude of the level of technical efficiency as well as the factors that influence technical inefficiency. The variable $u_i$ is a random variable that describes the technical inefficiency in activities related to the production. The greater the value of $u_i$, the greater the technical inefficiency. The value of the distribution parameter ($u_i$) effect of technical inefficiency in this study is shown by equation (3):

$$u_i = \delta_0 + \Sigma\delta_m Z_{im} + w_i \qquad (3)$$

Where:$u_i$ is the effect of technical inefficiency, $\delta_0$ is constant, $\delta_m$ refers to coefficient of independent variable, $Z_m$ is a (1 x m) vector of independent variables consisting of land size, age of farmers, farmers' education attainment, oil palm farming experience, seedling variety (superior and non-superior) and farmers category (partnership and independent), and $w_i$is error term.

## IV. RESULTS AND DISCUSSIONS

### A. Estimation of the Cobb-Douglas production function

In the preliminary analysis, multiple linear regression analysis was performed to estimate the Cobb Douglas production function. The analysis results coefficient of determination ($R^2$) is 0.5034. It means that 50.34% of the variations in the productivity of oil palm can be explained by the variables used in the model. As the statistical F probability value is less than 0.05, the estimation model of the production function using all independent variables can be accepted. This means that the production function model is feasible to predict the factors that affect the productivity of smallholder oil palm plantations in the Dharmasraya Regency. The results of the preliminary analysis revealed that three variables (the use of TSP and pesticide, and the age of trees should be removed from the model. Therefore, only nine variables remain in the model for further analysis.

The second stage is the estimation of the *Cobb Douglas* production function with the MLE (*Maximum Likelihood Estimation*) method. The results of the estimate using the stochastic frontier production function approach with the MLE method illustrate the best performance (best practice) of the respondent farmers at the current technology level. The estimation result is presented in Table 1.

**TABLE I**

**Maximum likelihood estimate (MLE) Estimation for the parameter of the *Cobb-Douglas* production function**

| Input Variable | Coefficient (β) | z-value |
|---|---|---|
| Constant | 8.173 | 39.46 |
| ln(labor) | 0.339 [a] | 5.98 |
| ln(Urea) | -0.025 [b] | -1.84 |
| ln(KCL) | 0.029 [b] | 1.79 |
| ln(NPK) | 0.038 [a] | 2.61 |
| ln(Dolomite) | 0.041 [a] | 3.57 |
| ln(manure) | -0.024 [a] | -2.04 |
| ln(herbicide) | -0.316 [a] | -2.24 |
| Seedling variety | 0.567 [a] | 4.97 |
| Farmers category | -0.567 [a] | -8.50 |

[a] significant at α level of 0.05 ;

[b] significant at α level of 0.10

The results reveal that all independent variables have a significant effect on the production of oil palm. Some variables, including the use of labor, KCL, NPK, Dolomite, and seedling variety, have positive signs as expected. In contrast, others (the use of Urea, manure, herbicide, and farmers' category) have negative signs. The coefficient value of 0.339 for labor means that a one percent increase in the use of labor can increase the productivity of oil palmby 0.339 percent. The average use of labor by farmers is 37.05 man-days per hectare per year. Thus, farmers are still rational if they increase the use of labor to increase the production of oil palm.

Variable of urea fertilizer and manure have a significant negative effect on the productivity of the oil palm. An increase in the amount of urea fertilizer and manure used will cause a decrease in the productivity of oil palm.This interesting finding may result from the fact that farmers also used NPK containing N. Therefore, the use of Urea and manure as the primary source of N would not be useful.

Estimates for the production elasticities(at mean levels of the inputs) with respect to the use of KCL, NPK, and Dolomiteare 0.029, 0.038, and 0.041, respectively. The positive values of the coefficient mean that an increase in the use of the three fertilizers will increase the production of oil palm.

The pesticide variable was found to have a significant negative effect on oil palm yield with the elasticity of -0.316. This figure shows that one percent of the additional amount of pesticide would cause a decrease in oil palm yieldby 0.316 percent. This negative effect may be caused by the inappropriate use of herbicides by farmers that lead to ineffective application.

The production elasticity of the seedling variety has a positive and significant effect on oil palm productionwith a value of 0.567. It indicates that the use of superior seeds will increase the productivity of oil palm in Dharmasraya by 0.567 percent. The negative sign of farmer category variable means that partnership farmers have lower production of oil palm than individual farmers.

Previous studies have different results in terms of production inputs. Alwarritzi, Nanseki, and Chomei (2015) and Woittiez, van Wijk, Slingerland, van Noordwijk, and Giller (2017) found that the use fertilizers have significant positive effects on oil palm yield, while research by Hasnah, Fleming, and Coelli (2004) reveals it to be insignificant. However, the impact of labor use on oil palm production is significant in our study that is similar to the result of research by Hasnah et al., but not in line with Alwarritzi et al. findings. Sabbouh, Alattuan, and Abdullah (2019), in their study on the technical and economic efficiency of Olive oil production, also found that fertilizers and labor use influenced Olive oil production.

### *B. Technical Efficiency Analysis of Oil Palm Farming*

The level of technical efficiency is obtained from the Cobb-Douglas production function model using the Stochastic Frontier approach. The results reveal thatthe level of technical efficiency of individual farmers ranges from 0.41 to 0.94 and the average of 0.73. It means that on the average, the productivity of oil palm in the study area has reached 73% of the maximum productivity.The technical efficiency level of our study is higher than that of Hasnah et al. found with an average level of 66%, but it is lower than that found by Alwarritzi et al. (2015), counting for 83%. The optimal productivity can be achieved if farmers apply good management practices. The distribution of technical efficiency can be seen in Figure 1.

Most farmers (57%) have a technical efficiency level greater than 0.7, which is considered moderate. About 11% of farmers have technical efficiency of less than 0.5. This means that farmers need to improve their agricultural practices to increase oil palm production.

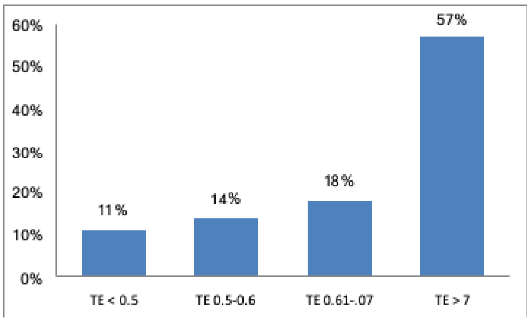


**Figure 1. The level of Technical Efficiency of Smallholder Oil palm Farmers in Dharmasraya Regency**

### C. *Factors Affecting the Technical Efficiency of Oil Palm Farming*

The factors that influence the level of technical efficiency are estimated by using a model of the effect of technical inefficiencies of the stochastic frontier production function. Where the inefficiency effect is an *error term* of the production function that is modeled. Table 2 describes the results of estimating the inefficiency effect model of the Stochastic Frontier Production Function.

**TABLE II**

**Estimating the effects of technical inefficiencies in the production function of *stochastic frontier* oil palm farming in Dharmasraya Regency**

| Variable | Coefficient | Z |
|---|---|---|
| constant | -2.008 | -1.78 |
| land size | 0.021 | 0.36 |
| age of farmer | 0.008 | 0.46 |
| education | -0.040 | -0.67 |
| experience | -0.044 | -1.40 |
| seedlings | 0.123 | 0.25 |
| farmer category | 1.030 * | 1.68 |

* significant at the α level of 0.10

Estimation results show that among six independent variables, only variable *farmer category* that influences the efficiency of oil palm farmers significantly at α = 0.10. This result indicates that independent farmers are more efficient than partnership farmers. This figure is in line with the estimated production function in which oil palm production of individual farmers is higher than that of partnership farmers. It may relate to the way farmers applied inputs. While partnership farmers are more dependent on the partner in managing their land than that of individual farmers.

Land size, farmers' characteristics, and seedling variety are found to be insignificant. It means that farmers with small and large size of land have the same level of efficiency. There is a similar figure in the effect of the age of farmers, education attainment, and farmer's experience in oil palm farming on technical efficiency. The technical efficiency level of oil palm is the same across the different characteristics of farmers.

According to Soekartawi (2002), the area of agricultural land can affect the scale of the business, and it will consecutively affect the efficiency or failure of a farming business. It is proved by a study of Hasan, Alio, and Abdullah (2018) on citrus production, in which land size category of 1 – 2 haachieved the highest efficiency level. However, we found that land size had no significant effect on production efficiency that conforms with the findings of Amos (2007).

Coelli and Battese (1996) identified a number of demographic and economic factors that could affect the technical efficiency of farmers. They include the ageand education level of farmers and land size. Their finding about educational effect is similar to analysis by Amos (2007), Alwarritzi et al. (2015) andHasnah et al. (2004), while the age of farmers is proved to have significant effect on technical efficiency by Amos, Alwarritzi et al. and study by Chiona, Kalinda, and Tembo (2014).

Superior seeds are one of the biological technologies that can be used in the cultivation of oil palm. Using superior seeds is assumed that farmers will be more able to achieve optimal production levels. However, the results of the estimation of the inefficiency effect show that the use of superior seeds is not significant.

## V. CONCLUSIONS

We found that all production inputs have a significant effect on oil palm production. Some variables have positive signs as expected, including the use of labor, KCL, NPK, Dolomite, and seedling variety, have positive signs as expected, while others (the use of Urea, manure, herbicide, and farmers' category) have negative signs. Farmers can increase the productivity of oil palm by increasing the use of production factors that have positive effects on oil palm yield. Moreover, farmers should consider reducing the amount of urea and manure used if they already used NPK to make fertilization more optimal. The pesticides used should be able to control all types of pests and diseases that interfere with the planting area.

The level of technical efficiency of smallholder oil palm farming in the Dharmasraya Regency varies significantly from 0.41 to 0.94, with an average value of 0.73. Farmers have the potential to improve technical efficiency if the production factors are used appropriately.The technical efficiency of oil palm farming is significantly influenced by farmers' category. Independent Farmers are more efficient than partnership farmers.

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