



## **The Determinants of Technical Efficiency of Oil Palm Smallholders in Indonesia**

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### **ABSTRACT**

The main objective of the present study is to analyze the technical efficiency (TE) and evaluate its determinant in smallholder oil palm farming in Indonesia. The stochastic frontier analysis was applied to 20,409 selected oil palm farmers from the results of the 2014 Estate Cultivation Household Survey (ST2013 SKB) conducted by BPS-Statistics Indonesia. The results showed that all the input variables had a positive influence on oil palm production along with existing inefficiencies among heterogeneous smallholder farmers. They also indicated that the mean level of the TE among oil palm smallholders was 0.6694. Furthermore, variables such as farmer age, education, type of farmer, and location of the farm had positive and significant effects on TE. Therefore, the development policies in the oil palm smallholder sector might focus on promoting education and facilitate the accessibility of farmers to extension services by giving guidance on farming management based on environmentally friendly principles to improve production regarding land expansion.

**Keywords:** Smallholder, Stochastic Frontier, Technical Efficiency

**JEL Classifications:** C51, D24, Q15

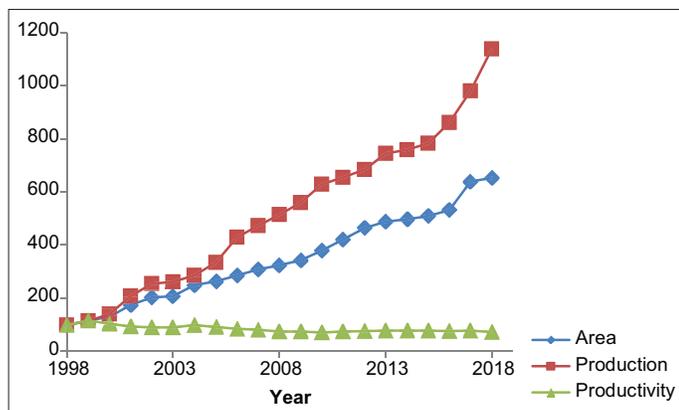
### **1. INTRODUCTION**

Oil palm oil is a prima donna commodity in the Indonesian estate sector. It is one of the sources of foreign exchange earnings, where the contribution to the value of non-oil and gas exports reached 10% in 2019. In the last 3 years, export volumes of Indonesian crude palm oil increased, i.e., from 28.7 million tons in 2017 to 29.5 million tons in 2019. However, the drop in the world oil palm prices decreased the value of exports from USD 20.3 billion in 2017 to USD 15.6 billion in 2019 (BPS, 2020). Although there is a decreasing price due to trade restrictions and a decline in global demand, this commodity remains the hope of more than 2.6 million farmer households operating, on average, 2.26 hectares per household (Directorate General of Estates, 2019). This sector is also an economic driver in some rural areas of Indonesia.

In 2018, smallholder plantation accounted for 55.09% of Indonesia's total oil palm acreage and 35.67% of national CPO production. In the last 20 years (1998-2018), the acreage increased 12 times (6 times in terms of production), but productivity has not much changed and tended to decrease (Figure 1). In 2018, the productivity of smallholder plantations was only 3.369 tons of CPO/hectare, far below that of large farms reaching 3.853 tons of CPO/hectares (Directorate General of Estates, 2019).

The increase in oil palm smallholder production is due more to land expansion than productivities. Most smallholders tended to be considerably less productive than a large plantation of commercial estates due to insufficient use and access to high-quality production inputs and adoption of poor management practices (Euler et al., 2016b; Jelsma et al., 2017). There is much room for improvement among farmers (Jelsma et al., 2019).

**Figure 1:** Planted area, production, and productivity of oil palm smallholder in Indonesia for the selected years (1998 = 100)



Small farmers in developing countries face difficulties in exploiting the potential of new technologies and other agricultural resources, causing them to be inefficient in making decisions (Tijani et al., 2017). Meanwhile, the current level of technology and resources still allows farmers to reduce the production gap with large plantations through efficiency. Efficiency is an essential factor for productivity growth, where technical efficiency (TE) shows the ability of farmers to obtain maximum output on a certain amount of input and technology (Kumbhakar and Lovell, 2000).

The study is aimed to analyze the technical efficiency (TE) and evaluate its determinant in Indonesian smallholder oil palm farming. It is expected that there are socioeconomic and environmental factors that can affect the efficiency and sustainability of agricultural practices of farmers in the future.

## 2. LITERATURE REVIEW

Previous studies on the efficiency of oil palm production were still limited compared to the food crop commodities, which at least includes technical efficiency and inefficiency factors. There are no studies on the technical efficiencies covering almost all of oil palm production areas in Indonesia. Technically efficient approach (TE) to investigate the determinants of performance and production efficiency of oil palm smallholders have been carried out by authors such Hasnah et al. (2004) in West Sumatra Indonesia, Alwarrtzi et al. (2015) in Riau Indonesia; Juyjaeng et al. (2018) in Thailand; Tijani et al. (2017) in Johor Malaysia. The results indicated various TE and determinants among the farmers in those countries.

Hasnah et al. (2004) analyzed the performance of oil palm NES farmers in West Sumatra. They obtained an average TE of 0.66, indicating that farmers were not efficient in managing their farms. They also mentioned that there were opportunities to increase the outputs through the performance of extension services, informal education, and progressive farming. A higher TE value (0.83) was obtained by Alwarrtzi et al. (2015), who used the form of the translog function in estimating TE of oil palm farmers in Riau. The determinants of technical efficiency are farmer groups, education, age of farmers, and farm diversification.

The study of Tijani et al. (2017) showed differences in technical efficiency across different plant age groups in Johor Malaysia. The results showed that extension services, household size, age of farmers, access to credit, land conservation, household income, experience, education level, farmer group membership, and government intervention affected the technical efficiency of farmers.

A study on the efficiency of oil palm production in Thailand by Juyjaeng et al. (2018) showed that the TE of farmer group members of the Large Agricultural Plot Scheme (LAPS) was higher (0.63) than that of non-members (0.52). The determinant of technical efficiency member LAPS is the length of farming, while it is the age of the farmer for non-LAPS.

## 3. METHODS

The data used in this study are cross-section data from the results of the 2014 Estate Cultivation Household Survey (ST2013 SKB) conducted by BPS-Statistics Indonesia. The analysis is carried out on 20,409 selected farmers who had a monoculture cropping system and a minimum of 15 trees of plants cultivated as a minimum limit enterprises.

In the analysis of the production function, a stochastic frontier model in the form of a translog is used. The stochastic production frontier model was developed by Aigner et al. (1977) and Meeusen and van Den Broeck (1977). This function is different from the traditional production function because the two components of the error term are as follows.

$$Y_i = f(X_i, \beta) e^{v_i - u_i} \tag{1}$$

Assuming that  $f(X_i; \beta)$  takes the translog form, then the stochastic production frontier model is as follows:

$$\ln Y_i = \beta_0 + \sum_{i=1}^4 \beta_i \ln X_i + \frac{1}{2} \sum_{i=1}^4 \beta_{ij} \ln X_i \ln X_j + (v_i - u_i) \tag{2}$$

where  $Y_i$  is the Fresh Fruit Bunches (FFB) oil palm production by the  $i^{th}$  farmer (kg),  $X_1$  is the number of weighted trees (trees),  $X_2$  is the total quantity of labor used (man-days),  $X_3$  is the amount of chemical fertilizers used (kilograms),  $X_4$  is the amount the pesticides used (liters),  $(v_i \text{ and } u_i)$  is error term component where  $v_i$  is the noise effect that cannot be controlled by farmers and assumed to be iid and symmetric ( $v_i \sim N(0, \sigma^2_{v_i})$ ) and  $u_i$  is the technical inefficiency in the model and assumed to be iid and truncated ( $u_i \sim N^+(\mu(Z_i), \sigma^2_u)$ ).  $u_i$  and  $v_i$  are distributed independently of each other.  $Z_i$  showed socioeconomic and environmental variables of farmers.

This study defines the variable of weighted trees, which will capture the effect of age of oil palm trees on the level of output. Variables are defined as follows:

$$WPT_i = w_1 PT_{1i} + w_2 PT_{2i} + w_3 PT_{3i} \tag{3}$$

Where  $WPT_i$  is the weighted number of oil palm on the  $i^{th}$  farmer,  $PT_1, PT_2, PT_3$  are the age categories of the plant according to Euler et al. (2016a), namely,  $PT_1$  the age of oil palm trees of 3-7 years after planting when yield increase before reaching the peak,  $PT_2$  the age of oil palm plantations 8-16 years when yield reach the peak, and  $PT_3$ , age more than 16 years when yield has declined. The coefficient  $w_i$  will be estimated from the average productivity data (kg/tree) of the sample. The average productivity of  $PT_1, PT_2, PT_3$  are 92, 113 and 111 kg/tree, respectively, so that the value of  $w_i$  are  $w_1 = 92/113, w_2 = 113/113$  and  $w_3 = 111/113$ . This approach had been applied by several researchers to describe the effect of tree age on production, Alwarritzi et al. (2015) on oil palm in Riau, Indonesia, Ofori-Bah and Asafu-Adjaye (2011) on cocoa in Ghana, and Hung et al. (1993) on rubber in Vietnam.

The technical efficiency (TE) was measured using Battese and Coelli (1995) approach as follows:

$$TE_i = \frac{Y_i}{f(X_i, \beta) \exp(v_i)} = \exp(-u_i) \tag{4}$$

The parameters of the stochastic frontier and technical inefficiency model are estimated simultaneously. The technical inefficiency model uses the following equation:

$$u_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 \tag{5}$$

where  $u_i$  is the effect of technical inefficiency,  $Z_1$  farmer age (years);  $Z_2$  farmers education (years);  $Z_3$  dummy get extension services (1=yes 0=no);  $Z_4$  dummy types of farmers (1-supported farmers 0-independent farmers) and  $Z_5$  dummy farm location (1-mineral soil 0-peat soil).

#### 4. RESULTS AND DISCUSSION

Before proceeding with the results, the present study conducted a hypotheses test to determine the functional form models and inefficiency in the model by calculating the likelihood ratio (LR) test (Table 1). First, it tested that the second-order parameter of the translog model is zero. The null hypothesis was rejected at a significant level of 1%. This result indicated that the translog model was more consistent representing the dataset than the Cobb-Douglas model. Second, it tested for inefficiencies present in the model, where the null hypothesis states that the inefficiency effect is 0. This null hypothesis was rejected at a significant level of 1%, so there was an effect of technical inefficiency on smallholder oil palm production. From these results, it can be concluded that the form of the translog model and the maximum likelihood estimation (MLE) method is suitable for this study. The results of the MLE estimation are presented in Table 2.

The estimated signs of input parameters in the form of output elasticity of input indicated that all the input variables had a positive influence on oil palm production. All inputs in the production function, i.e., weighted trees, labor, fertilizers, and pesticides, were inelastic, implying that an increase of 1% in every input will lead to a rise in FFB output of <1%. Of all the five input variables in the

model, the weighted trees variable was the most crucial factor, with the most significant effect on the output with production elasticity equaled to 0.7038. The sum of all partial output elasticities equaled to 0.9692, indicating a decreasing return to scale, a proportional increase in all inputs results in a less than proportional increase in FFB output.

The TE value of oil palm farmers ranged from 0.0457 to 0.9582, with an average TE of 0.6694. However, most farmers (56.9%) were efficient because they had technical efficiency values >0.70. From the average TE value, there was room for farmers to increase production by 33.0% on existing technology and resources.

Table 3 shows the estimation results of the determinants of technical inefficiency. Due to the inverse relationship between technical inefficiency and technical efficiency, parameter estimates are interpreted in terms of impacts on TE. In Table 4, the percentage

**Table 1: Likelihood ratio test of hypotheses**

Null hypotheses	Likelihood ratio ( $\lambda$ )	Critical value $\chi^2_{0,01}$	Decision
$H_0: \beta_{ij} = 0$	931	22.53	Reject $H_0$
$H_0: \gamma = \delta_0 = \delta_1 \dots \delta_5 = 0$	130	16.70	Reject $H_0$

**Table 2: Maximum likelihood of estimation of oil palm production**

Variable	Coefficient		Standard error
Constanta	4.9411	***	0.0771
ln weighted trees (lwpt)	0.9463	***	0.0298
ln labor (llab)	0.0711	***	0.0227
ln chemical fertilizers (lfer)	0.0368		0.0034
ln pesticides (lpes)	-0.0021	***	0.0053
$0.5 \times lwpt^2$	-0.0306	***	0.0078
$0.5 \times llab^2$	0.0536	***	0.0043
$0.5 \times lfer^2$	0.0074		0.0004
$0.5 \times lpes^2$	0.0006	***	0.0006
lwpt $\times$ llab	-0.0193	***	0.0047
lwpt $\times$ lfer	0.0035	***	0.0006
lwpt $\times$ lpes	0.0026	***	0.0006
llab $\times$ lfer	-0.0045	**	0.0005
llab $\times$ lpes	-0.0014	*	0.0005
lfer $\times$ lpes	-0.0001	***	0.0001
Parameters and other			
sigma_u	3.2666	***	0.8253
sigma_v	0.2703	***	0.0038
lambda	12.0868	***	0.8239
Output elasticities			
Weighted trees	0.7038	***	0.0055
Labor	0.2101	***	0.0046
Chemical fertilizers	0.0538	***	0.0025
Pesticides	0.0015	**	0.0007
RTS	0.9692		

\*\*\*, \*\* and \* indicate the significance level of 1%, 5% and 10%

**Table 3: Estimates of the technical inefficiency model**

Variable	Coefficient		Standard error
Constant	-13.9835	*	7.8488
Farmer age	-0.0736	*	0.0398
Education	-0.1737	*	0.0964
Extension services	-2.8731	*	1.6029
Type of farmer	-4.1315	*	2.1424
Farm location	-1.5931	*	0.9338

\*Significant at  $\alpha$  10%

of farmers and technical efficiency is presented according to the determinant variable TEs.

The results showed that farmer age, education, type of farmer, and farm location variables were significant in improving farmers' TE. Farmer age had a negative sign and a significant effect on technical inefficiency. This result means that older farmers are more efficient than younger farmers. More than 50% of farmers were more than 45 years old. Older farmers were more efficient (TE 0.6772) than young farmers (TE 0.6556) and adult farmers (TE 0.6625) who were <45 years old. This aspect is presumably because the older farmers have had a long experience, so managerial skills make them more efficient. Previous studies demonstrated the positive influence of farmer age on TE, including Onumah et al. (2013) on cocoa farmers in Ghana, Tijani et al. (2017) on oil palm farmers (who have over 19 years plant age) in Malaysia, and Juyjaeng et al. (2018) on non-member of Large Agriculture Plot Scheme in Thailand.

Furthermore, the significant negative coefficient on the education variable implied that farmers with more years of formal education were more efficient. This finding was consistent with Alwarrizti et al. (2015), Tijani et al. (2017) and Ngango and Kim (2019). The largest proportion of formal education of oil palm farmers in Indonesia was primary education (60.6%). Farmers who did not have a formal education had the lowest average TEs (0.6564), while highly educated farmers had higher TEs (0.6734). Educated farmers have a more structured mindset and broader insight that tended to absorb the information more accessible and more responsive in adopting new technologies and innovations.

As expected, the coefficient of extension services is negative and significant. It meant that farmers who receive advisory services tended to have higher levels of TEs. Farmers who had received advisory services are relatively more efficient (TE 0.7124) than those who did not (TE 0.6662). This aspect should be noted because only 7.9% of farmers received extension services,

while the remaining 92.1% did not. Through extension services, farmers are introduced to best practices in oil palm cultivation, new technology, and field guidance so that they can improve their efficiency. The results of previous studies identified the significant effect of extension services on technical efficiency were Onumah et al. (2013), Ngango and Kim (2019).

The type of farmer had a significant effect on technical efficiency. Supported farmers were more efficient (TE 0.7093) than independent farmers (TE 0.6630). This aspect should be noted because the largest proportion of oil palm farmers was independent farmers, reaching 85.2%. Supported farmers were involved in oil palm farming through partnerships with large plantation companies. The relationship between the two is through a contract in which the companies are responsible for technical assistance and marketing (International Finance Corporation, 2013). Meanwhile, independent farmers adopt technology independently, that is, without any direct support and government involvement (Euler et al., 2016b), and they are free to sell to any buyer (International Finance Corporation, 2013). This result can be a justification that supporting farmers have taken advantage of technology transfer and guidance from companies. A similar result was also obtained from Alwarrizti et al. (2015).

The location of the farm had a significant effect on technical efficiency. Farmers who cultivated oil palm in mineral soil land might be more efficient (TE 0.6718) than peat soil (TE 0.6556). This result was consistent with the study of Alwarrizti et al. (2015). Farmers on peat soil spend more on production costs, considering that peat soil is fragile, relatively infertile, and irreversible (Ritung and Sukarman, 2016). Marginal and agronomically inappropriate land use implies high production costs with potential environmental severe impacts. To support food and energy securities, the utilization of peat soil remains one option in supporting long-term agricultural development. Still, it's only limited to degraded or abandoned (bushes or grasslands) peat soil (Las et al., 2016).

**Table 4: Percentage of the farmer and technical efficiency by determinant variables**

Variable	Percentage of farmers (%)	Average of technical efficiency
Age of farmers (year)		
≤25	1.34	0.6556
26–45	48.17	0.6625
>45	50.49	0.6772
Education		
No have formal education	17.99	0.6564
Primary education	60.56	0.6725
Higher education	21.45	0.6734
Extension service		
Yes	7.94	0.7124
No	92.06	0.6662
Type of farmers		
Partner/Supported farmers	14.75	0.7093
Independent farmers	85.25	0.6630
Farm location		
Mineral soil	87.65	0.6718
Peat soil	12.35	0.6556

Considering the age groups of oil palm trees, the results varied on average yields (in FFB kilogram per tree) and TEs (Table 5). When the yield increases before the peak period (3-7 years after establishment plantation), the average productivity was 92.33 and TE 0.6399. When the yield reached the peak period (8-16 years), the average productivity and TE were 113.24 and 0.6962, respectively. When plants achieve the economic age (25 years), the average productivity and TE were still high, reaching 114.50 and 0.7126, respectively. Average productivity and TE began to decline after passing the economic age of 90.62 and 0.6475, respectively. Farmers need to pay attention to the plantation that has passed

**Table 5: Mean TEs of oil palm smallholder and productivities by the age of trees**

Variable	Age of trees (Year)				Total
	3–7	8–16	17–25	>25	
Mean TE	0.6399	0.6962	0.7126	0.6475	0.6694
Productivity FFB (kg/trees)	92.33	113.24	114.50	90.62	102.58
N	10.109	7.247	2.631	422	20.409

FFB: Fresh Fruit Bunch

economic age with low efficiency and decreased productivity by starting to think about replanting.

## 5. CONCLUSIONS AND POLICY RECOMMENDATIONS

The analysis of output elasticity of input and returns to scale reveal that all inputs used in the production function are inelastic, suggesting that a proportional increase in all inputs results in less than a commensurate rise in FFB output. The mean level of the TE among oil palm smallholders is estimated at 0.6694. However, more than 56% of farmers have TE above 0.70. The results further reveal that farmer age, education, extension services, type of farmers, and location of farm significantly improved farmers' TE.

The following policy implications which contributed to the efficiency in this study are proposed. The government should promote education in rural areas and improve the knowledge and skills of young farmers through training programs and internships. Also, it is necessary to strengthen the role of extension services in enhancing the technical practice aspect of farmers and information dissemination of the latest technology covering all farmers in all locations. The farmers who cultivated in peat soil should have guidance to manage their farming based on environmentally friendly principles and sustainable agriculture systems with the minimum possible ecological risk.

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