Technical efficiency and corn farming productivity: a stochastic frontier analysis of small-scale farmer in Indonesia

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Abstract. Corn is one of the strategic agricultural commodities in Indonesia. West Java is one of the corn production centres in Indonesia and the province with the highest corn productivity nationally. The high productivity of corn farming in West Java is interesting for further study. This paper examines factors affect corn production and how far is the level of efficiency in the use of input in corn production of small-scale farmers in West Java. The study employed a quantitative approach and a cross-sectional survey. The Cobb–Douglas production function and trans-log function were used in estimating the productivity of input, while the technical efficiency was analyse using Stochastic Production Frontier. The results show that land and seed were the most influential factors on corn production. The estimation result from Stochastic Frontier Model showed that variable of land, seed, hired labour and family member, statistically significant impact on technical efficiency of corn production. Moreover, the estimated average technical efficiency of corn farming was approximately 72% with more than 70% of corn farmer had efficiency above 60%.

1 Introduction

Corn is one of the strategic agricultural commodities in Indonesia. Corn has been known for a long time by Indonesia citizen as one of staple food. Apart from being consumed as food, corn is also consumed as an ingredient in animal feed products.

Data from the Indonesian Ministry of Agriculture states that the annual corn demand for food consumption, animal feed and the food industry in average is 14.37 million tons with annual consumption growth of 5.68% [1]. On the production side, corn production growth in Indonesia continues to increase. Recent study shows that since 1993-2018 corn production has increased with an average growth of 6.82% [2].

Figure 1 shows trend in corn production in Indonesia in the last decade, since 2010 to 2020 based on a report by Food and Agriculture Organization (FAO). In general, there is an

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increasing trend in corn production during 2010 to 2020 with the highest production in 2018 with more than 30 million ton. However, there is a declining production in 2019 for more than 20%. This decreasing in production continues slightly in 2020 with the total production of 22.5 million ton in 2020 [3]. Decreasing trend in production in the last two years from 2019 to 2020 needs to be taken seriously so that solutions can be found to increase production in the future.

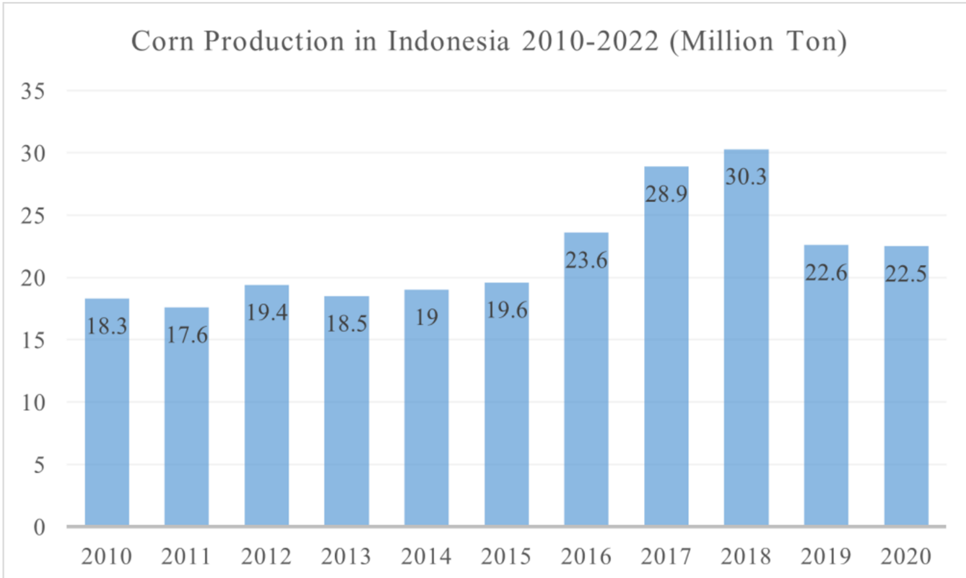

Fig. 1. Corn Production in Indonesia (2010-2020)
Source: FAO [3] compiled by authors

The downward trend in corn production is indeed an important matter. This is because the domestic corn supply has not been able to meet the demand for the Indonesian food industry, so it is still imported. Local corn supply for the food industry in Indonesia has only reached 700 thousand tons per year. Meanwhile, the demand of corn for food industry in Indonesia is expected to reach 1.2 million tons in 2021. This trend is expected to increase to 1.6 million tons in 2022, in line with the start of operations for several new corn starch industries [4]. There are several ways that can be done to increase corn production in Indonesia, one of which is by increasing corn productivity by implementing efficient use of production inputs. In addition, increasing production efficiency can also be done by conducting training to farmers on good agriculture practice.

West Java Province is one of the corn production center in Indonesia with a harvested area of 206,700 hectares produces 1.34 million tons of corn in 2020 [5]. Moreover, according to a report by Statistics Indonesia, corn productivity in Indonesia is 54.74 quintals per hectare (ku/ha) in 2020 and West Java is the province with the highest corn productivity nationally with 69.97 ku/ha [6].

The high productivity of corn farming in West Java is interesting for further study. This is important since in general, farmers pay less attention to the use of factors of production properly, so that on the one hand there are those who are lacking in providing production inputs, and on the other hand many farmers exceed what is needed so that they are not efficient in using their factors of production [7]. Maintaining high productivity of corn is important aspect to increase production and reduce dependence from imported product.

Previous study show that variable of land, seed, fertilizer and training influence the technical efficiency of corn production [8] [9].

The research question of this study is what factors affect corn production and how far is the level of efficiency in the use of input in corn production of small-scale farmers in West Java? As the highest productivity region in producing corn, understanding factors that affect the efficiency of the use of corn production factors is interesting. Therefore, this study aims to examine factors affect corn production and how far is the level of efficiency in the use of input of production in corn production on small-scale farmers.

2 Methodology

This study investigates factor affecting the production and technical efficiency of corn, case of small-scale farmer in West Java Province. There were 80 farmers included in the study which were selected using simple random sampling from 513 registered farmer of 12 farmer group in Ciamis Regency, West Java Province, Indonesia.

This study used a quantitative approach and a cross-sectional survey. In order to analyze the relation between input variable and output of corn production, the Cobb–Douglas production function and translog function are commonly used in estimating the productivity of input [10]. The Cobb-Douglass production function was chosen since it was proved in previous studies to provide the best link between inputs and outputs for corn production. The theoretical framework adopted in this study ties in with the work of [11] and [12]. The functional form of the Cobb-Douglas function can be written as follows:

$$LnY_i = \sum_{j=1}^{n} aj\, Ln(X_{ij}) + \varepsilon_i \qquad i = 1, 2, 3, \ldots. n \tag{1}$$

Where Y_i denotes farmer corn production (yield), X_{ij} represents the input variables, a is constant term, j is the coefficient of input and ε_i denotes error term. The study assumes a constant return to scale. That is, the sum of the coefficients equals 1. In other words, if the input increases at a constant rate, the output will also increase at the same rate [12]. Therefore, from Equation 1 (Eq.1), the functional form of the Cobb-Douglas function can be written as follows:

$$\begin{aligned} LnProd = A + \beta_1 LnLand + \beta_2 LnSeed + \beta_3 LnUrea + \beta_4 LnNpk + \beta_5 LnOrgc + \beta_6 LnPest \\ + \beta_7 LnFlab + \beta_8 LnHlab + \beta_9 Train + \beta_{10} Sex + \beta_{11} LnEdu + \beta_{12} LnExper \\ + \beta_{13} LnFam + \varepsilon_i \end{aligned} \tag{2}$$

Where LnProd is the logarithm natural of corn production, A is the constant term. β_i are elasticity inputs variable including land, seed, Urea fertilizer, NPK fertilizer, organic fertilizer, pesticide, labor (family labor, hired labor), dummy variable being participants of agriculture training and ε_i is error term.

Moreover, the technical efficiency of input was analyzed using Stochastic Frontier Production model. The frontier production model in this study was based on Balete and Olagunju et.al stochastic efficiency model [13] [14].

$$LnY_i = f(LnX_{i,} C_{i,}) + \varepsilon_i \qquad \text{given that } \varepsilon_i = v_i - u_i \tag{3}$$

Where LnY_i denotes corn production of the $_i$th farmer, X_i is a set of productive input variables and other independent variables, Ci represents the binary variable that measures participation on agricultural training (1= join; 0 = not-join), εi is the error term. The error term consists of two components. The first component v_i is a two-sided error term, and the second part u_i is a one-sided error term that measures efficiency. The inefficiency of the production function given in the equation implies that all corn farmers (i.e. both trained and untrained) have discriminatory access to technology and other input products. It's assuming you don't have one. In fact, this assumption is not true in our case. Because corn farmers decide whether or not to join a cooperative. This can be influenced by several observed and unobserved factors. The outright formula for Stochastic Frontier Production function is as follows:

$$LnProd = A + \beta_1 LnLand + \beta_2 LnSeed + \beta_3 LnUrea + \beta_4 LnNpk + \beta_5 LnOrgc + \beta_6 LnPest + \beta_7 LnFlab + \beta_8 LnHlab + \varepsilon_i \quad (4)$$

Variable Description

Table 1. Summary description of variables included in the model.

Variable	Name	Description	Unit
Dependent Variables			
Corn Production	LnProd	Quantity of corn produced	Ton
Independent Variables			
Land	LnLand	Land area for corn planted	Hectare
Seed	LnSeed	Amount of seed used on corn production	Kg
Urea Fertilizer	LnUrea	Amount of urea fertilizer used on corn production	Kg
NPK Fertilizer	LnNpk	Amount of NPK fertilizer used on production	Kg
Organic Fertilizer	LnOrgc	Amount of organic fertilizer used on corn production in 100 kg (quintal)	Kg
Pesticide	LnPest	Amount of pesticide used on corn production	Kg
Family Labor	LnFlab	Amount of family labor used on corn production	Man-day
Hired Labor	LnHlab	Amount of hired labor used on corn production	Man-day
Training	Train	Dummy variable: 1 if a farmer participates in agriculture training, 0 otherwise	1/0
Age	Age	Farmer age	Year
Gender	Sex	Dummy variable gender of farmer: 1 if male, 0 otherwise	1/0
Education	LnEdu	Year of education of farmer	Year
Experience	LnExper	Year of experience in agriculture	Year
Family Member	LnFam	Number of family member	Number

Table 1 shows the summary description of variables included in the model. The dependent variable used in this study is corn production (LnProd) of farmers measured in 1000 kilogram (ton). On the right-hand side, the independent variable including land (LnLand), seed (LnSeed), urea fertilizer (LnUrea), NPK fertilizer (LnNpk), organic fertilizer, pesticide, labor (family labor, hired labor), age, gender, education, farming experience, family member and dummy variable being participants of agriculture training.

3 Result and discussion

3.1 Summary statistics

The descriptive statistics of all variables included in the model have been presented in Table 2. The average corn production per farmer was 1.54 tons with the highest farmer could produce 8.5 ton per season. From the input production side, average land used by farmers was 0.5 hectare. This is typically the majority of small-scale farmer land ownership in Indonesia which spread between 0.1 to 2 hectare per capita [15].

Moreover, the average use of seed in were 8.26 kilograms (kg) with the highest farmer using 30 kg of seed. The farmer in this study also uses fertilizers, including organic and non-organic. Urea was the most widely used fertilizer by farmers with an average farmer using 68.37 kilograms of urea. Furthermore, farmers also used NPK and organic fertilizer with an average use of 67 and 11.45 kilograms respectively. Other production inputs used by farmers in this research were pesticides and labor. The labor consists of family workers and outside family workers (hired labor). The use of family labor and non-family labor is a common practice in small-scale farming in Indonesia [16].

Table 2. Summary statistics.

Variable	Unit	Mean	Std. Dev.	Min	Max
Production					
Corn Production	Ton	1.53825	1.460798	0.1	8.5
Input					
Land	Hectare	0.4628625	0.3150697	0.07	2
Seed	Kg	8.25625	6.394219	1	30
Urea	Kg	68.36875	63.81494	0	400
NPK	Kg	67.08125	57.62007	1	300
Organic	Kg	11.44875	15.6558	0.3	120
Pesticide	Kg	.4125937	3.13692	0	28
Family Labor	Man-day	12.9875	12.3734	1	56
Hired Labor	Man-day	18.52031	10.78977	1	55
Training	Dummy	.3	.4611488	0	1
Demographic Factors					
Age	Year	54.1125	12.5153	26	90
Gender	Dummy	.55	.5006325	0	1
Education	Year	7.1	2.035134	6	16
Experience	Year	8.7625	4.685674	2	20
Family Member	number	3.1	1.392566	1	9

Based on the demographic aspect, the average age of corn farmers in this study was 55 years old, with the youngest farmer being 26 years old and the oldest farmer being 90 years old. The aging farmer is one of the problems faced by Indonesian agriculture [17]. Furthermore, on the educational aspect, the average education level of corn farmers is 7.1,

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meaning that the majority of farmers have completed basic education. Moreover, the average score of farmer participation in agricultural training was 0.3 which indicated that the majority of farmers did not participate in agricultural training compared to those who attended training. Previous studies showed that, the participation on training program is important since it could boost productivity in agriculture [18] [19].

3.2 OLS regression

Table 3 shows the results of factors affecting corn production using the Ordinary Least Squares (OLS) method. Breusch-Pagan/Cook-Weisberg test was employed to test the present of heteroskedasticity problem. The result showed that F-stat value of 0.14 with a probability of 0.7081, therefore the model presented in this study was well specified.

Table 3. Factors associated with corn production.

Variable	Coefficients	Std. Err.	t-Statistics	P>|t|
cons	-.4767451	1.568937	-0.30	0.762
LnLand	.4576143***	.1865743	2.64	0.017
LnSeed	.4642912***	.1471098	3.16	0.002
LnUrea	.1099592	.0844213	1.30	0.197
LnNpk	-.0074982	.076811	-0.10	0.923
LnOrgc	.0281723	.0432184	0.65	0.517
LnPest	.0194178	.0228488	0.85	0.399
LnFlab	.0749333	.0607784	1.23	0.222
LnHlab	.1188249	.0725491	1.64	0.106
Train	.0968324	.1348481	0.72	0.475
Age	-.1134826	.2618277	-0.43	0.666
Sex	.0086051	.1169424	0.07	0.942
LnEdu	.071694	.2793801	0.26	0.798
LnExper	-.0463582	.1013307	-0.46	0.649
LnFam	-.2148258	.1432141	-1.50	0.139
Number of obs	79			
R-squared	0.7548			
Adj R-squared	0.7012			
F(14, 64)	14.07			
Prob > F	0.0000			

Note: ***/**/* significant at 1%, 5%, and 10% level.

The results of Ordinary Least Squares (OLS) productivity estimation showed that R Square is 0.7448. This means that 74.5 percent of the variation in corn production can be explained by independent variables, including land area, seed, urea fertilizer, NPK fertilizer, organic manure, pesticides, labor and the dummy variable of participation in agriculture training. While the remaining 26.5% could be explained by other variables that are not included in the study such as farming experience, education level, gender and age of farmer.

Results showed that land and seed have a statistically significant impact on corn production. The elasticity value of land and seed 0.46 and 0.46 respectively and statistically significant at 1% level. Bear a meaning that a 1% increase on land area and seed could increase corn production by 0.46% respectively, holding other factor constant. Land area is the main factor that effect corn production [20]. Seed also positive and significantly impact corn production, increasing the use of seeds to a certain level could possibly increase corn production [21].

Unexpected results were shown by the variables of fertilizer (NPK, urea, organic), pesticide, labor (family labor, hired labor) and agriculture training which did not significantly affect corn production in this study. The use of fertilizers in certain soil conditions sometimes does not have a significant effect on increased production [22].

3.3 Stochastic frontier model of corn production

Table 4 shows that the estimated average technical efficiency of corn farming was approximately 72.04%. Moreover, the highest technical efficiency was 88.73% and the minimum score below 40% at 37.28%. The average technical efficiency is lower compare to the previous research which indicates at 78% in Indonesia [23] and around 86.3% globally [24]. This result shows that the technical efficiency of corn farming in this study still needs to be improved.

Table 4. Estimated average technical efficiency.

Variable	Obs	Mean	Std. Dev.	Min	Max
Corn Production	79	.7204159	.1140143	.3728038	.8873167

Furthermore, Table 5 presented the Frequency Distribution of Technical Efficiency Estimates for Corn Farmers. This study showed that more than 70% of corn farmers had efficiency above 60%. This result indicates that there is an opportunity to improve the efficiency of corn farming [25].

Table 5. Frequency distribution of technical efficiency estimates for corn farmers.

Efficiency Score (%)	Freq. (Number of Corn Farmers)	Percent	Cum.
≤40	1	1.27	1.27
40-60	11	13.92	15.19
60-80	49	62.03	77.22
≥80	18	22.78	100.00
Total	79	100.00	

Moreover, Table 6 shows the results of Stochastic Frontier Model of Corn Production. The result shows that variable of land, seed, hired labor and family member statistically significant impact on technical efficiency of corn production in Indonesia. An increase in the land area, seed and hired labor could increase the technical efficiency of corn by 0.48%, 0.46% and 0.12% respectively. While training had statistically insignificant effect on technical efficiency. Furthermore, an increase in family member of corn farmer, could decrease the technical efficiency corn by production 0.27%. This result in line with previous study which showed that the use improved seeds could increase efficiency of farming [26].

Table 6. Estimates from stochastic frontier model of corn production.

Variable	Coefficients	Std. Err.	t-Statistics
Dependent variable (Corn Production)			
Constant	-.2849362	1.416384	-0.20
Land (Ha)	.4820024***	.1717518	2.81
Seed (Kg)	.4578877***	.133465	3.43
Urea fertilizer (Kg)	.1051447	.0702604	1.50
NPK fertilizer (Kg)	-.011373	.0648462	-0.18
Organic fertilizer (Kg)	.0288482	.0350549	0.82
Pesticide (Kg)	.0131815	.0208749	0.63
Family labor (Man-day)	.0652652	.0541855	1.20
Hired labor (Man-day)	.1152081*	.0623316	1.85
Variance Parameters			
Sigma squared	.3103029	.1209876	
Lamda	1.506031	.2582549	
Wald chi2(13)	242.40		
Prob > chi2	0.0000		

4 Conclusions

This study concluded that land and seed were the most influential variable on corn production. The estimation result from Stochastic Frontier Model showed that variable of land, seed, hired labor and family member statistically significant impact on technical efficiency of corn production. Unfortunately, training had statistically insignificant effect on technical efficiency. Moreover, the estimated average technical efficiency of corn farmers was approximately 72% with more than 70% of corn farmers had efficiency above 60%.

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