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REGIONAL DIFFERENCES IN TECHNICAL EFFICIENCY OF INDONESIAN OIL PALM SMALLHOLDERS

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Abstract. The paper compares technical efficiencies and technological gap ratios for oil palm smallholders in islands/regions of Indonesia. A stochastic metafrontier model was applied to estimate the technological gap and compare on-farm technical efficiency. The results provide empirical evidence of heterogeneity in production technology across smallholders located in different regions. The results may provide support for specific agricultural policy regionally, in terms of supported farmer schemes and improvement of managerial capabilities of farmers on using of resources efficiently.

Keywords: Technical efficiency; stochastic-metafrontier; smallholder

INTRODUCTION

Indonesia currently is the largest oil palm-producing country in the world, where around 57% of the world's CPO production comes from Indonesia. Exports of CPO and its derivative products throughout 2019 reached 36.17 million tons (Directorate General of Estate Crops, 2021). In addition to large plantations (government and private sector), oil palm plantations are also cultivated by smallholders. Nearly 34% of the 15 million hectares of oil palm planting area in Indonesia noted are smallholder plantations. Almost 73 % of Indonesia’s oil palm smallholder plantations were located on Sumatra islands, 22% were on Kalimantan Island, and the remaining 5 % were outside of Sumatra and Kalimantan Islands.

Although oil palm production has increased over the years, it has increased less than the area cultivated. The most significant problem of the oil palm industry in Indonesia is how to increase productivity growth, especially for smallholders. Indonesian oil palm smallholders produced an average of 3.24 metric tons per hectare, far below that of large plantations reaching 4.44 tons of CPO/hectares (Directorate General of Estate Crops, 2021).

The low productivity trend has generated a debate on whether the farm-level policy should be geared towards new technology and/or technical change (Danso-Abbeam & Baiyegunhi, 2020). In the agricultural development economic literature, agricultural productivity increases can be done in two ways, that are the introduction of new technology and improvement in the managerial capabilities of the farmer. New technologies can be very expensive for farmers. In the presence of farmers inefficiencies, so making efficient use of the existing technology may be an effective approach to improve productivity.

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Over the years, many studies have been conducted on technical efficiencies of oil palm smallholders in Indonesia (Fariani et al., 2019; Alwarritzi et al., 2015; Hasnah et al., 2004). They assessed technical efficiency as still partial and had not contained data sampled from all regions of Indonesia. Research to assess technical efficiencies on oil palm smallholders in Indonesia has been conducted by Varina et al., (2020) using a metafrontier approach, which compares frontier groups of oil palm smallholders by management patterns. So, this study aims to investigate the technical efficiency of oil palm smallholders in Indonesia by considering the comparability of frontier sizes among oil palm smallholder groups according to region/ islands.

METHOD

In this study, we used data from the results of the 2014 Estate Cultivation Household Survey which has been conducted by BPS-Statistics Indonesia. The analysis is carried out on 21,040 selected farmers, whereas 15,933 farmers from Sumatera, 3,502 farmers from Kalimantan, and the remaining 1,605 from other islands.

The estimation of technical efficiency was carried out using a metafrontier approach, the methodology proposed by Huang et al. (2014). A metafrontier analysis accounts for heterogeneity in farm technologies across groups (Battese et al., 2004; O'Donnell et al., 2008). A stochastic metafrontier production function of farmers from different groups, possibly adopting heterogeneous technologies, is estimated as a two-step procedure (Ng'ombe, 2017). The first step involves estimating group-region frontiers and the second step to determine the metafrontier production function. The efficiencies relative to the metafrontier production function consist of three components: 1) technical efficiency measures (TE) derived from the group frontiers, corresponding to the distance between the observed input-output of *i*-th farmer and the group frontier, 2) the technology gap ratios (TGR) corresponding to the distance between the group frontier and the meta-frontier, and 3) the meta-frontier technical efficiency (MTE) which measures the distance from the observed input-output of *i*-th farmer to the meta-frontier (Khanal et al., 2018; Melo-Becerra & Orozco-Gallo, 2017).

In the analysis of the production function, a stochastic frontier model in the form of a translog is used.

$$ln\, ln\, Y_i = \beta_0 + \sum_{j=1}^{5} \beta_j\, ln\, ln\, X_{ji} + \frac{1}{2}\sum_{j=1}^{5} \sum_{k=1}^{5} \beta_{jk} lnX_{ji} lnX_{ki} + (V_i - U_i)$$

$$V_i \sim N\,(0;\sigma^2_v)$$

$$U_i \sim N^+\,(\mu(Z_{ji});\, \sigma^2_u)$$

where Yi is the Fresh Fruit Bunches (FFB) oil palm production by the i_{th} farmer (kilograms), X1 is the age of productive plants (year), X2 is the number of the productive trees (trees),

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X3 is the total quantity of labor used (man-days), X4 is the number of chemical fertilizers used (kilograms), X5 is the amount the pesticides used (liters), (V_i and Ui) is error term component where Vi is the noise effect that cannot be controlled by farmers and assumed to be iid and symmetric ($V_i \sim N(0,\sigma^2_V)$ and Ui is the technical inefficiency in the model and assumed to be iid and truncated ($U_i \sim N+(\mu(Z_{ji}),\sigma^2_U)$). Z_j showed socioeconomic and environmental variables of farmers, including age, education, extension service, farmer group membership, funding sources, and partnership.

The method of measuring technical inefficiency refers to the technical inefficiency effect model from Battese & Coelli (1995)

$$U_i = \delta_0 + \sum_{j=1}^{6} \delta_j Z_{ji}$$

where Z_1 denotes the farmer age (years), Z_2 denotes the length of education (years), Z_3 has a value of 1 if the farmer receives extension services, and 0 if otherwise, Z_4 has a value of 1 if the farmer is a member of the farmer group and 0 if otherwise. Z_5 has a value of 1 if the farmer receives a credit to financing their farms and 0 if otherwise, Z_6 is the dummy with a value of 1 if supported/ partnership farmers and 0 if independent farmers.

Test of Hypotheses

Hypotheses' tests are examined to determine the adequacy of the adopted model. The hypotheses are carried out to test the functional form of the production function, non-stochastic effects on the production function, technical inefficiency, and use of the metafrontier. The null hypotheses are (1) H_0: βij = 0 i ≠ j, the second-order parameter of the translog form is zero; (2) H_0: $\gamma = \delta_0 = \delta_1 = \delta_2 = \ldots\ldots \delta_6 = 0$. There is no inefficiency effect in the model at all levels; (3) H_0: $f_{SUM}(X,\beta_{SUM} = f_{KAL}(X,\beta_{KAL}) = f_{OTH}(X,\beta_{OTH})$, the production technology in all region/islands are similar, so there is no need for the specification of the meta-frontier model. The generalized likelihood-ratio statistic (LR), $\lambda = -2\{ln[L(H_0)] - ln[L(H_1)]\}$ is used to validate these hypotheses, where L(H0) and L(H1) denote the log-likelihood function values for the null (H_0) and alternative (H_1) hypotheses, respectively.

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RESULTS & DISCUSSION

Fitness of adopted model

The results of the hypotheses tested are shown in Table 1. The first hypothesis showed that the functional form of the translog was better than Cobb-Douglas in representing the data. The second hypothesis stating that the coefficient of determinant inefficiency model is zero,

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rejected, there is at least one that is not 0, so inefficiency among smallholders can be explained by the variables specified in the model. In the third hypothesis test, the null hypothesis stating that technologies used by smallholders under three regions/islands are the same was rejected. So, the metafrontier approach was suitable for comparing the efficiency between oil palm smallholders in three regions. This evidence supports the fact that the farmers are operating under heterogeneous technologies.

Table 1. Results of Hypotheses Tested

No	Null Hypotheses	Statistic LR (λ)	Critical Values χ^2 0,01	Decision
1	Ho: $\beta ij = 0$			
	Sumatera	996	38.30	Reject Ho
	Kalimantan	518	38.30	Reject Ho
	Others	407	38.30	Reject Ho
2	Ho: $\gamma = \delta 0 = \delta 1 = \ldots \delta 6 = 0$			
	Sumatera	110	17.76	Reject Ho
	Kalimantan	82	17.76	Reject Ho
	Others	39	17.76	Reject Ho
3	Ho: $f_{SUM}(X;\beta_{SUM})=f_{KAL}(X;\beta_{KAL}=f_{OTH}(X;\beta_{OTH})$	640	38.30	Reject Ho

Input Elasticities

Table 2 shows the MLE estimation parameters resulting from the stochastic frontier model of the production function of oil palm smallholder farmers in Indonesia by region. The calculation of the elasticity of production indicated that all input used in the production function was inelastic, meaning that a 1% increase in every input would lead to a less than 1% increase in FFB output. The elasticities indicate the same pattern across the region where the variable number of productive plants had the highest elasticity and variable pesticide had the lowest elasticities. Oil palm production by smallholder indicates an increasing return to scale in all regions, implying the farmers operate in their first stage of the classical production function.

Table 2. Estimates for the parameters of the translog stochastic frontier model by region

Variable	Sumatera		Kalimantan		Others	
Estimated Output elasticities						
Age of plants	0.2259	***	0.2163	***	0.2666	***
Productive trees	0.6961	***	0.6987	***	0.6495	***
Labor	0.1992	***	0.2441	***	0.3309	***
Chemical Fertilizer	0.0441	***	0.0885	***	0.0632	***
Pesticide	0.0014	**	-0.0003		0.0002	

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Socioeconomic Variables					
Age of farmers	-0.0623	***	0.0351		-0.0014
Education	-0.1248	**	0.0529		-0.0728
Extension services	-0.2436		-3.3494	**	-2.3202
Membership of farmer group	-1.8924	***	-1.2298	*	-2.4781
Funding sources	-1.6414	**	3.6023	**	0.3356
Management pattern	-2.9612	***	-4.2386	**	-0.6955
Intercept	-8.7648	**	-13.6175	*	-4.0987

*** p<0.01. ** p<0.05. * p<0.1.

Region-specific stochastic frontier and metafrontier parameter estimates in the TL were dropped to save space.

Available at author

The estimated elasticity of FFB output to the variable of age plants is significant in all regions, with values ranging from 0.21 to 0.27. The average oil palm plant age on Sumatera, Kalimantan and other islands were 9.4; 9.7, and 12.2 years, which had just entered the beginning of the peak production period. The labor variable had the second-highest elasticity after productive plants, except Sumatra in the third. Labor variable on oil palm production in other islands was more responsive than in two other regions. It is presumably because the number of young and mature farmers in this region was bigger than others. The positive labor coefficient is consistent with the studies of Hasnah et al. (2004) and Fariani et al. 2019).

The estimated elasticity of FFB output to the variable of fertilizers is significant in all regions The positive effect of fertilizer use on oil palm production is consistent with the results of the study of Hasnah et al. (2004), Alwarritzi et al. (2015), and Fariani et al. (2019). Furthermore, this study showed that the fertilizer variable on oil palm production in Kalimantan was more responsive than two other regions. It is proven by the greater use of fertilizer by farmers in those areas than in two others. The results also showed that pesticide use by smallholders did not significantly improve oil palm production in Kalimantan and other islands.

Technical Efficiency and Technology Gap Ratio

Table 3 showed the distribution of technical efficiency (TE), technology gap ratio (TGR), and Meta technical efficiency (MTE) of oil palm smallholders in Indonesia by region. There was enough dispersion of regional-specific TEs scores among farmers. The average technical efficiency of smallholders in Sumatera, Kalimantan and other islands were 0.6864; 0.6580; and 0.7382 respectively based on the benchmark for each frontier. It meant that to be fully efficient towards the frontier, smallholders in Sumatera, Kalimantan and other islands need to increase production by 31%; 34% and 26%, respectively, without using

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additional resources. These TEs were not comparable because they didn't account for heterogeneity production technology in oil palm smallholders.

Table 3. Mean of TEs, MTEs and TGRs across region

Statistics	Island/ Regions		
	Sumatera	Kalimantan	Others
Regional specific TEs			
Mean	0.6864	0.6580	0.7382
SD	0.1880	0.2086	0.1410
Min	0.0486	0.0598	0.1189
Max	0.9499	0.9588	0.9351
TEs with respect to Metafrontier			
Mean	0.6484	0.6093	0.5993
SD	0.1780	0.1982	0.1555
Min	0.0424	0.0554	0.0835
Max	0.9323	0.9117	0.8798
Regionl TGRs			
Mean	0.9450	0.9235	0.8077
SD	0.0256	0.0534	0.1270
Min	0.5562	0.5577	0.3365
Max	0.9904	0.9962	0.9972

The mean of technology gap ratio (TGR) scores showed that farmers in Sumatera seem to be more efficient in adopting the best available smallholder production technology than farmers in Kalimantan and other islands. The difference in mean TGRs scores among them was statistically significant at α 1 percent. It was presumably because farmers in Sumatera have adopted technology first from the Nucleus Estate and Smallholders (NES) and Perkebunan Inti Rakyat (PIR) programs which had developed by the government in the 1980s, so that the technological gap between farmers is not too large (smaller variance value) and is nearest to metafrontier. On the other hand, farmers on other islands show relatively low TGR scores, far from metafrontier and relatively have a large variance. This is presumably because the ability of farmers in other islands to absorb technology in their farming varies widely. These differences arise due to regional differences in weather conditions, agroecology, and infrastructure.

The MTEs (TEs with respect to metafrontier) scores showed that farmers in all regions were technically inefficient (MTE scores <0.70). However, oil palm farmers in Sumatra were relatively more efficient in production than farmers in Kalimantan and other islands. There was a difference in MTE between farmers in Sumatra and farmers in Kalimantan and other islands, but no differences between farmers in Kalimantan and other

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islands. The scores of TEs, TGRs, and MTEs suggested that the primary source of inefficiency comes from managerial inefficiency rather than the technology undertaken in oil palm smallholders.

Determinants of Technical Inefficiency Level

Estimates of determinants of technical inefficiency are presented in the bottom section of Table 2. Socio-economic environmental variables, i.e., farmer age, education, extension service, funding sources and management pattern, had various signs and significant effects on TEs across regions. For farmers age variables had a negative sign and significant effect on efficiency on farming in Sumatra, while other regions did not significant. It meant that older farmers in Sumatera tend to be more efficient than younger farmers.

In particular, the level of education had a negative sign and was statistically significant to improve TEs in Sumatera. In other words, with higher education, farmers will be able to improve efficiency in their farms. These results were consistent with the study by Ngango & Kim (2019), Alwarritzi et al. (2015) and Fariani et al. (2019). On the other hand, for Kalimantan and other regions, the education coefficient was not significant, so that the effect of education on the technical efficiency in these regions was not supported.

Variables of extension services and membership of farmer groups show the expected signs for all regions. The negative coefficient meant that extension service activities and membership of farmer groups would affect better farmers efficiency. The study of Onumah et al. (2013) on cocoa farmers in Ghana also proved a significant positive relationship between extension and efficiency. With the extension, farmers will get innovations in oil palm cultivation and communication links among farmers and between extension workers to improve efficiency.

Sources of financing had a significant effect on efficiency, both for farmers in Sumatra and Kalimantan. However, it comes with the opposite sign. For farmers in Sumatra, the existence of credit in their farm financing had a positive effect on on-farm efficiency. On the other hand, farmers in Kalimantan had a negative impact. The positive effect of credit on technical efficiency has been stated in previous studies (Alwarritzi et al., 2015; Onumah et al., 2013), and the negative effect of credit access on technical efficiency has been reported by Haryanto et al. (2016) on rice farmers. The negative effect was presumably because farmers need not only access but timeliness and amount of funds. Smallholders who have access to formal financial institutions with inadequate and untimely additional funds, actually burden farmers to pay principal and interest.

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Variables of management patterns show expected signs for all regions. The type of farmer had a significant effect on technical efficiency in Sumatra and Kalimantan. Supported farmers were more efficient than independent farmers. This aspect needs attention from us because 85% of farmers were independent farmers. Independent farmers adopt technology independently without any direct support and government involvement (Euler et al., 2016).

CONCLUSION

Oil palm production is a relatively heterogeneous production technology across the region. All the input variables have a positive and significant effect on FFB output, except pesticides in Kalimantan and other islands. The number of productive trees mainly determined the production level of oil palm smallholders. The study also identified some socioeconomic variables as sources of technical inefficiencies. The estimated value of TGR showed that farmers in Sumatra had adapted the best production technology in oil palm smallholder, better than farmers in Kalimantan and other islands. Concerning the technical efficiency of oil palm smallholder production in Indonesia as measured by the MTEs, farmers in Sumatra were more efficient than farmers in Kalimantan and other islands.

The metafrontier results indicate that government policies should be developed to reduce the technology gap between particular regions. The government should promote the knowledge and skills of young farmers and extension workers through training programs, internships, and dissemination of new agricultural technology.

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