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Changes of technical efficiency and total factor productivity of cocoa farming in Indonesia

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Abstract

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The decomposition of the Malmquist index shows the private category farming during the period 2012-2016 was on the frontier. This indicates that private farming categories were more efficient using inputs in Indonesia. Farming category smallholder was not efficient in using input. Malmquist total factor productivity index for 2012-2016 for farming category is > 1. This means they have experienced positive growth over the past 5 years and vary but there was no definite trend for every cocoa farm. Farming category smallholder and government each experienced the smallest and largest productivity growth. The average productivity growth of 33 provinces in Indonesia for the period 2012-2016 was 1.9% per year. The lowest and highest productivity growths of cocoa farming were 0.6% and 35% for Riau and Nusa Tenggara Barat Province. Kepulauan Riau Province did not show productivity growth whereas in Central Kalimantan Province there was the highest decrease of productivity that was equal to 16.3%. To promote productivity growth, policies should be made to improve farmers' knowledge through extension and training, as well as improving technology and research in agriculture.

Keywords: cocoa farming productivity; farming category; smallholders; Indonesia

Introduction

Increases in agricultural productivity are very important because they correlate with a decrease in poverty levels in rural areas (Sharma and Dupare, 2016). Furthermore, high agricultural productivity growth can improve the earnings of agricultural laborers. Decreased agricultural productivity can affect demand and pricing of food, create a lack of diverse job opportunities and reduce adoption of technology for smallholders. In Indonesia, the productivity of cultivated cocoa plants by smallholders continues to decrease (Ditjenbun, 2017).

Cocoa plantations have had an important role in the development of Indonesian agriculture. Cocoa contributed significantly to the Indonesian economy in foreign trade through exports of cocoa beans and the cocoa food industry and cosmetic/pharmaceutical products, as well as providing raw materials for the domestic market. In addition, this commodity was a major provider of employment for millions of Indonesians (Murjoko, 2017). Cocoa processing involves several stages that require workers for cultivation, maintenance, harvesting, processing, industrial production and marketing (Wahyudi et al., 2008).

Recently, however, cocoa exports showed a downward trend. The highest export by weight of this commodity occurred in 2012, recorded as 46 thousand tons, while the lowest occurred in 2014 with 25.4 thousand tons. In 2016, the highest export of 26.3 thousand tons and with the export value of 103 million USD was recorded (Murjoko, 2017).

The development of cocoa production in Indonesia cannot be separated from the vast development program in the 1980s, which was known as the 'Project of Rehabilitation and Export Plant Rejuvenation'. This made cocoa production rose rapidly in the 1990s (Neilson, 2009). Cocoa farms in Indonesia were generally small-scale, about two hectares or less, even outside Java (Neilson, 2009). The very high rise in cocoa prices during the economic crisis of the late 1990s benefited cocoa farmers, especially in eastern Indonesia. Cocoa production in Indonesia contributed significantly to poverty alleviation, especially in rural areas.

The productivity of cultivated cacao plants by smallholders continued to decrease because the plants were old, susceptible to increased diseases and pest infestations, and the management of land resources was variable in effectiveness (Neilson, 2009; Sudjarmoko, 2013; Effendy et al., 2013; Effendy, 2015). Increase in cultivated cocoa productivity by smallholders was needed to raise the income of smallholders and boost foreign exchange revenue. Given the importance of cocoa production in Indonesia, there were two issues that were not being addressed. First, there was no empirical study in this sector that analyzed the growth of Total Factor Productivity (TFP). Second, a substantial decrease was observed in cocoa production (2012-2016), while other plantations, such as coffee and palm oil, increased in Indonesia (Ditjenbun, 2017).

The growth of agricultural productivity cannot be separated from changes in technical efficiency (Färe et al., 1994: Coelli and Rao, 2005; Kolawole, 2009; Ogundari, 2014). The efficiency achieved refers to how well a production system is made in the use of resources to produce output (Thiam et al., 2001; Liu et al., 2015). To improve the efficiency of cocoa farming, the government advocated various policies, such as Gernas (Neilson, 2009). Several studies have also introduced various methodologies to promote efficiency (e.g. Alston et al., 2009; Jaime and Salazar, 2011; Manjunatha et al., 2013; Ndlovu et al., 2014).

Based on the above considerations, the main objective of this research was to estimate the technical efficiency (TE) of cocoa production in Indonesia based on the farming category and region using panel data for the period 2012-2016. This study used a data envelopment analysis (DEA) approach to estimate the efficiency of cocoa farming. Malmquist productivity index was used to measure total factor productivity (TFP) changes in cocoa farming in Indonesia to technical changes and efficiency changes (Coelli, 1996; Coelli et al., 2005). This estimate allows us to make comparisons between the farming category and the region in terms of its technical efficiency and help identify less technically and technically inefficient states of operation and region than others and thus have significant input saving potential to improve the living standards of small farmers.

Materials and Methods

Study area and data

This research used panel data at the provincial level, covering the period from 2012 to 2016. The data were obtained from Indonesia Plantation Statistics, which contained information about six regions (islands) consisting of 33 cocoa-producing provinces. The data of cocoa production input used in this research is labor, fertilizer, and area. Labor was measured as the number of workers employed in cocoa farming. Fertilizer was measured from the amount of chemical fertilizer used in cocoa farming. The area was defined as the area of cocoa plants that have been producing. The data in Table 1 provides a summary of area and production statistics for 6 cocoa producing regions during the period 2016.

Table 1 shows the largest cocoa-producing region was Celebes with 55% of the total land area for production yielding 59% of cocoa in Indonesia. Cocoa farming in Indonesia was mostly cultivated by smallholders, each with a land area of about two hectares or less (Neilson, 2009).

Table 1
Cocoa producing regions in Indonesia, data for 2016

Regions (islands)	Smallholder estate		Government estate		Private estate	
	Area (ha)	Production (t)	Area (ha)	Production (t)	Area (ha)	Production (t)
Sumatera	217.087	161.311	289	411	7.255	9.769
Java	30.437	17.829	11.298	11.097	6.993	6.880
Nusa Tenggara and Bali	33.039	19.086	14	7	328	240
Kalimantan	13.863	8.324	-	-	-	-
Celebes	457.518	385.601	291	166	2.847	2.466
Maluku and Papua	48.307	30.365	2.044	1.179	5.599	2.087
Total	800.251	622.516	13.936	12.860	23.022	21.442

Source: Data tree crop estate statistics of Indonesia 2017 after being processed

Method

TE is defined here as the ability of a producer to create output with a given input (Farrell, 1957; Charnes et al., 1978). This definition allows the use of DEA based on mathematical programming techniques (Berg et al., 1992; Tipi and Rehber, 2006). This approach enabled the use of non-parametric linearity estimates to calculate technical efficiency and growth of total factor productivity about cocoa production data in Indonesia.

The DEA approach had a different advantage compared with stochastic frontier analysis (Caves et al., 1982; Coelli, 1996; Coelli and Rao, 2005) since in this case it was non-parametric, required no assumption of the curvature of the frontier (production function) and did not require price data, where input costs for the agricultural commodities in Indonesia were difficult to determine and were often distorted by taxes and subsidies. DEA is a method based on linear programming for estimating a frontier that includes all input-output data from decision-making units (DMU). The resultant indicator is a measure of TE of the sampled organization. DMU observations on the frontier have a TE value = 1. If DMU was below the frontier, it is technically inefficient, in the sense that organization could reduce input-usage to produce the same level of output or could increase output with the same level of input-usage. Inefficient DMU shows a value of TE < 1.

TE values can reflect opportunities for reducing input- or expansion-output for inefficient DMU. This research used an input-oriented DEA model. The input-oriented DEA model reduces the number of inputs which used by the organization to keep the output steady. The assessment of technical efficiency and Malmquist index of cocoa farming in Indonesia used DEAP Version 2.1 (see Coelli, 1996).

The DEA based Malmquist Total Factor Productivity (TFP) index was measured by approach of Caves et al. (1982), Färe et al. (1992), Coelli and Rao (2005) and Coelli et al. (2005). To illustrated the technique, a company could change a set of inputs x = (x_1, x_2, ..., x_n) into a set of outputs q = (q_1, q_2, ..., q_m). To determine the Malmquist productivity index, a period in which production had changed from (x_t, q_t) into (x_{t+1}, q_{t+1}) was considered. The Malmquist productivity index for each period t and period t+1, would be the ratio.

$$m_t(x_t,q_t,x_{t+1},q_{t+1}) = \frac{d_t(x_{t+1},q_{t+1})}{d_t(x_t,q_t)} \tag{1}$$

$$m_{t+1}(x_t,q_t,x_{t+1},q_{t+1}) = \frac{d_{t+1}(x_{t+1},q_{t+1})}{d_{t+1}(x_t,q_t)}$$

where d_t shows the value of distance function in period t. If the technology had changed over the period, then these two indexes would be different values. Therefore, the Malmquist productivity index was defined as the geometric mean of the two indexes.

$$m(x_t,q_t,x_{t+1},q_{t+1}) = \left(\frac{d_t(x_{t+1},q_{t+1})}{d_t(x_t,q_t)} * \frac{d_{t+1}(x_{t+1},q_{t+1})}{d_{t+1}(x_t,q_t)}\right)^{0.5} \tag{2}$$

Equation (2) could be rearranged so that it was equivalent to the product of a Technical Efficiency Change index (TEC) and an index of Technical Change (TC).

$$\begin{aligned} m(x_t,q_t,x_{t+1},q_{t+1}) &= \left(\frac{d_t(x_{t+1},q_{t+1})}{d_t(x_t,q_t)} * \frac{d_{t+1}(x_{t+1},q_{t+1})}{d_{t+1}(x_t,q_t)}\right)^{0.5} \\ &= \left(\frac{d_t(x_{t+1},q_{t+1})}{d_t(x_t,q_t)} * \frac{d_{t+1}(x_{t+1},q_{t+1})}{d_{t+1}(x_t,q_t)} * \frac{d_{t+1}(x_{t+1},q_{t+1})}{d_t(x_t,q_t)} * \frac{d_t(x_t,q_t)}{d_{t+1}(x_{t+1},q_{t+1})}\right)^{0.5} \\ &= \left(\left(\frac{d_{t+1}(x_{t+1},q_{t+1})}{d_t(x_t,q_t)}\right)^2 * \frac{d_t(x_t,q_t)}{d_{t+1}(x_t,q_t)} * \frac{d_t(x_{t+1},q_{t+1})}{d_{t+1}(x_{t+1},q_{t+1})}\right)^{0.5} \\ &= \frac{d_{t+1}(x_{t+1},q_{t+1})}{d_t(x_t,q_t)} * \left(\frac{d_t(x_t,q_t)}{d_{t+1}(x_t,q_t)} * \frac{d_t(x_{t+1},q_{t+1})}{d_{t+1}(x_{t+1},q_{t+1})}\right)^{0.5} \\ &= TEC(x_t,q_t,x_{t+1},q_{t+1}) * TC(x_t,q_t,x_{t+1},q_{t+1}) \end{aligned} \tag{3}$$

TEC reflects the impact of change in efficiency, a TEC > 1 means that technical efficiency improves, and TEC < 1 means technical efficiency deteriorates. TC reflects the technical change, which could be expressed by an organization's ability to produce more (or less) with the given input level in t, associated with the desired level at t+1. TC > 1 means technical progress occurs between periods; TC < 0 means technical setbacks occurred between the two periods.

If technical efficiency change is decomposed into scale efficiency change (SEC) and pure technical efficiency change (PTEC) so that equation (3) changes into:

$$m(x_t, q_t, x_{t+1}, q_{t+1}) = SEC(x_t, q_t, x_{t+1}, q_{t+1}) * PTEC(x_t, q_t, x_{t+1}, q_{t+1}) * TC(x_t, q_t, x_{t+1}, q_{t+1}) \quad (4)$$

where

$$SEC(x_t, q_t, x_{t+1}, q_{t+1}) = \frac{d_t^v(x_t, q_t)}{d_t^c(x_t, q_t)} * \frac{d_{t+1}^c(x_{t+1}, q_{t+1})}{d_{t+1}^v(x_{t+1}, q_{t+1})} \quad (5)$$

$$PTEC(x_t, q_t, x_{t+1}, q_{t+1}) = \frac{d_t^v(x_{t+1}, q_{t+1})}{d_{t+1}^v(x_t, q_t)} \quad (6)$$

Note that the extra superscripts, v, and c, relate to the variable returns to scale (VRS) and constant returns to scale (CRS) technologies, respectively.

Results and Discussion

Changes in cocoa farming technical efficiency in Indonesia

The input-oriented technical efficiency based on the CRS and VRS as well as scale efficiency are shown in Figure 1. In 2012–2016, the mean TE of the cocoa farming in Indonesia is 0.584 and 0.641 with the CRS and VRS assumptions, respectively. This means that cocoa farming in Indonesia could reduce production input by 41.6% (35.9%) and keep the same level of output. The average scale of cocoa farming efficiency in Indonesia was 0.743, meant that on average the optimum size has not been reached, they had to adapt themselves to their land operations to an optimum scale.

Figure 1 presents the technical efficiency and scale efficiency of cocoa farming in Indonesia during the 5 years period. In 2012 to 2016, the technical efficiency and scale efficiency of cocoa farming in Indonesia have not been shown the same trend. There was a tendency for TE movements to fluctuate for government and private category categorization and very low for categorical people farming with the assumption of CRS. In 2012 to 2014 the cocoa farming category private category assumed CRS was in frontier and in 2015 to 2016 cacao farming category of government residing in the frontier. Scale efficiency for category 'smallholder' and 'government' presented a downward trend in 2014 and was constant in 2015 to 2016. In 2012 to 2014 the scale efficiency of category 'private' was stable and declining in 2015.

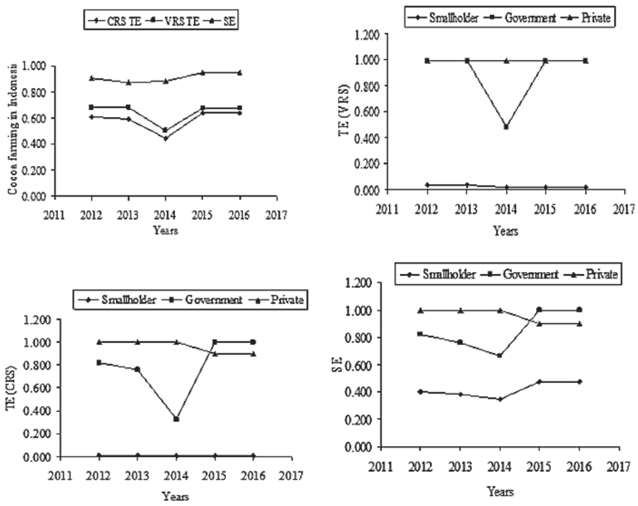

Fig. 1. Technical efficiency (TE) and scale efficiency (SE) of cocoa farming in Indonesia

Source: Data of 2017 cacao plantation after being processed with DEAP 2.1.

On the assumption of VRS, there was one farming category in the frontier (with TE value = 1). The farming category 'Private', during the period of 2012-2016 was at the frontier. The farming category 'Government' in 2014 was not at the frontier, but for the other year was in the frontier. It shows that the farming categories 'Private' and 'Government' were more efficient in maximizing their inputs in Indonesia. The farming category 'Smallholder' had the lowest TE value (0.03): means they were less efficient in maximizing their inputs, because their cocoa plants were old, the cocoa beans were not superior in quality, disease and pest attacks could not be controlled by smallholders, and the management of land resources that were less appropriate (Neilson, 2009; Sudjarmoko, 2013; Effendy et al., 2013; Effendy, 2015).

The average input oriented TE of the farming category was 0.641; which indicates that the average farming category in Indonesia TE was at 64.1%. This can be interpreted that the cocoa farming in Indonesia should reduce the use of inputs by 35.9%.

Decomposition of the Malmquist index by period and cocoa farming category

Based on equation (3) the Malmquist productivity index was decomposed into technical efficiency change

Table 2

TFP change decomposition by period and farming category in Indonesia

Period	TEC	TE	PTEC	SEC	TFPC
2012–2013	0.987	0.995	1.039	0.950	0.982
2013–2014	0.578	2.253	0.632	0.915	1.302
2014–2015	1.622	0.753	1.282	1.265	1.222
2015–2016	1.000	0.903	1.000	1.000	0.903
Farming category	TEC	TE	PTEC	SEC	TFPC
Smallholder	0.922	1.111	0.878	1.050	1.025
Government	1.050	1.111	1.000	1.050	1.167
Private	0.974	1.111	1.000	0.974	1.082

Source: Data of 2017 cacao plantation after being processed with DEAP 2.1.

index (TEC) and an index of technical change (TC). To identify the scale efficiency change, technical efficiency change is decomposed into scale efficiency change (SEC) and pure technical efficiency change (PTEC). Malmquist total factor productivity (TFP) index and the other index for period 2012 to 2016 is reported in Table 2.

Table 2 shows that the largest average productivity growth (TFPC) was 16.7% in the category 'government' and the lowest was 2.5% in the category 'smallholder'. Higher productivity growth rates reflected higher growth rates in output and lower usage of input (Liu et al., 2015; Rodríguez and Elasraag, 2015).

Average TEC increased 5% for category 'government', and category 'smallholder' and private decreased by 2.7% and 2.6% respectively. This indicates the spread of technology in Indonesia was not evenly distributed. The growth of TFP in the category 'government' was due to growth in technical efficiency.

Table 2 shows the Malmquist Total Factor Productivity (TFP) index for the period 2012 to 2016 fluctuated, period 2012 to 2013 and 2015 to 2016 declined 1.8% and 9.7% respectively, while period 2013 to 2014 and 2014 to 2015 improved 30.2% and 22.2% respectively. It means they experienced growth over the past five years, although not linear growth. There was no definite trend for any farming category. Agricultural production depends on many uncertainties including weather and market value (Ali and Klein, 2014).

Decomposition of the Malmquist index by period and province

The decomposition of the Malmquist index by period and province are reported in Table 3.

Table 3 shows changes in productivity and its components over time. During the analysis period, TFP changes and its components varied. This was caused by the variation in output and input was also high. Changes in productivity and its components show a clear trend, except for constant TE components but in the last year, TFPC declined. The average TFPC of the total sample for the 2012-2016 was 1.9% per year.

Table 3 also shows the decomposition of TFP changes by the province in Indonesia. The lowest and highest productivity growth rates (TFPC) in cocoa farming were 0.6% and 35% for Riau and Nusa Tenggara Barat Province. Kepulauan Riau Province did not occur productivity growth (TFPC = 1), in Central Kalimantan Province there was the highest decrease of productivity (TFPC) which was 16.3%. Higher levels of productivity growth (TFPC) reflected higher growth rates in output and lower growth rates in input use (Liu et al., 2015). The average technical efficiency change (TEC) is 1.9%, but there was no technical change (TE = 1) across the entire Indonesian province. The lowest and highest technical efficiency (TEC) growth rates for cocoa farming were 0.6% and 35% for Riau and Nusa Tenggara Barat respectively. Kepulauan Riau Province did not experience technical efficiency growth (TEC = 1), in Central Kalimantan Province there was the highest decrease of technical efficiency (TEC) which was 16.3%. The average productivity growth (TFPC) and efficiency (TEC) of cocoa farming in Indonesia were the same, due to technical changes (TE = 1) in all Indonesian provinces. The increase in total factor productivity in Indonesian cocoa production comes from improvements in TE. But the growth rate of TE was small, this was partly due to the decrease in SE (Liu et al., 2015). Pure technical efficiency for five periods was not growing (PTEC = 1), indicating that policies should be applied to improve farmers' knowledge through extension and training in agriculture (Effendy et al., 2013; Effendy, 2015), and improving agricultural technology and research in Indonesia (Liu et al., 2015).

Table 3
Total factor productivity change and decompositions for periods and provinces in Indonesia

Period	TEC	TE	PTEC	SEC	TFPC
2012–2013	1.028	1.000	0.997	1.032	1.028
2013–2014	1.039	1.000	1.007	1.031	1.039
2014–2015	1.055	1.000	0.981	1.076	1.055
2015–2016	0.958	1.000	1.017	0.942	0.958
Province	TEC	TE	PTEC	SEC	TFPC
Aceh	0.888	1.000	1.000	0.888	0.888
North Sumatera	1.172	1.000	1.000	1.172	1.172
West Sumatera	0.909	1.000	1.000	0.909	0.909
Riau	1.006	1.000	0.989	1.017	1.006
Kepulauan Riau	1.000	1.000	1.000	1.000	1.000
Jambi	0.971	1.000	0.996	0.975	0.971
South Sumatera	0.947	1.000	0.974	0.972	0.947
Kep. Bangka Belitung	0.975	1.000	0.999	0.976	0.975
Bengkulu	0.965	1.000	0.998	0.967	0.965
Lampung	0.875	1.000	1.000	0.875	0.875
West Java	1.007	1.000	0.992	1.016	1.007
Banten	1.323	1.000	1.047	1.264	1.323
Central Java	1.029	1.000	0.998	1.031	1.029
D.I. Yogjakarta	0.998	1.000	0.995	1.003	0.998
East Java	0.995	1.000	1.000	0.995	0.995
Bali	0.984	1.000	0.990	0.994	0.984
Nusa Tenggara Barat	1.350	1.000	1.025	1.318	1.350
Nusa Tenggara Timur	0.937	1.000	1.000	0.937	0.937
West Kalimantan	1.017	1.000	0.995	1.022	1.017
Central Kalimantan	0.837	1.000	0.992	0.845	0.837
South Kalimantan	1.013	1.000	1.000	1.013	1.013
East Kalimantan	1.134	1.000	1.024	1.107	1.134
North Kalimantan	1.055	1.000	1.005	1.050	1.055
North Celebes	0.967	1.000	0.992	0.975	0.967
Gorontalo	1.060	1.000	1.006	1.053	1.060
Central Celebes	1.051	1.000	1.000	1.051	1.051
South Celebes	1.090	1.000	1.000	1.090	1.090
West Celebes	1.072	1.000	1.000	1.072	1.072
Southeast Celebes	1.051	1.000	1.000	1.051	1.051
Maluku	1.039	1.000	1.000	1.039	1.039
North Maluku	1.028	1.000	1.000	1.028	1.028
Papua	1.014	1.000	1.000	1.014	1.014
West Papua	1.040	1.000	1.000	1.040	1.040

Conclusions

The farming category 'Private' during the period of 2012-2016 was in frontier (with TE value = 1). The farming category 'Government' in 2014 was not in the frontier, but for the other years, it was. It shows that the farming categories 'Private' and 'Government' were more efficient at using input in Indonesia. The farming category 'Smallholder' had the lowest TE value (0.027), owing to the fact that the cocoa plants were old, the cocoa beans were inferior to others, disease and pests could not be easily controlled by smallholders, and the land management activities were less effective. The overall average of input-oriented TE from the cocoa farming was 0.641; which indicates that the TE average of the farming category in Indonesia was at 64%. It could be interpreted that the cocoa farming in Indonesia could reduce the usage of input by 36% provided that all cocoa farms in Indonesia operated efficiently. Based on technical efficiency values input oriented on the assumption of VRS shows that there is an opportunity to improve the technical efficiency of cocoa farming in Indonesia. One of the ways of doing this is to focus on replacing old plants by using high potential superior seeds resistant to pests and diseases. Besides using the superior seeds, land management practices need to be modified to maximize the usage of input efficiently. The largest average productivity growth (TFPC) was 16.7% in the category 'government' and the lowest was 2.5% in the category 'smallholder'. Higher productivity growth rates reflected higher growth rates in output and lower usage of input. Average TEC increased 5% for category 'government', and category 'smallholder' and private decreased by 2.7% and 2.6% respectively. This indicates the spread of technology in Indonesia was not evenly distributed. The growth of TFP in the category 'government' was due to growth in technical efficiency. The Malmquist Total Factor Productivity (TFP) index for the period 2012 to 2016 fluctuated, 2012 to 2013 and 2015 to 2016 declined 1.8% and 9.7% respectively, while period 2013 to 2014 and 2014 to 2015 improved 30.2% and 22.2% respectively. It means they experienced growth over the past five years, although not linear growth. There was no definite trend for any farming category. Agricultural production depends on many uncertainties including weather and market value.

The decomposition of Malmquist index indicated that the average TFPC of 33 provinces in Indonesia for the period 2012-2016 was 1.9% per year. The lowest and highest productivity growth (TFPC) of cocoa farming was 0.6% and 35% for Riau and Nusa Tenggara Barat Province. Kepulauan Riau Province did not occur productivity growth (TFPC = 1), in Central Kalimantan Province there was the highest decrease of productivity (TFPC) which was 16.3%. Higher levels of productivity growth (TFPC) reflected higher growth rates in output and lower growth rates in input use. Pure technical efficiency for five periods was not growing (PTEC = 1), indicating that policies should be applied to improve farmers' knowledge through extension and training in agriculture and improving agricultural technology and research in Indonesia.

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