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Technical Efficiency Of Integrated Smallholder Oil Palm With Cattle In Riau Province, Indonesia

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Abstract – The point of the study is to examine the level of technical efficiency of smallholders oil palm plantations that integrate and do not integrate, as well as to identify factors that impact technical inefficiency. This study relied on cross-section data from 300 houses. The technical efficiency value of smallholder oil palm plantations integrated with cattle was measured and compared in this study using the stochastic frontier production function in linear form with the natural logarithm transformation of the Cobb-Douglas production function. Oil palm output is determined by the number of plants, the use of labor outside the home, the usage of pesticides, and the use of labor inside of the family for integrated farmers. Non-integrated farmers, on either hand, are only influenced by the number of plants. On average, integrated farmers achieve 94.49 percent technical efficiency, whereas non-integrated farmers achieve 82.40 percent. The dependent ratio, household size, farmer experience, and extension support do influence technical efficiency in smallholder oil palm plantations that integrate.

Keywords – Integrated Palm Oil-Cattle, Stochastic Frontier, Technical Efficiency.

I. INTRODUCTION

The agriculture sector in Indonesia plays a substantial role in national economic development. In 2019, the agriculture sector contributed 12.38% to Gross Domestic Product (GDP) [1]. The most contribution is from the sub-sector of plantations that the main commodity is oil palm. The palm oil contribution was the export of the food industry that reached 62.03%.

During the last five years, there has been an increase of oil palm plantations area by 3.46 million hectares or an average annual growth of 7.41%. In 2019, the oil palm plantations in Indonesia were managed by large private plantations (PBS) as much as 54,75%, 4.26% by large state plantations (PBN), and 40.99% managed by smallholders (PR). The development of smallholder plantations needs serious attention because it grows indeed high (3.73%) compared to PBS and PBN. Besides that, PR is the livelihood of more than 2.66 million farming households in Indonesia [2].

The upward trend in PR has not been followed by increases in oil palm productivity. Currently, there is a productivity disparity between smallholder and large-scale oil palm operations [2]. In 2018, Indonesia's average productivity was only 17 tons per hectare, lagging behind Malaysia (19 tons per hectare), Colombia (19 tons per hectare), and Thailand (20 tons per hectare) [3].

Smallholder oil palm plantations have low output due to low-quality seed supplies, improper fertilizer and pesticide use, and inconsistent cleaning intervals [25]. Smallholder farmers' improper fertilization results in low fertilization doses [4] [3].

Organic fertilizer, particularly from cattle, is one of the ways that farmers may satisfy the need for simple and inexpensive fertilizer. Organic fertilizer can be produced by farmers that diversify their business by include livestock. Farmers will benefit from farming integration activities because they will be able to provide fertilizer for plants, increase oil palm production [5], reduce production costs associated with inorganic fertilizer procurement, and eliminate nuisance plants, all of which will improve efficiency [6].

In agricultural economics, production efficiency is widely used to determine farmer performance. Technical efficiency, also known as output-oriented efficiency, and allocative efficiency, also known as input-oriented efficiency, are the two main types of efficiency [7]. Because improving efficiency may increase farming's competitive position, efficiency analysis is important for determining agricultural factors such as farm size, land ownership, degree of specialization, and financial variables [8]. For economic actors and policymakers to devise suitable policies to increase agriculture performance, efficiency analysis is also critical [9].

Riau Province is one of Indonesia's places where oil palm and cattle have been integrated for a long time. The integration of oil palm-cattle in Riau began in 2006 on a household size on smallholder oil palm farming [10]. Furthermore, oil palm plantations in Riau Province play an important role in the national oil palm industry, as the province's area of oil palm plantations in 2019 was 2.7 million ha, accounting for 19.89 percent of Indonesia's total oil palm plantations, with 64.62 percent of them being people's plantations [2].

The present study aimed to investigate the level of technical efficiency of smallholder oil palm plantations that integrate with cattle compared to non-integration and identify factors that influence technical inefficiency.

II. RESEARCH METHODS

The research was carried out in Riau Province. The locations were chosen purposively, namely the districts of Siak, Kampar, Kuantan Singingi, Pelalawan and Indragiri Hulu with the consideration that this area is one of the areas that have a large number of smallholder oil palm plantations and is an integrated cattle development area in Indonesia. The primary was formed from the production performance of 300 farmer households. The sample includes 165 farm households with cattle farming operations linked with oil palm plantations and 135 oil palm farmers that do not integrate. Data collected is household and farming activities in 2020 The study was conducted for six months, from February to July 2021.

The analysis used in this study is the estimation of the Stochastic Frontier Production Function which is presented in linear form with the natural logarithm transformation (ln) of the Cobb-Douglas production function [11]. The following is the Cobb-Douglas production function model:

$$\text{PKS}i = \alpha \text{JTS}^{\beta 1}\text{UMRT}^{\beta 2}\text{PANORG}^{\beta 3}\text{PEST}^{\beta 4}\text{TKDK}^{\beta 5}\text{TKLK}^{\beta 6}e^{\varepsilon} \quad (1)$$

The production function is transformed into multiple linear forms with the natural logarithm transformation (ln) as follows:

$$Ln\ \text{PKS}i = \beta 0 + \beta 1 ln\text{JTS} + \beta 2 ln\text{UMRT} + \beta 3 ln\text{PANORG} + \beta 4 ln\text{PEST} + \beta 5 ln\text{TKDK} + \beta 6 ln\text{TKLK} + ei \quad (2)$$

where PKS : oil palm production (tonnes), JTS : number of oil palm plants (trees), UMRT : plant age (years), PANORG : amount of inorganic fertilizers (kg), PEST: number of pesticides (liters), TKDK : number of workers in the household (HOK), TKLK : number of workers outside the household (HOK), i : vector of parameters to be estimated and ei : residual. Expected coefficient values: $\beta 1$, $\beta 2$, $\beta 3$, $\beta 4$, $\beta 5$, $\beta 6 > 0$.

The stochastic frontier production function equation for cross-section data uses the concept developed by [11], namely:

$$Y_i = \exp(X_i\beta + v_i - \mu_i) \quad (3)$$

Furthermore, referring to [12], the linear form of the equation is

$$\ln PKS_i = \beta_0 + \beta_1 \ln JTS_i + \beta_2 \ln UMRT_i + \beta_3 \ln PANORG_{ji} + \beta_4 \ln PEST_i + \beta_5 \ln TKDK_i + \beta_6 \ln TKLK_i + v_i - \mu_i \quad (4)$$

Estimation was carried out in two stages, the first using the Ordinary Least Square (OLS) method, and the second using the Maximum Likelihood Estimation (MLE). Regression analysis using the OLS method was carried out to test the statistical assumptions.

Analysis of the stochastic frontier production function simultaneously can also perform efficiency calculations. The technical efficiency calculation method refers to [13] as follows:

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{exp(x_i\beta + v_i - u_i)}{\exp(x_i\beta + v_i)} = \exp(-\mu_i) \quad (5)$$

where TE_i: Technical efficiency (0 >TE > 1), Y_i : actual palm oil production and Y_i*: frontier production.

From equation (4), [13] explained that in the stochastic model, v_i and μ_i are error components (ε). v_i is noise (uncontrollable external factor) which is assumed to be normally distributed with the mean equal to zero and variance δ^2_v and μ_i are technical inefficiency effects which have non-negative value which is assumed to be normally distributed with variance δ^2_u and mean μ_i.

The error component v_i is related to external factors such as weather, pest and disease attacks, and so on, including input variables that are not specified in the production function. Meanwhile, error component μ_i is related to internal factors that affect inefficiency. The formula for inefficiency is as follows:

$$\mu_i = \delta_i z_i + \omega_i \quad (6)$$

where δ_i : variable parameter, z_i : variable affecting inefficiency, ω_i : variable with variance determined by truncation of normal distribution and zero mean. Specifically, the variable in the technical inefficiency model is:

$$\mu_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + 5Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} + \omega_i \quad (7)$$

The variables are Z_{1i}: age of the ith farmer (years); Z_{2i} : formal education for the ith farmer (years); Z_{3i} : the value of the dependency ratio for the ith farmer household (number of dependents divided by the total size of the household); Z_{4i} : extension dummy for the ith farmer (score 1 if he received extension advice during the past year and zero, if not); Z_{5i} : size of the ith farmer household; Z_{6i} : dummy membership in farmer groups or cooperatives for the ith farmer (value of one if the ith farmer becomes a member of the farmer group or cooperative; and zero, if not); Z_{7i} : experience in oil palm plantation for the ith farmer; and is the coefficient explaining the production inefficiency variable from oil palm farming. Expected sign for each parameter coefficient is δ1>0 and δ2, δ3, δ4, δ5, δ6, δ7<0. This model is estimated using Stata 15.1 application.

III. RESULTS

A. Characteristics of Responden

Figure 1 presents the characteristics of farmers and farms. The average age of integrated farmers is 48.81 years, which is older than the average age of non-integrated farmers of 46.24 years. Non-integrated farmers have a higher education level of 9.71 years or have finished junior high school education, whereas integration farmers have an average duration of schooling of just 8.30 years. The number of household members among integration and non-integration farmers is relatively similar, at 3.67 and 3.72 persons ,respectively, or equal four persons,. Integrated farmers had 20.72 years of experience in oil palm gardening, while non-integrated farmers had 19.44 years.

Table 1. Characteristics of integrated and non-integrated oil palm plantations farmers

Characteristics of Responden	Integrated Farming	Non-Integrated Farming
Farmer's age (years)	48.81	46.24
Formal education (years)	8.30	9.71
Number of household members (persons)	3.67	3.72
Farming Experience (years)	20.72	19.44

Land area (ha)	3.88	2.92
Oil palm farming revenue (Rp)	120,617,708	81,592,889
Cattle farming revenue (Rp)	30,852,727	0
FFB production (tonnes/ha)	18.29	18.05

Source: Processed Primary Data

The average area of oil palm plantations for integrated farmers is 3.88 ha while non-integrated farmers are 2.92 ha. With each of these areas, then farmer integrated farming has a greater revenue than non-integration. Integrated farmers, apart from receiving income from oil palm production, also receive income from the sale of cattle with an average value of more than Rp. 30 million/year. In the amount of FFB production (fresh fruit bunches) there are also differences with the amount of 18.29 tons/ha/year and 18.05 tons/ha/year for integrated and non-integrated farmers, respectively.

B. Analysis of Stochastic Frontier Production Function

The estimation results of the production function model using the MLE method are in Table 2, all coefficients are in accordance with the hypothesis except for the input variable PANORG. Two variables have a significant effect (α 1%) namely the number of plants (JTS) and labor outside the family (TKLK) in the integration pattern, while in the non-integration only the number of oil palm plantations (JTS).

Table 2. Estimated results of the stochastic frontier production function

Variable	Integrated farm			Non-Integrated farm		
	Coeffisien		Std. Err.	coefisien		Std. Err.
ljts	0.632561	***	0.071411	0.472273	***	0.076504
lumrt	0.043713		0 .078995	0.06329		0.080871
lpanorg	-0.00435		0.017899	-0.00725		0.051339
lpest	0.120271	**	0.050741	0.091329	*	0.051885
ltkdk	0.109141	*	0.060564	0.115693		0.092643
ltklk	0.06924	***	0.020353	0.030237		0.02867
intersep	-0.78845		0.37331	0.400376		0.527144
sigma_u	0.278249		0.369295	0.705113		0.487096
sigma_v	0.357791	***	0.026166	0.274302	***	0.034927
γ	0.777688	**	0.385828	2.570575	***	0.497934
LR test	19.02			12.35		
Log likelihood	-67.4264			-45.2697		

Note: * siqnificant on the level on α=10%; ** α=5%, *** α=1%

In all models, quantity of oil palm trees was the most responsive to oil palm output, as evidenced by coefficients larger than 0.63 for integrated and 0.47 for non-integrated, respectively. when compared to other variabel production parameters. In integrated farming, a 10 percent increase in the number of oil palm plantations will result in a 6.33 percent increase in oil palm production, while a 10 percent increase in the number of productive plants will result in a 4.72 percent increase in oil palm production in non-integrated farming, assuming the following factors: other production constant or ceteris paribus.

A significant influence is also found in the TKLK variable with a coefficient value of more than 0.07. When comparing integrated and non-integrated farmers, the availability of outside labor has a substantial impact on oil palm productivity. This indicates that the integration activity requires a lot of labour so that the workforce in the household is still not sufficient to maximize the potential of the integration system. In integrated farmers, the need for labor outside the household is greater because farmers have routine activities every day in raising cattle. Looking for grass and grazing cattle is one action that requres a lot of time.

Variable plant age (UMRT) and use of inorganic fertilizers (PANORG) did not significantly affect oil palm production. The age of the oil palm plantations had no significant effect because most of the respondents' age of oil palm was more than 16 years. The use of inorganic fertilizers has a negative impact on oil palm production, but has no significant effect. In general, farmers already know the recommended amount of fertilizer, only sometimes the application is not appropriate depending on the type of fertilizer available and the amount of money the farmer has. The tendency of farmers at the time of fertilization, will buy fertilizer that is available at that time, and the amount depends on the amount of money they have. This situation is a characteristic of farmer households because on the integration of rice-cattle integration that the demand for fertilizer is influenced by the price of fertilizer and the area of the plant and the area of rice harvested has a positive and significant effect on the demand for fertilizer [14].

The use of pesticides on integrated farmers has a significant effect on the significance level of 5% with a positive sign, while the non-integration farmers have a significant effect on the significance level of 10%. A significant influence is also found in the use of labor in the family (TKDK) at a significant level of 10%, while non-integrated farmers have no significant effect. This happens because the role of family members in managing integrated farming requires more labor, namely cattle maintenance. This is in accordance with the opinion of according to [15] that households do not use hired labor in carrying out the cattle production process. So, the alocation of family labor for livestock farming has a negative effect on the alocation of family labor for rice farming [14]. The lower the alocation of labor in cattle farming, the greater the alocation of labor in rice farming.

C. Technical Efficiency Analysis

The Tecnical efficiency estimation findings are shown in Table 3. The average degree of efficiency of the integration pattern is 94.49 percent, while non-integration is 82.40 percent. This result demonstrates that employing compost from cow dung for oil palm has a beneficial influence on smallholder oil palm production when compared to non-integration. According to according to [17], in the integration of food crops-livestock farmers, the average efficiency level of integrated farmers is 79.1 percent, whereas non-integration is 67.7 percent. Meanwhile, according to according to [6], who studied smallholder oil palm farmers in Riau Province, the average efficiency level of oil palm farmers was 84 percent, and according to [16] of 60.01 percent. According to [3], the average efficiency of smallholder plantation in Indonesia is 66.94 percent.

Table 3 Technical Efficiency estimation of integrated and non-integrated smalholder oil palm plantations

Description	Integrated farm	Non Integrated farm
Average	0.9449	0.8240
Standart Deviation	0.1213	0.1297
Minimum	0.2632	0.3340
Maksimum	0.9925	0.9776

Source: Processed Primary Data (2020)

The efficiency level for each farmer is different. For this reason, farmers are grouped based on efficiency level intervals as presented in Table 4.

Table 4. Technical Efficiency Distribution of Integrated and Non-Integrated Oil Palm Smallholders

Description	Level of tecnical efficiency							
	<30%	>30-40	>40-50	>50-60	>60-70	>70-80	>80-90	>90
Integrated Farming								
Frequency	1	2	3	1	2	0	9	147
Percentage	0.61	1.21	1.82	0.61	1.21	0	5.45	89.09
Non-integrated Farming								
Frequency	0	4	3	3	5	22	57	41
Percentage	0	2.96	2.22	2.22	3.71	16.3	42.22	30.37

The level of efficiency between integrated and non-integrated farmers differs significantly. When compared to the percentage of farmers including an efficiency level of more than 70 percent, the number of integrated farmers is higher than that of non-integrated farmers (94.54 percent vs 88.89 percent, respectively). This indicates that increasing input management and labor utilization by implementing integrated farming leads to better farm management than non-integrated farming. Most efficiency values in integrated oil palm farming are > 9o percent and non integration are > 80-90 percent.

The influence of land area and plant age on oil palm farming needs to be seen how the impact on the level of efficiency, which is presented in Table 5.

Table 5. Technical Efficiency Distribution based on land area and age of oil palm

Description	Integrated farming					Non Integrated farming				
	Number of Farmers (persons)	Technical Efficiency				Number of Farmers (persons)	Technical Efficiency			
		Average	Std. Dev.	Min	Max		Average	Std. Dev.	Min	Max
Land area of oil palm (Ha)										
<=2	80	0.9349	0.1395	0.3545	0.9925	74	0.8062	0.1403	0.3340	0.9424
>2-4	57	0.9583	0.0791	0.4605	0.9918	42	0.8535	0.0823	0.5652	0.9776
>4-8	16	0.9284	0.1797	0.2632	0.9912	17	0.8265	0.1695	0.3720	0.9389
>8-10	7	0.9663	0.0436	0.8677	0.9876	1	0.9358	-	0.9358	0.9358
>10	5	0.9773	0.0101	0.9637	0.9862	1	0.7457	-	0.7457	0.7457
Oil palm age (year)										
<=7	15	0.7691	0.2639	0.2632	0.9924	9	0.6461	0.2155	0.3340	0.8606

>7-16	52	0.9322	0.1264	0.3971	0.9917	47	0.8004	0.1429	0.3686	0.9776
>16-25	62	0.9750	0.0249	0.8478	0.9922	56	0.8406	0.0908	0.5652	0.9389
>25	36	0.9848	0.0060	0.9691	0.9925	23	0.9014	0.0333	0.8168	0.9427

The area of oil palm plants tends to enhance efficiency. When the size of oil palm farms is compared to the degree of efficiency. The efficiency level is greater than 80% at all levels of oil palm plantation area, except for non-integrated farmers with more than 10 ha of oil palm plantation area, where the efficiency level is 74.57 percent. This circumstance demonstrates that farmers at all levels of land ownership may attain high technological efficiency. Estimating the degree of efficiency in crop and livestock production in Poland reveals that farm size has a substantial influence on the level of efficiency [18]. The size of the farm also influences output. Similarly, farm size also impacts the level of efficiency, the more farm size will be impacted for better efficiency [19].

In terms of plant age, the older the plant, the higher the efficiency level, for both integrated and non-integrated farmers, until the plant is more than 25 years old.. Farmers are still able to regulate their inputs properly in plants that are more than 25 years old, ensuring that oil palm production stays consistent. The same result states that the maximum age of oil palm reaches 32 years, although after 19 years its production tends to decrease [20].

D. Factors affecting inefficiency

It is important to examine factors that influence technical inefficiency to measure relevant factors affecting farm production for policies to increase farm production [21]. The level of technical efficiency is influenced by other variables that do not directly affect farm production but are thought to affect efficiency. The variable is in the form of socio-economic characteristics of farmers which is the effect of inefficiency. This inefficiency effect is seen from the socio-economic variables of farmers, namely the age of the respondent, formal education, dependent ratio, counseling obtained, household size, membership in groups or cooperatives, and oil palm gardening experience, which are presented in Table 6.

Table 6. Estimation of technical inefficiency of integrated and non-integrated oil palm smallholders

Variabel	Integrated Farming		Non-Integrated Farming	
	coefficient	Std. Err.	coefficient	Std. Err.
Z1 Age	0.0286	0.021199	0.004281	0.044529
Z2 Formal education	-0.1341	0.094965	-0.00423	0.103133
Z3 Dependent ratio	-3.5372 **	1.668885	-2.46938	3.266108
Z4 Extention Service	-0.4429 *	0.678469	-0.22518	0.934604
Z5 Household size	0.85971 **	0.423037	0.287731	0.497397
Z6 Group	3.55260	5.437606	-0.77495	1.251334
Z7 Experience	-0.2735 **	0.124678	-0.17054	0.209369

Description: * significant α=10%; ** significant α=5%

The estimation of factors that affect technical inefficiency shows that the variables measured have a significant effect on integrated farmers, while non-integrated farmers have no significant effect on all variables. Variables Z3, Z5 and Z7 have a significant effect of 5% and Z4 have an effect on a significant level of 10 percent. The variables used in the model are not all in accordance with the hypothesis. Variables that do not match the hypothesis are household size and group membership.

Positive signs are found in the variables of respondent's age (Z1), household size (Z5) and participation in groups/cooperatives (Z6) while education (Z2), dependent ratio (Z3), getting counseling (Z4) and oil palm gardening experience (Z7) is negative. The respondent's age has a positive sign, which means that with increasing age, the level of inefficiency in farming increases. This can be caused by the reduced power and ability of farmers. The same thing was obtained by [22] that the addition of age reduces technical efficiency. In addition, younger farmers are more efficient than older farmers [7]. Different results were obtained by [23] and [3]. According to [3] that age is a variable that significantly affects the increase in ET of oil palm farmers in Indonesia.

In respect to household size, the larger the number of household members, the less effective farming is. This situation can occur when household members involved in farming have not been able to carry out cultivation activities such as recommendations, such as fertilizing, harvesting and spraying grass with herbicides. A different result was obtained by [24] that an increase in household members was able to provide sufficient labor for cocoa farming in Nigeria. Meanwhile, the participation of farmers in farmer groups or cooperatives does not have a big impact on increasing efficiency. This could occur if farmers involvement in groups or cooperatives is not followed by an active role in those groups, or if the groups or cooperatives in which farmers join are not functioning well. However, according to [6], group activities can increase the efficiency of smallholder oil palm farmers.

Education has a negative influence on inefficiency, means that improving formal education can give greater understanding so that farmers can explore appropriate cultivation practices to boost their agricultural produce. This finding is consistent with the findings of [6] and [3], who believe that increasing the level of education among oil palm farmers will boost technical efficiency. Different results were obtained by [23] that increasing formal education will reduce the level of efficiency in oil palm production.

For dependent ratio variable, the higher the value of the dependent ratio, which means that more family members are not working, causing working family members to work more efficiently, especially in using time and utilizing farm inputs. In terms of other variables, such as extension and experience in oil palm, it can be assumed how when farmers get more information from extension activities, their understanding improves and they are expected to be able to carry out agricultural activities successfully as well. Meanwhile, in the experience variable, the longer the farmer farms, the greater the farmer's abilities and the issues that arise in farming may be handled swiftly and without causing losses. According to [22] experience will increase with age, but the ability will tend to decrease with age.

IV. CONCLUSION

The impact of production variables in oil palm production varied between integrated and non-integrated farmers. Oil palm production is influenced by the number of plants, the use of labor outside the household, the use of pesticides, and the use of labor within the family in integrated farmers, but it is influenced by the number of plants and the use of pesticides in non-integrated farmers.

The average degree of technical efficiency achieved by integrated farmers is 94.49 percent, while non-integrated farmers get 82.40 percent. Farmers at all levels of land ownership may reach this level of technical efficiency. The amount of technical efficiency is affected by plant age differences. The older the plant, the higher the degree of technical efficiency until the plant is more than 25 years old. The dependent ratio, household size, farmer experience, and extension services are influence technical efficiency in smallholder oil palm plantations that integrate.

The following are the study's implications:

1. The impact of using cattle feses as additional fertilizer in oil palm plantations is able to improve the technical efficiency of oil palm farmers. As a result, the government must encourage farmers to more aggressively combine oil palm with cattle.
2. Efforts to improve the implementation of oil palm-cattle integration are carried out by maximizing the use of labor in farmer households and increasing extension activities on integration and the technology used.

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