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Factors affecting variation of total factor productivity in cocoa farming in the Central Sulawesi, Indonesia

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Abstract

One of the main cocoa producing areas in Indonesia is the Central Sulawesi region. Cocoa farmers have been given extension and training about agricultural technology such as pruning, fertilizing and side grafting. Nevertheless, the cocoa productivity is still low. This case has been questioned by authorities; so this research aims to measure and analyze the factors that have affected the variation of total factor productivity (TFP) in cocoa farming in the Central Sulawesi. The study selected a total of 424 cocoa farmers using a simple random sampling technique. The model of stochastic frontier function of translog forms was used to anticipate factors affecting cocoa production. The Cobb-Douglas production function was used in TFP variation. The results showed that TFP of cocoa farming varied from a minimum of 0.371 to a maximum of 1.407 with an average of 0.803. Technical efficiency, education, extension access, cocoa farming experience, sanitation, and fermented cocoa beans affected TFP variation significantly. These six factors appeared to be the main determinant factors of TFP variation. However, technical efficiency was the most important factor, so policies should aim at mobilizing resources toward expanding education and extension. In addition, extension services should provide information to cocoa farmers on using inputs efficiently.

Keywords: Education, extension services, technical efficiency, translog model.
Abbreviations: D_dummy variable of fermentation status; EA_extension access; ED_education; FE_farming experience; HH_household heads; MLE_maximum-likelihood estimates; OLS_ordinary least squares; SN_sanitation; TE_technical efficiency; TFP_total factor productivity; TTI_törnqvist-theil index.

Introduction

Cocoa is one of the plantation commodities that is quite important for the Indonesian economy, especially as a provider of employment, source of income and in its role as a resource for foreign exchange (Departemen Perindustrian, 2007; Sudjarmoko, 2013; Effendy, 2015a). Cocoa development in Indonesia is inseparable from the various problems encountered in the upstream sectors, including low plant productivity and pest and disease attacks (Effendy, et al., 2013a; Sudjarmoko, 2013; Effendy, 2015a).

Cocoa productivity remains low by several factors. The price of cocoa is determined by the international market, total cocoa production, higher input prices, pests and plant diseases, and age of old cocoa plant (Effendy, 2015a). Given the importance of cocoa production in Indonesia, there are two important issues to highlight. First, there has been no empirical study that analyzes the factors affecting the cocoa industry's total productivity factor (TFP). Second, a substantial decrease has occurred in cocoa production from 772,771 tons in 2010 to 641,997 tons in 2015 (Ditjenbun, 2015).

Several studies have been conducted on cocoa in Indonesia (Wahyudi and Misnawi, 2007; Effendy et al., 2013b; Rinaldi et al., 2013; Sudjarmoko, 2013; Effendy, 2015b), but none have illustrated the productivity growth. Productivity is an important determinant of competitiveness evolution. Competitiveness is one of the main factors that determines the increase in product demand, leading to increased likelihood of production.

One of the main cocoa producing areas in Indonesia is the Central Sulawesi Region. Cocoa productivity in Central Sulawesi is still low (0.88 t ha^{-1}), compared with common genetic potential of plant, which usually reaches 1.8 to 2.75 tones ha^{-1} (DPDJP, 2009; Ditjenbun, 2015). Cocoa farmers in Central Sulawesi have been given extension and training about agricultural technology such as pruning, fertilizing and side grafting, but in many cases the productivities of cocoa plant have remained low. Effendy et al. (2013b) and Rinaldi et al. (2013) have shown the technical efficiency of cocoa farming ranges from 0.3 to 0.9, meaning there is still inefficiency in cocoa farming. If there is inefficiency, it is necessary to consider its effect on productivity growth (Rodríguez and Elasraag, 2015).

Given the above considerations, the main objective of this research is to conduct a TFP analysis in cocoa production in the Central Sulawesi Region and investigate the factors that have affected TFP variation. Many researches have analyzed TFP variation using time series data (Hossain et al., 2012; Ali and Klein, 2014; Fathabad and Danaeifar, 2015; Cechura et al., 2015; Rodríguez and Elasraag, 2015), but this research used cross-sectional data to analyze the TFP variation at the farmer level in Indonesia. For researches using cross-sectional data, sample data can be randomly selected and can be repeated to obtain a reasonable one (Hayashi, 2000).

Results and Discussion

Description of research variables

Description of research variables in the research area is presented in Table 1.

The average cocoa land area was 1.6 ha farm^{-1} with an average output of 1,591 kg. The main factors in cocoa farming were land area, chemical fertilizer, labor, and pesticide. Education shows that the literacy level of farmers in the research area is still low. The average number of access to the agricultural extension outreach, which followed by the farm manager was less than 5 times (60%). The average amount of farming experience in the research area was 12 years, so people involved in cocoa production were experienced in their field. Cocoa farm managers conducted sanitation work an average of 3 times in a year, so farmers were not clearing the cocoa garden enough. Percentage of farmers who fermented cocoa beans was less than 30%.

Estimated result of production function of cocoa farming

The maximum-likelihood estimates (MLE) (Parameter maximum-likelihood) of the parameters in the model of translog stochastic frontier production function (equation 1) obtained using Frontier 4.1 (Coelli, 1994) (Table 2).

The adjusted R-squared (0.86) is estimated from the ordinary least squares (OLS), which is used as the starting value for MLE. These variables explain 86% of the total cocoa production variance. 11 coefficients out of 15 differed significantly at α= 10%, demonstrating the importance of some interaction and non-linearity between variables (Coelli et al., 2003).

All four direct effects, two squared terms, and four cross products have coefficients significantly at α= 10%, showing that cocoa farming in the Central Sulawesi has a nonlinear function in several dimensions. Moreover, there was important interaction between variables.

The four inputs, such as land, labor, fertilizer and pesticide, appear to be the main determinant factor of cocoa farming. However, fertilizer is the most important input with 0.456 output elasticity, followed by pesticide at 0.138 and labor at 0.104. The land had the lowest output elasticity level (0.024) at α= 5%. The indicator of returns to scale is the sum of the coefficients on the four inputs, which was 0.72. This number indicates that cocoa farming has decreasing return, whereas increasing fertilizer dose may decline production in the Central Sulawesi.

The gamma value of statistical diagnosis was significant at α= 1%. This simple statistical test further reinforced the assumption that there was a technical inefficiency of cocoa farming in the Central Sulawesi. This estimate was in accordance with previous work (Lambarraa et al., 2007).

The relation of technical inefficiency and total factor productivity (TFP)

The inefficiency data were calculated using the formula 1-TE and TE obtained from equation (2). The variation of TFP at the farmer level is based on the technical inefficiency level of cocoa farming in the Central Sulawesi (Fig 1).

Figure 1 shows the higher technical inefficiency of cocoa farming, causing lower TFP. The inefficiency ranged from 0.018 – 0.568, indicating that farmers higher technical efficiency may enhance cocoa productivity in the Central Sulawesi. The technical efficiency of cocoa farming at the farmer level varied from a minimum level of 0.432 to a maximum 0.982 with an average of 0.857.

The situation could be improved via efficiently using the production inputs in Equation 1, namely: land, labor, fertilizer, and pesticide. Table 1 shows cocoa farming is in the condition of decreasing returns (production elasticity = 0.72), so improving the inputs would increase the production of cocoa.

In this research, the total factor productivity (TFP) was calculated based on the Törnqvist-Theil index (TTI) form with the stochastic frontier function model of translog to determine the production change from input adjustment (Cechura et al., 2015). TFP cocoa farming at the farmer's level varied from a minimum level of 0.371 to a maximum level of 1.407 with an average of 0.803.

The factors that affect TFP variation in cocoa farming

Table 3 presents the results of multiple Cobb-Douglas model regressions against factors affecting TFP variation.

The TFP model is significant at α= 1% with the adjusted R squared value of 0.721. These variables explain 72.1% variance. TE, ED, EA, FE, SN, and D significantly affected TFP variation at α= 20%. These six factors were the most determinant of TFP variation, but TE was the most important factor with an output elasticity of 0.802 followed by D at 0.183 and significance at α= 1%. The EA had the lowest level of output elasticity (0.008) and significance at α= 20%. TE was statistically significant at α= 1% and had a positive relation with TFP variation. When TE increased, TFP was also increased. In this way, TE was a significant growth source in cocoa farming in the Central Sulawesi. TE variation could be accelerated by education, extension access, and farming experience (Effendy et al., 2013b; Rinaldi et al., 2013).

The ED, EA, FE, and SN were statistically significant at α= 20% and had a positive relation with TFP variation. All four variables increased when TFP was increased.So, it is clear that they are a significant growth source in cocoa farming in the Central Sulawesi. The ED, EA, FE, and SN may likewise affect the technical inefficiency of cocoa farming, influencing productivity growth (Effendy et al., 2013b; Rinaldi et al., 2013; Rodríguez and Elasraag, 2015).

The D was statistically significant at α= 1% and had positive relations with the TFP variation. In other words, farmers who fermented their cocoa beans generated a higher TFP. The process increased their competitiveness in the international market, so the price received by farmers also increased, improving their purchasing power against production input and boosting productivity growth.

Table 1. Descriptive statistics of research variables.

Variable	Units	Mean	Std. Deviation
Output (Y)	kg farm^{-1}	1,590.53	718.44
Land (X_1)	ha farm^{-1}	1.63	0.56
Labor (X_2)	man-days farm^{-1}	206.79	93.67
Chemical fertilizer (X_3)	kg farm^{-1}	890.33	355.21
Pesticide (X_4)	litre farm^{-1}	8.96	4.16
Total factor productivity (TFP)	number	0.80	0.173
Technical efficiency (ET)	number	0.86	0.120
Education (ED)	Likert scale	2.85	1.111
Extension access (EA)	number	4.40	1.981
Farming experience (FE)	year	11.66	6.512
Sanitation (SN)	number	3.41	3.33
Fermentation (D)	dummy	0.297	0.458

Source: processed from survey research data, 2016.

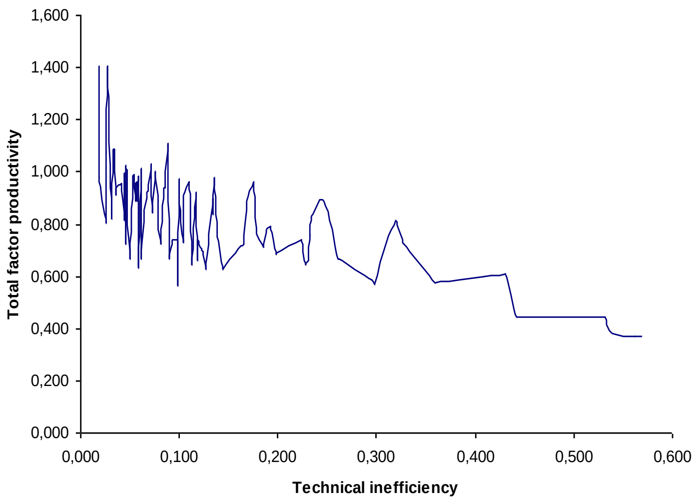

Fig 1. The change of total factor productivity at the cocoa farmer level.

Table 2. Estimation of stochastic production frontier for cocoa farming in the Central Sulawesi.

Variable	Translog Model	
	Coefficient	t-ratio (p)
Production Function		
Constant	7.508	460.048***
ln Land	0.024	2.093**
ln Labor	0.104	12.748***
ln Fertilizer	0.456	55.143***
ln Pesticide	0.138	16.519***
(ln Land)^2	-0.001	-0.148
(ln labor)^2	-0.037	-4.394***
(ln Fertilizer)^2	0.015	1.551
(ln Pesticide)^2	-0.042	-5.810***
ln Land*ln Labor	0.004	0.272
ln Land*ln Fertilizer	-0.007	-0.535
ln Land*ln Pesticide	-0.016	-1.730*
ln Labor*ln Fertilizer	-0.035	-3.364***
ln Labor*ln Pesticide	0.015	1.792*
ln Fertilizer*ln Pesticide	-0.023	-2.032**
Diagnosis statistics		
sigma-squared	0.221	6.238***
gamma	0.985	192.872***
mu	-0.933	-5.319***
log likelihood function	214.223	
LR test of the one-sided error	161.423	
Adjusted R^2 from OLS	0.860	

Note: *** Significant at α 1% ($p < 0.01$), **Significant at α 5% ($p < 0.05$), *Significant at α 10% ($p < 0.10$).

Table 3. Estimation parameter of total factor productivity variation in cocoa farming with OLS method.

Model	Coefficients	t ratio	Sig. (p)
Constant	-0.185		
Ln TE	0.802****	21.011	0.000
Ln ED	0.019***	2.392	0.017
Ln EA	0.008*	1.309	0.191
Ln FE	0.021**	2.593	0.010
Ln SN	0.013**	1.566	0.118
D	0.183****	13.325	0.000
Sum of elasticities	1.046		
Adjusted R Square	0.721		

Note: OLS = Ordinary Least Squares; **** Significant at α 1% ($p < 0.01$); *** Significant at α 5% ($p < 0.05$); ** Significant at α 15% ($p < 0.15$); * Significant at α 20% ($p < 0.20$).

Table 4. Smallholder plantation area in Indonesia in 2014.

No.	Region	Area		Production (ton)
		ha	% to National	
1	**Sulawesi (Celebes)**	**975,821**	**59.61**	**456,965**
2	Sumatera	400,038	24.44	125,176
3	Java	58,433	3.57	13,928
4	NTT + NTB + Bali	70,075	4.28	15,639
5	Kalimantan (Borneo)	35,012	2.14	8,797
6	Maluku + Papua	97,498	5.96	31,113
	Total	1,636,877	100.00	651,618

Source: Ditjenbun (2015).

Table 5. Smallholder plantation area in Sulawesi Region in 2014.

Province in Sulawesi	Area (ha)	Production (ton)
North Sulawesi	16,628	3,676
Gorontalo	13,146	3,768
Central Sulawesi	**282,321**	**146,844**
South Sulawesi	247,436	114,868
West Sulawesi	172,258	70,125
Southeast Sulawesi	244,032	117,684
Total	975,821	456,965

Source: Ditjenbun (2015).

Table 6. Research areas and their characteristics.

District	Villages	Sample size (HH)
Donggala	Watatu Salumpaku	87
Poso	Lape Kilo	95
Sigi	Sejahtera Tongoa	144
ParigiMoutong	Kotaraya KayuAgung	98
Total		424

Note: HH = Household Heads.

Materials and Methods

Study areas and sampling methods

The research was conducted in the Central Sulawesi, within the central area of Cocoa production in Indonesia (Table 4 and Table 5). The data was sourced from the Directorate General of Plantation in 2015 (Ditjenbun, 2015).

The Central Sulawesi is located between 2^0 22' North Latitude and 3^0 48' South Latitude and between 119^0 22'−124^0 22' East Longitude. Throughout 2015, the lowest average air temperature was 27.10^0C, occurred in February, while the highest was 29.50^0C in October and December. This study chose four districts randomly with two villages in to be randomly surveyed (Table 6). In this research, 424 samples were randomly taken from cocoa farmers. The production input data, production input prices, total output, cocoa beans price at farmer level, and information about characteristics of cocoa farmers' households were collected from survey during January to April 2016.

Data and empirical models

This research examined cross-sectional data obtained from the survey of 424 cocoa farmers in the Central Sulawesi

Region of Indonesia. This data helped to measure the TFP variation at the cocoa farmer level.

The TFP was calculated based on the Törnqvist-Theil index (TTI) (Coelli et al., 2005). The TTI determines the production changes resulting from adjusting inputs if a function has a translog form (Cechura et al., 2015).

Function model of stochastic frontier in the translog form in this research are:

$$Y_i = \beta_0 + \sum_{j=1}^{4} \beta_j X_{ji} + \sum_{j=1}^{4}\sum_{k=1}^{4} \beta_j X_{ji} X_{ki} + V_i - U_i \quad (1)$$

Y = dependent variable,
β_0 = constant,
β_1- β_4 = coefficient independent variable,
X_1-X_4 = independent variable,
V_i = random error models,
U_i = random variable that represents the technical inefficiency sample i.

Dependent and independent variables are defined as follows:

Y = cocoa output,
X_1 = land,
X_2 = labor,
X_3 = fertilizer,
X_4 = pesticides.

Land indicates the area that farmers are using for cocoa plantation. Labor represents the total laborers required in cocoa farming. Fertilizer indicates the total amount of fertilizers used by farmers, while Pesticide is the total amount of pesticides used by farmers to control pests and plant diseases likely to affect cacao plants.

The Cobb-Douglas production function used to analyze TFP variation in this research. TFP was extracted from cocoa farming in the following pattern:

$LnTFP = \alpha_0 + \alpha_1 LnTE + \alpha_2 LnED + \alpha_3 LnEA + \alpha_4 LnFE + \alpha_5 LnSN + \alpha_6 D$ (2)

Technical efficiency (TE) was measured by equation (1). Education (ED), extension access (EA), farming experience (FE), and sanitation (SN) were included in the model according to Rinaldi et al. (2013) and Effendy et al. (2013b). They showed four variables affected the technical inefficiency of cocoa farming. The ED represents the education level of the household head of cocoa farming, while EA represents the frequency of following the agricultural extension received by the household head. The FE represents the length of time that household head spent in cocoa farming, and SN represented the frequency of doing maintenance work on the crop of cocoa trees. Moreover, the model employs a dummy variable of fermentation status (D) where farmers did fermentation on cocoa beans were given a value of 1 and who did not be given 0.

Conclusion

TFP cocoa farming at the farmer level varied with an average of 0.803. The land, labor, fertilizer, and pesticide were the main determinants in the cocoa productivity; however, fertilizer became the most important input. All of four inputs were in decreasing return condition, so improving input doses would decline production in the Central Sulawesi. Technical efficiency, education, extension access, farming experience, sanitation, and fermentation status significantly affected TFP variation; however, technical efficiency became the most important. Extension access had the lowest output elasticity level.

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References

Ali MK, Klein KK (2014) Water use efficiency and productivity of the irrigation districts in Southern Alberta. Water Resour Manage. 28: 2751–2766.

Cechura L, Kroupova Z, Rudinskaya T (2015) Factors determining TFP changes in Czech agriculture. Agric Econ – Czech. 61 (12): 543–551.

Coelli TJ (1994) Frontier Version 4.1: A Computer program for stochastic frontier production and cost function estimation. Department of Econometrics, University of New England, NSW.

Coelli TJ, Rahman S, Thirtle C (2003) A stochastic frontier approach to total factor producttvity measurement in Bangladesh crop agricuifure, 196I-92. J Int Dev. 15: 321--333

Coelli TJ, Rao DSP, O'Donnell CJ, Battese GE (2005) An introduction to efficiency and productivity analysis. (2nd ed.) New York, Springer.

Departemen Perindustrian (2007) Gambaran sekilas industri kakao. https://www.google.co.id/?gws_rd=ssl#q=Asosiasi+Kakao+Indonesia+(2005).+Prospek+Agroindustri+Kakao+Indonesia+di+Pasaran+Dunia+Sampai+Dengan+2010.

Ditjenbun (2015) Tree crop estate statistics of Indonesia 2013 – 2015 cocoa. Directorate General of Estate Crops Jakarta.

DPDJP (2009) Buku panduan teknis budidaya tanaman kakao (Theobroma cacao L.). Gerakan peningkatan produksi dan mutu kakao nasional (Gernas), Departemen Pertanian Direktorat Jenderal Perkebunan (DPDJP), Jakarta.

Effendy (2015a) Increasing of cocoa farmers household income with two stage least squares method. Mod Appl Sci. 9 (6):120 – 127.

Effendy (2015b) Application of side-grafting technology to increase cocoa productivity: case study in Sigi Regency-Indonesia. J Appl Sci. 15 (4): 715 – 718.

Effendy, Hanani N, Setiawan B, Muhaimin AW (2013a) Effect characteristics of farmers on the level of technology adoption side-grafting in cocoa farming at Sigi Regency-Indonesia. J Agri Sci. 5 (12): 154 – 160.

Effendy, Hanani N, Setiawan B, Muhaimin AW (2013b) Characteristics of farmers and technical efficiency in cocoa farming at Sigi Regency-Indonesia with approach stochastic frontier production function. J Econ Sust Develop. 4(14): 72 – 77.

Fathabad HM, Danaeifar I (2015) The granted effects of agricultural bank credits on total factor productivity in agriculture production. Europ Online J Nat Soc Sci. 4 (1): 1085-1096.

Hayashi F (2000) Econometrics. Published by Princeton University Press 41 William Street, Princeton, New Jersey 08540.

Hossain MK, Kamil AAA, Baten MA, Mustafa A (2012) Stochastic frontier approach and data envelopment analysis to total factor productivity and efficiency measurement of Bangladeshi rice. PLoS ONE. 7(10): 1-9.

Lambarraa F, Serra T, Gil JM (2007) Technical efficiency analysis and decomposition of productivity growth of Spanish olive farms. Span J Agri Res. 5 (3): 259–270.

Rinaldi J, Fariyanti A, Jahroh S (2013) Fermented cocoa production efficiency on small-scale through stochastic frontier approach in Bali. Bul Ristri. 4 (1): 79-88.

Rodríguez XA, Elasraag YH (2015) Assessing the total factor productivity of cotton production in Egypt. PLoS ONE. 10(1): 1-14.

Sudjarmoko B (2013) State of the art Indonesian cocoa industrialization. Sirinov. 1 (1): 31 – 42.

Wahyudi T, Misnawi (2007) Facilitating the quality and productivity improvements of Indonesian cocoa. Warta Pusat Penelitian Kopi dan Kakao Indonesia. 23 (1): 32-43.