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TECHNICAL EFFICIENCY OF OIL PALM PLASMA SMALLHOLDERS IN INDONESIA

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ABSTRACT

This study examines the technical efficiency and influencing factors of oil palm production by plasma smallholders in Indonesia. The common method of analysis for this type of study is the stochastic frontier method based on the translog production function. The agricultural business household income survey (2013) of the Central Statistics Agency was used as a secondary data source where there were 2438 oil palm plasma smallholders registered in the Indonesian oil palm sector. The study found that the average value of technical efficiency of these plasma smallholders is 0.59 which means that there is room for improvements to increase it further. East Kalimantan has the highest efficiency value, compared to other provinces. Moreover, education and association memberships of smallholders, and seed quality had positive effects but the effect is negative with age of the smallholders in the oil palm sector in Indonesia. The distribution of technical efficiency level of farmers showed that only 0.94% of plasma farmers were efficient in their production. The Indonesian government should emphasize training programmes for plasma farmers to improve their efficiency in production

Keywords: Indonesia, palm oil, plasma farmer, technical efficiency.

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INTRODUCTION

Oil palm (*Elaeis guineensis*) is one of the strategic commodities in Indonesia. In 1982, the total oil palm plantation area was 294 560 ha and has increased to 14 326 350 ha as of 2018 (BPS, 2018). This rapid development has resulted in Indonesia becoming the world's largest palm oil-producing country since 2006. The existing potential will have a multiplier effect for increasing income for the community, increasing the government's income, reducing poverty and improving natural resources. The bright prospect of palm oil in the world vegetable oils trade has encouraged the Indonesian government to spur the development of its oil palm industry (Bachtiar, 2010).

In Indonesia, there are three main sectors in the oil palm industry. They are state companies, private companies and smallholders. In 2018, smallholder farmers owned 40.61% of the total oil palm plantation area with a productivity of 3.37 t/ha (BPS, 2018). It also creates job opportunities for nearly 2.6 million smallholders. The state companies and private companies planted 9.5% and 49.89% of total oil palm areas with a productivity of 4.06 and 4.62 respectively (BPS, 2018). Among the three main sectors, the productivity of the smallholder sector is the lowest. It means that the smallholder sector produces its products below their best potential.

The smallholder sector can be categorised into independent farmers (80%) and plasma farmers (20%). The independent farmers manage their plantation schemes themselves independently. The plasma farmers associated themselves with large companies through plasma-nucleus schemes. In the development of the oil palm industry, a plasma nucleus scheme is an important program. The plasma nucleus scheme is the partnership program between

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smallholders and companies in which the latter organises the development of palm oil production. In this program, the smallholders provide land and labour while the companies support production facilities, technical guidance and management as well as the market for the products (Euler *et al.*, 2016).

The low productivity of oil palm smallholders is alleged because the allocation of input usage is not optimal. Their managerial capability in managing and allocating production inputs will influence technical efficiency. Smallholders who, in their cultivation techniques, can manage the use of production factors to achieve maximum production yields can be said to be efficient (Varina *et al.*, 2020). Due to this, it is necessary to investigate the factors that influence production and technical efficiency in the smallholder sector. Therefore, technical efficiency and its determinants are still needed to be analysed for this sector.

Many studies explored the technical efficiency and productivity of oil palm production in Indonesia. Rahman *et al.* (2017) studied the effect of economic variables on the implementation of business diversification of household oil palm plasma smallholders. Ngadi (2019) analysed the income inequality of plasma farmers. Many studies focused on smallholder farmers and private companies. To our knowledge, the analysis of the technical efficiency of plasma farmers in Indonesia is still limited. This study aims to fill this gap to analyse the technical efficiency and its determinants for oil palm production by the plasma smallholders, comparing the technical efficiency at the provincial level and the individual farmer's level in palm oil production in Indonesia.

LITERATURE REVIEW

Hasnah *et al.* (2004) analysed the technical efficiency of NES-*Trans* oil palm plantations in West Sumatra using a stochastic frontier approach. Results showed that the average technical efficiency of NES-*Trans* farmers with the translog model is 0.66. It was found that the increase in outputs that occurred was due to better counselling and did not have to increase the number of inputs in production.

Iwala *et al.* (2006) analysed technical efficiency using the stochastic frontier in the oil palm region of Nigeria. The results concluded that the level of technical efficiency varies between oil palm farmers, ranging from 0.463 to 0.999. In addition, research results show that the age of oil palm trees, the cost of fertilisers and chemicals, and the cost of harvesting and managing have a positive correlation with production. On the other hand, the use of labour had a negative contribution to oil palm production because of the large number of workers used. Similarly, the level of education of farmers also contributed negatively to efficiency level.

Lim *et al.* (2011) analysed the efficiency of 230 rice farmers in Malaysia with variables of farm size, use of fertilisers and the number of workers. The results showed that the efficiency value was 0.85 with an indication of all inputs used in optimum conditions.

Nordin *et al.* (2017) analysed the technical efficiency of independent oil palm smallholders in Sabah and Sarawak Malaysia. This study used technical efficiency analysis with a stochastic frontier approach and, the results showed that only 4.5% of oil palm smallholders were above the efficiency score of 0.9. The technical inefficiency here was caused by the inadequate application of fertilisers, *Ganoderma* disease, pest attacks, nutrient factors in oil palm soil, high production costs and erratic weather factors.

Mustapha (2011) analysed the agricultural efficiency of rubber smallholders in Besut, Terengganu, Malaysia. The analysis used the output (y) as a dependent variable. The cultivated land per hectare (x1) and the intensity of land use per day (x_2) are used as independent variables. The results showed that rubber farmers' plantations are at a score of 0.95 to 1.00 the value of the Technical Efficiency score.

Furthermore, Tijani *et al.* (2017) analysed technical efficiency across various age groups of oil palm in Johor, Malaysia. Crop age categories are classified as under 9 years crop age, 9-18 year crop age and 19 years and above crop age. The study revealed that 19 years and above crop age have the highest efficiency. All the crop age categories have a constant return to scale in the study area. The results of the analysis found that household extension factors, farmer age, access to credit, soil conservation, household income, experience, education level, farmer group membership and government intervention were the determining factors for technical efficiency.

Puruhito *et al.* (2019) studied the technical efficiency and influencing factors of oil palm in West Sulawesi. The level of technical efficiency is positively related to the land area, the use of the family member, the use of NPK fertiliser, the age of the oil palm trees and the distance of the estate to the river. The age of the farmer and the difference in plasma pattern have a positive effect on the inefficiency of oil palm plantations.

Ismiasih (2017) analysed the technical efficiency and influencing factors of palm oil production in West Kalimantan Province. This study used the Cobb-Doughlas production function. The result showed that the value of average technical efficiency is 0.83 and the age of the farmers, education level of farmers, counselling participation, and membership of farmers' unions and cooperatives are significant factors for increasing technical efficiency. Ibitoye *et al.* (2011) analysed the influencing factors on the production of oil palm in Ondo State, Nigeria. The regression analysis result showed that the level of education and the number of training for oil palm farmers are significant for oil palm production.

METHODOLOGY

This study was conducted to analyse the technical efficiency of Indonesian oil palm plasma smallholders in Indonesia. In this regard, technical efficiency is obtained from the ratio of an output produced by a smallholder to the output when he/she is fully efficient. Fully efficient means that all inputs are processed optimally without any wasted residuals.

Fried *et al.* (2008) explained that technical efficiency is the ability to produce as much output as possible from certain inputs or by producing output with technology and the use of as few inputs as possible. In calculating technical efficiency, there are two models, namely parametric and nonparametric models. However, the nonparametric model has limitations. The nonparametric method did not take into account statistical noise. Therefore, this study used a parametric model, mentioned by Coelli *et al.* (2005) as Stochastic Frontier Analysis (SFA) which has accommodated the calculation of errors caused by statistical noise and the effects of technical inefficiency.

The stochastic frontier model was introduced by Aigner *et al.* (1977) and Meeusen and Broeck (1977). The stochastic production function developed by Battese and Coelli (1992), Battese and Coelli (1995) and Coelli *et al.* (2005) can be expressed as follows;

$$Yi = X_i\beta + V_i - U_i \qquad (1)$$

where Y_i is the production of the i-th firm; X_i is the vector of inputs quantities of the i-th firm; β is a vector of unknown parameters; V_i is random variables and U_i is the inefficiency term. Equation (1) can be rewritten in regression form as Equation (2).

$$lny_i = \beta_0 + \sum_M \beta_m \, ln \, x_{mi} + \varepsilon_i \qquad (2)$$

where, y_i is the output, x_i is the farm, m is the input used in the oil palm production, β is the coefficient and ε_i is the error term.

Following Coelli *et al.* (2005), the technical efficiency of oil palm production by plasma farmers can be estimated with Equation (3);

$$TE_i = \frac{y_i}{y_i^*} = \frac{\exp\,(x_i\beta + v_i - u_i)}{(\exp\,(x_i\beta + v_i)} = \exp\,(-u_i) \qquad (3)$$

TE is the technical efficiency, y_i is the observed output, y_i^* is the maximum output and u_i is the value of technical efficiency. The value of technical efficiency (TE) is between zero and one ($0 \leq TE_i \leq 1$). When TE =1, it indicates a firm is fully efficient, otherwise fully inefficient.

The empirical model used in this study is a translog production model and this model is analysed by using the software Frontier 4.1. The translog production model used in this study can be written as Equation (4);

$$\begin{aligned} lny_i = {} & \beta_0 + \beta_{Po}\, lnPo_i + \beta_{Pu}\, lnPu_i + \beta_{Ps}\, lnPs_i + \\ & \beta_{Tk}\, lnTk_i + \beta_{Ln}\, lnLa_i + 0.5\beta_{Po}\, (lnPo_i)^2 + \\ & 0.5\beta_{Pu}\, (lnPu_i)^2 + 0.5\beta_{Ps}\, (lnPs_i)^2 + 0.5\beta_{Tk} \\ & (lnTk_i)^2 + 0.5\beta_{La}\, (lnLa_i)^2 + \beta_{Po}\, \beta_{Pu}\, lnPo_i \\ & lnPu_i + \beta_{Po}\, \beta_{Ps}\, lnPo_i\, lnPs_i + \beta_{Po}\, \beta_{Tk}\, lnPo_i \\ & lnTk_i + \beta_{Po}\, \beta_{La}\, lnPo_i\, lnLa_i + \beta_{Pu}\, \beta_{Ps}\, lnPu_i \\ & lnPs_i + \beta_{Pu}\, \beta_{Tk}\, lnPu_i\, lnTk_i\, \beta_{Pu}\, \beta_{La}\, lnPu_i \\ & lnLa_i + \beta_{Ps}\, \beta_{Tk}\, lnPs_i\, lnTk_i + \beta_{Ps}\, \beta_{La}\, lnPs_i \\ & lnLa_i + \beta_{Tk}\, \beta_{La}\, lnTk_i\, lnLa_i + v_i + u_i \end{aligned} \qquad (4)$$

where, y_i is the output of oil palm plantations on the i[th] plantation. *Po* (number of trees in the whole farm), *Pu* (fertiliser), *Ps* (pesticide), *Tk* (labour) and *La* (land) are the inputs used in the production process. β_s represent the estimated coefficient. v_i is the random error and u_i represents technical efficiency. The influencing factors of technical efficiency can be estimated by Equation (5).

$$u_i = \delta_0 + \delta_1 X_{1i} + \delta_2 X_{2i} + \delta_3 X_{3i} + \delta_4 X_{4i} + \varepsilon_i \qquad (5)$$

where, X_{1i} is the level of education of the farmers on the i[th] plantation, while X_{2i}, X_{3i} and X_{4i} are the age of the farmers, quality of seeds and the membership of farmers association respectively.

The value of technical efficiency and all other influencing parameters as stated in Equations (4) and (5) are simultaneously estimated by using Software Frontier 4.1. After running the data, we calculated the average technical efficiency value of each province by combining the value of the technical efficiency of the province.

DATA AND VARIABLES

The data in this study are taken from the official secondary data released by the Central Bureau of Statistics (BPS) in Indonesia through the Agriculture

Survey (Agriculture Household Income Survey) data for Indonesia in 2013. The data represent the total number of 2438 plasma smallholders in the oil palm plantation in Indonesia. Palm oil output (y) includes all the value of the primary product, the value of by-products, the value of self-harvested production and the value of slash. The number of trees is adjusted by the weighted tree (*K*) (Alwarritzi *et al.*, 2015; Hasnah *et al*., 2004; Varina *et al*., 2020). The weighted trees can be calculated by using either the non-linear least square regression method or the age-yield profiles method from the literature (Hasnah *et al.*, 2004). This study follows the second method, *i.e*. age-yield profile. The weighted trees can be defined as Equation (6):

$$K_i = c_1K_{1i} + c_2K_{2i} + c_3K_{3i} \quad (6)$$

where K_i is the number of weighted trees on farmer i. K_1, K_2, K_3 are the age categories of 3-7 years, 8-16 years and above 16 years respectively. c_1, c_2 and c_3 are the weight of each age category. By following Varina *et al.* (2020), the value of c_1, c_2 and c_3 are 0.81, 1 and 0.98 respectively.

Fertilisers (*Pu*) include several types of fertilisers, namely Urea, TSP/SP36, ZA, KCL, NPK, organic fertilisers (manure/compost) and other fertilisers. Pesticides (*Ps*) include solid and liquid pesticides which are used in the production of palm oil. Labour (*Tk*) is the number of employees in oil palm plantations. Land area (*La*) is calculated by multiplying the number of trees with the spacing between trees. The education (X_{1i}) is based on the education level of the farmers and is measured by the number of years of schooling. Age (X_{2i}) is the age of smallholders. Seed quality (X_{3i}) is classified as uncertified seed (0) and certified seed (1). Member of farmers association (X_{4i}) is marked as one (1) if farmers are a member of farmers association and zero (0) for otherwise.

RESULTS AND DISCUSSION

Table 1 shows the summary statistics of palm oil production.

Table 1 shows that the plasma smallholders of oil palm in Indonesia can produce an average output of USD7333.34 with a standard deviation of USD10 177.45 and the minimum and maximum output values are USD5.16 and USD193 858.47 respectively. The average number of trees is 412 with a standard deviation value of 574.09 and minimum value is 16 and a maximum value is 12 658. The plasma farmers used the average fertilisers and pesticides of USD874.64 and USD116.08 respectively with a standard deviation of USD1778.92 and USD207.60. The mean value of labour is 4 persons and the standard deviation is 3.37. The minimum use of labour is one person and the highest labour is 96 persons. The average years of education are equal to 2.50 years with a standard deviation value of 1.76 and the lowest level of education is 0 (no formal education) and the highest level is 14 years (postgraduate). The average age of farmers is 47 years old and the minimum and maximum age levels are 18 years old and 99 years old respectively. Seed quality and members of farmers' associations are defined as dummy variables.

Table 2 shows the results of the maximum likelihood estimation of oil palm production and factors influencing the technical efficiency of oil palm production. In the inefficiency model, the negative sign of a variable shows a decrease in inefficiency (an increase in efficiency) and the positive sign shows an increase in inefficiency (a

TABLE 1. SUMMARY STATISTICS

Variable	Unit	Obs	Mean	Std. dev.	Min	Max
y (output)	US dollar	2438	7 333.34	10 177.45	5.160	193 858.47
Po (tree)	Number of weighted trees	2438	412.00	574.09	16.000	12 658.00
Pu (fertiliser)	US dollar	2438	874.64	1 778.92	3.150	45 348.35
Ps (pesticide)	US dollar	2438	116.08	207.60	0.190	4 588.36
Tk (labour)	Number of people	2438	4.00	3.37	1.000	96.00
La (land)	Hectares	2438	4.58	48.87	0.002	2 160.00
X_1 (education)	Years of schooling	2438	2.50	1.76	0.000	14.00
X_2 (age)	Years	2438	47.00	10.73	18.000	99.00
X_3 (seed quality)	Dummy	2438	0.84	0.35	0.000	1.00
X_4 (member of farmers association)	Dummy	2438	0.05	0.23	0.000	1.00

Source: BPS.

decrease in efficiency) (Battese and Coelli, 1995). Education is found to positively influence oil palm production at a 5% significant level. The result shows that the higher the level of education, the higher the level of technical efficiency. If the education level of farmers increases by one year, the technical efficiency increase by 0.39. This is because the farmers with a higher level of education can learn easily about any matters concerning advanced technology and can find new knowledge for improving technical efficiency. This result is opposite to the finding (Ismiasih, 2017). But this is consistent with the results of Fariani *et al.* (2018) in which education can increase technical efficiency. This is because education can be an important factor in shaping the mindset and decision-making process of undertaking the business (Emilia and Hutabarat, 2014). Meanwhile, the age of the farmer is found to have a significant negative influence on oil palm production at a 1% level. This means that younger farmers are higher in efficiency as compared to older farmers. If the farmers are younger, the technical efficiency can increase to 0.03. This is because the oil palm plantation activities require physical strength that better suits the younger farmers. This is consistent with the result of Ismiasih (2017) and Puruhito *et al.* (2019).

The quality of the seed is found to positively affects the level of efficiency at a 10% level of significance, meaning that certified seeds can increase the efficiency level of oil palm production. Using certified seeds can increase the technical efficiency by 1.70. This result is consistent with the study by Kariyasa (2015) which indicates that the use of certified seeds can increase the productivity of oil palm. The association membership of farmers also shows some significant effect on efficiency at a 5% level. If farmers are members of the farmers association, the value of technical efficiency increase to 6.25. This tells that farmers who are members of farmers' associations have better efficiency for their better access to knowledge on new methods, facilities and infrastructures.

Table 3 shows the output elasticity of each input variable such as the number of weighted trees (Po), fertiliser (Pu), pesticide (Ps), labour (Tk) and land area (La). Output elasticity can be calculated by partially taking the first-order derivative of the selected translog model. Output elasticity means how much the percentage of output will rise when the use of input is increased by 1%. According to the results, the value of elasticity of all input variables is positive and inelastic. This means that the output will increase by less than 1% by increasing the number of inputs used by 1%. Among the inputs used in the production of palm oil, the highest average elasticity is the tree on palm oil output with a value of 0.73. This means that an increase in output produced by oil palm plantations can be caused by an increase

TABLE 2. MAXIMUM LIKELIHOOD ESTIMATION OF OIL PALM PRODUCTION

Variable	Coefficient	Estimated value	T ratio
Constant	β_0	2.99***	5.37
Po	β_{po}	0.61***	3.26
Pu	β_{pu}	0.64***	5.17
Ps	β_{ps}	0.15	1.36
Tk	β_{tk}	0.42**	2.07
La	β_{la}	0.15*	1.97
Po^2	β_{popo}	0.90	1.57
Pu^2	β_{pupu}	0.04**	2.16
Ps^2	β_{psps}	0.04***	2.82
Tk^2	β_{tk}	0.02	0.55
La^2	β_{lala}	-0.01	-1.17
PoPu	β_{popu}	-0.06**	-2.47
PoPs	β_{pops}	0.03	1.11
PoTk	β_{pol}	-0.07	-1.55
PoLa	β_{pola}	0.01	0.56
PuPs	β_{pups}	-0.06***	-3.40
PuTk	β_{putk}	0.02	0.73
PuLa	β_{pula}	-0.02***	-2.71
PsTk	β_{psl}	-0.02	-1.01
PsLa	β_{psla}	0.00	0.28
TkLa	β_{tkla}	0.03*	1.77
Inefficiency			
Constant	δ_0	-20.34***	-5.32
Education	δ_1	-0.39**	2.17
Age	δ_2	0.03***	3.80
Seed quality	δ_3	-1.70*	-1.85
Member of farmer association	δ_4	-6.25**	-2.08
Sigma Square	σ^2	0.11***	5.91
Gamma	γ	0.98***	474.14
Log-likelihood function		-2239.84	
Error one-sided LR test		474.02	

Note: ***, ** and * are the significant level of 1%, 5% and 10% respectively.

TABEL 3. ESTIMATION RESULTS OF OUTPUT ELASTICITY CONCERNING EACH INPUT

Variable	Elasticity
Elasticity of tree (ε_{Po})	0.73
Elasticity of fertiliser (ε_{Pu})	0.10
Elasticity of pesticide (ε_{Ps})	0.07
Elasticity of Labour (ε_{Tk})	0.04
Elasticity of land (ε_{La})	0.02
Total (ε)	0.98

Note: Total elasticity= $\varepsilon_{Po} + \varepsilon_{Pu} + \varepsilon_{Ps} + \varepsilon_{Tk} + \varepsilon_{La}$.

in the number of trees. The value of the elasticity of the fertiliser is 0.10, meaning that by increasing the spending of fertiliser by USD1, it can increase the output by 0.10 units. The value of the elasticity of pesticide (0.07), labour (0.04), and land (0.02) show that the value of each elasticity is too small to affect the output.

The mean value of technical efficiency for each province is shown in *Table 4*. The East Kalimantan has the highest efficiency score with an efficiency value of 0.72. The Jambi is the second largest and a value is 0.71 and the third one is the Riau with a value of 0.69. The provinces with the three lowest efficiencies are South Sulawesi, Central Sulawesi and Aceh with the value of 0.48, 0.47 and 0.33.

TABLE 4. MEAN VALUE OF TECHNICAL EFFICIENCY OF OIL PALM PRODUCTION

No.	Province	Technical efficiency
1	East Kalimantan	0.72
2	Jambi	0.71
3	Riau	0.69
4	West Sulawesi	0.68
5	North Sumatera	0.66
6	South Kalimantan	0.65
7	South Sumatera	0.65
8	West Sumatera	0.64
9	West Kalimantan	0.63
10	Central Kalimantan	0.63
11	Lampung	0.61
12	Bangkulu	0.55
13	Kepulauan bangka Belitung	0.51
14	Southeast Sulawesi	0.51
15	South Sulawesi	0.48
16	Central Sulawesi	0.47
17	Aceh	0.33
Average		0.59

Table 5 shows the distribution of technical efficiency levels of plasma smallholders. The value of technical efficiency is somewhere between 0 and 1. By following the works of previous researchers (Ariyanto *et al.*, 2020; Coelli *et al.*, 2005), smallholders can be technically efficient if their value of efficiency is greater than or equal to 0.9. If the value is between 0.7 to 0.9, the firm's technical efficiency level can be considered moderate. If the value is less than 0.7, the firm is technically inefficient. The result shows that more than 50% of the plasma farmers have moderate efficiency scores. In contrast, 45.98% of plasma farmers are not efficient in their production. Only 0.94% of plasma farmers are regarded as efficient. Since the proportion of efficient plasma farmers is very low, the plasma farmers are recommended to extend their use of inputs to increase the efficiency level of their oil palm plantation.

TABLE 5. DISTRIBUTION OF THE LEVEL OF TECHNICAL EFFICIENCY

The value of technical efficiency	Number of plasma farmer	Percentage
TE < 0.7	1121	45.98
0.7≤ TE< 0.9	1294	53.08
TE ≥ 0.9	23	0.94
Total	2438	100.00

CONCLUSION

The average value of technical efficiency of oil palm plasma smallholders in Indonesia is found to be 0.59. This shows that there is room for improvements for these plasma smallholders to increase their efficiency level. The translog function suggests that the number of trees highly influences the technical efficiency and hence the production of palm oil by the plasma smallholders. In addition, other influencing factors include their level of education, age, their memberships with associations and seed quality. By increasing all these factors, plasma farmers can increase their efficiency level. The companies involved in the plasma-nucleus schemes should facilitate these plasma smallholders with training programs and knowledge-sharing sessions, thereby increasing the education level and technical efficiency of the farmers. The companies under the plasma-nucleus schemes also need to provide support to the plasma smallholders in using quality seeds while encouraging them to actively join farmers' associations.

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