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# The Determinants of Farmers' Technical Efficiency in Corn Production: Empirical Evidence from Jambi Province

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# The Determinants of Farmers' Technical Efficiency in Corn Production: Empirical Evidence from Jambi Province

**Edison**

University of Jambi, Indonesia

*Corresponding Email: ediedison950@yahoo.co.id

**Abstract.** The various levels of production will reflect uncertainty and risk factors in corn farming. The main problem in corn farming is that the productivity level is still low. This low level of productivity is due to farmers' limited ability to allocate inputs such as seeds, fertilizers, and appropriate pesticides in peat land. This study aimed to estimate technical efficiency and its determinants in corn production in Jambi Province, Indonesia. In this study, 2020 corn planting season data were used. A sample of 120 corn farmers was taken randomly by the stratified random sampling technique based on cross-sectional data that were collected in 2021. The Cobb-Douglas stochastic frontier production function with incorporation of inefficiency effects was employed to analyze the data. According to the results, the technical efficiency rate ranged from 63.46% to 99.54%, with an average of 74%. The significant factors found to positively affect corn yield were seed quantity, potash fertilizer, labor, and corn variety. Meanwhile, nitrogen fertilizer and pesticide were negatively related to corn yield. The significant determinants of technical efficiency that were positively related to technical inefficiency included educational attainment, training, credit access, and household labor
**Keywords**: Technical efficiency; corn farming; determinants of technicalefficiency; stochastic frontier production function.

## 1. Introduction

One of the agricultural commodities that is under continuous development for the purpose of food security improvement is corn. Corn plants are food plants that are highly beneficial to human or animal life. Until now, corn is second to rice as a strategic commodity. Seen from the market perspective, the potential of corn marketing continues to increase [1]. This can be seen from the growing demand for corn in Indonesia, which is currently quite large at more than 10 million tons of dry shelled corn per annum. The largest share of corn consumption is for animal feed; 51% of the raw material for animal feed, especially for poultry, is corn. Besides, the role of agriculture in labor absorption is critical, given that the majority of the population in Jambi Province that lives in rural areas is engaged in businesses [2].

The problems that arise in corn production are narrow land area and fluctuating levels of corn productivity because of low levels of soil fertility and short raining periods [3]. As a result, the level of productivity of corn farming at the national level is low, as shown by Jambi's corn production of 2.67 tons/hectare in 2018 [4]. One of the regions that produce corn in Indonesia is Jambi; economic development in the agricultural sector, especially in the food crops sector, is a priority in this province. Agricultural commodities, especially for food, contributed significantly to the GRDP of Jambi, and it is especially true in the case of corn because most of Jambi area (65,972 hectares) is dry land. Muaro Jambi Regency particularly has a prominent role in corn production; with an area of 319 hectares, yield of 851.73 tons, and average productivity level of 2.67 tons/hectare, this regency's high productivity helps improve the regional economy [4].

The development of temporary corn production has been effective over the past few years, but it may be relatively difficult to repeat in the future [5]. Production data were extracted from the corn crop development program in Jambi Province during the New Order Era (1986–1988) and the Reform Era (1989–2019) from three typologies of existing cornfields. The various levels of production will reflect uncertainty and risk factors in corn farming. Furthermore, economic crisis and financial difficulties have resulted in reduced input best practices for corn farming [6]. From this point of view, some experts at agricultural policy are interested in observing the response of supply and demand for inputs to corn farmers. Estimates of bid responses such as changes in input use have been reported in several studies [7–9], but very few have examined the response inputs concerning technical efficiency.

The main problem in Muaro Jambi Regency's corn crop production is that the productivity level is still low. This low productivity is due to farmers' limited ability to allocate inputs such as seeds, fertilizers, peat land, and appropriate pesticides [1]. It is also assumed to be caused by input best practices which tend to vary every year, especially in relation to rising prices of chemical fertilizers and pesticides [1]. Technical efficiency is another essential issue to find out in increasing productivity; there is limited input and lack of opportunities in developing good technology adoption [9][11–12]. Improving corn productivity through a combination of input best practices and technical efficiency can increase income. The level of technical efficiency itself can be obtained by improving the level of management capability of farmers. Therefore, the following problems were formulated in this research:
(1) What inputs can affect productivity level in corn farming?

(2) Is the use of corn farming inputs good and what inputs can affect technical efficiency level?

The production function is related to input allocation and the level of yield produced [13]. The purpose of input allocation is to maximize the amount of output with a certain number of inputs used. The production function is a function that explains the mathematical relationship between the inputs used to produce a certain level of output [14]. It can be explained as follows:

$$q = f(K, L, M, \ldots) \quad (1)$$

where q is the output of certain goods during a period, K is the capital input used during that period, L is the labor input in hours, and M is the raw material input used.

Equation (1) shows that the amount of output depends on a combination of capital, labor, and raw materials use. The more precise the input combination, the more likely the output can be produced optimally. [14] states that the production process at the level of corn farming generally follows a Cobb-Douglas function relationship pattern. The Cobb-Douglas function has several advantages: (1) it is relatively easy and simple compared to other production functions because it can be transformed into a simple linear form; (2) the coefficient of rank also shows the optimum amount of elasticity of production from the use of factors of production; and (3) the estimated elasticity of each factor of production is the product used in the process of estimating the business scale (return to scale) of the factors of production used in the ongoing production process.

However, the Cobb-Douglas function as an analysis tool has a number of drawbacks: (1) incorrect specification of the variable will produce negative production elasticity or too big or too small a value and (2) error measurement of this variable lies in the validity of the data, whether the data used be correct, too extreme to the top, or vice versa. This measurement error will cause the amount of elasticity to be either too high or too low. In practice, management is an important factor in increasing production, but this variable is sometimes difficult to measure and use as an independent variable when the Cobb-Douglas function is used [14].

### Technical Efficiency Model

In this research, technical efficiency analysis [15–16] is applied through the use of the following equation:

$$TE_i = E\,[\exp(-U_i) / e_i]\ i = 1, 2, 3, \ldots ..N \quad (2)$$

where $TE_i$ is i-producer's technical efficiency and exp (- E $[U_i \mid e_i]$) is the expected value(mean) of $u_i$ using the terms $\sum_i$, so $0 \leq TE \leq 1$. The value of technical efficiency refers to the opposite of the effect of technical inefficiency, which can also be applied to functions that have an amount of output from a particular input (cross-section data). Producer technical efficiency is classified as efficient enough if it has a value of > 0.7, and it is not classified as efficient if it has a value of ≤ 0.7.

According to [17], the theory of production efficiency is an advanced version of the basic economic theory that is concerned with the use of limited input to obtain optimal output or with the use of smallest possible cost to obtain a certain level of output. Production efficiency is the relative magnitude of the ability of business activities to apply inputs to obtain certain output at the technological level [18]. If the above rule is applied to agricultural production activities, farmers will try to produce efficiency in applying best practice inputs [19]. If farmers do not apply inputs efficiently, then perchance the inputs are not used optimally to improve agricultural profits and obtain a surplus. Conversely, if they apply inputs efficiently, additional contributions to agriculture can only be generated by exploration efforts taking into account growth in this field [17].

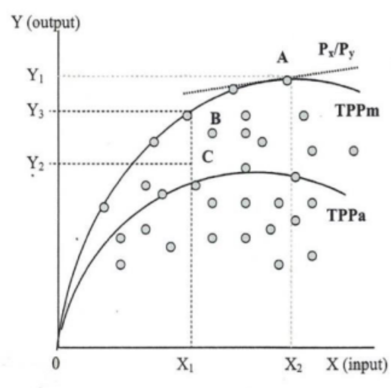


**Figure 1**. Frontier Production Function

Three types of efficiency are illustrated in Figure1 [15][20]. The $TPP_m$ curve shows the maximum possible output as x increases, which also shows the production frontier function, and the $TPP_a$ shows the average product that is usually estimated using the ordinary least squares (OLS) technique. Each input that succeeds in producing output is right on the $TPP_m$ production curve (maximum output); the use of an amount of input reaches maximum output. Meanwhile, the output achieved under the $TPP_m$ curve is expressed as technical inefficiency. The criterion for profit maximization in society will be fulfilled at the optimum production level of the input, for example on the use of input at the Xi level and the production of output at the Y1 level at point A. At point C, any company using X2 input and producing Y2 output shows achievements for both technical and allocative efficiencies. The level of efficiency achieved is $Y_2 / Y_3$. In other words, the company that produces $Y_2$ using $X_2$ input at point B achieves technical efficiency but is not efficient allocation-wise. Then, the allocative efficiency is $Y_3 / Y_1$, while the economic efficiency is Y2 / Y1 [21–23].

## 2. Methodology

The study was conducted in Muaro Jambi Regency because this area is one of the centers of Jambi peat land corn production. To be exact, Kumpeh District was chosen as the location of the study. The location of this research was chosen purposively under the consideration that the location is the corn production center of Muaro Jambi Regency representative of the peat land typology. This research was conducted in the beginning of 2021.

This research was conducted in Kumpeh District, Muaro Jambi Regency, considering that farmers there had relatively good productivity in corn crop development, which was helpful for the researchers to obtain primary data. One hundred twenty people were chosen randomly using the stratified random sampling technique. The study used primary and secondary data. To obtain a picture of the real conditions in the study location, primary data for the 2020 planting season were obtained from villages and then used. The area was determined intentionally given the fact that Kumpeh District of Muaro Jambi Regency is a corn plant center which is representative of the peat land typology. The area selection was based on the consideration of high-productivity corn cultivation and large- and medium-sized farmers in the peat land.

To estimate the empirical model, the research used the Cobb-Douglas production function. According to [24], the function is applied to see the input-output relationship in the Stochastic Frontier function equation in 2 stages. First, the ordinary least squares (OLS) method is used to estimate the production input coefficient $\beta$. Second, the maximum likelihood estimation (MLE) method is applied to predict all production parameters $\beta$m, intercept $\beta_0$, as well as factor variants from both error vi and $u_i$ components [25]:

$$Y = \beta_0 X_1^{\beta 1} X_2^{\beta 2} X_3^{\beta 3} X_4^{\beta 4} X_5^{\beta 5} X_6^{\beta 6} e^{vi-ui} \quad (3)$$

The study used the trans-log function on an empirical model of the production function.

$$\text{Log } Y = \beta_0 + \beta_1 \text{ Log } X_1 + \beta_2 \text{ Log } X_2 + \beta_3 \text{ Log } X_3 + \beta_4 \text{ Log } X_4 + \beta_5 \text{ Log } X_5 + \beta_6 \text{ Log } X_6 + (v_i - u_i) \quad (4)$$

where Y is corn production (kg), $X_1$ is land area (ha), $X_2$ is seeds (kg), $X_3$ is urea fertilizer (kg), $X_4$ is NPK fertilizer (kg), $X_5$ is pesticide (LTR), $X_6$ is labor (HOK), and $\beta_0$ is intercept. Furthermore, $\beta_1$–$\beta_6$ are parameters, and $v_i$ - $u_i$ is error term.

Estimation of the production function used a particular sample by a two-stage method. Chi-square test was used to estimate the production function. The estimation results obtained from the two-stage method are consistent [21]. The level of technical efficiency of corn plants can be estimated by applying the following equation:

$$TE_i = exp(- E[U_i|e_i]. \quad i = 1, \ldots, n \quad (5)$$

where [26] TE is technical efficiency obtained by the i-farmer, exp (-E[$U_i|\varepsilon_i$] is the expected value of $U_i$ with the condition εI being $0 \leq TE_i \leq 1$

## 3. Results and Discussion

The research findings concerning variables that affect the technical efficiency of corn production were extremely exciting and magnificent. Table 1 provides descriptions and summary statistics for the variables (i.e., variables, descriptions, averages, standard deviations, and minimum and maximum values). The findings are as follows: 11 tons of mean output per hectare, 2.27 ha of mean land area used, 20 hours of labor, 101 kilograms of urea fertilizer, 75 kilograms of NPK fertilizer, 2.8 liters of pesticide, and 3 extensional activities.

**Table 1**. Descriptions and summary statistics of the variables

| Variable | Description | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Output | Total yield per hectare | 10.44 | 1.09 | 3.5 | 24 |
| Ln(land) | Total land used in hectares | 2.27 | 3.97 | 0.5 | 6.5 |
| Ln(seed) | Quantity of seeds applied per hectare in kilograms | 34.16 | 2.89 | 10.00 | 16.00 |
| Ln(urea fertilizer) | Quantity of urea fertilizer applied per hectare in kilograms | 101.27 | 54.92 | 77 | 150 |
| Ln(NPK fertilizer) | Quantity of SP36 fertilizer applied per hectare in kilograms | 75.22 | 73.04 | 50 | 100 |
| Ln(pesticide) | Quantity of pesticide applied per hectare in liters | 2.80 | 1.97 | 1.20 | 4.00 |
| Ln(labor) | Total of labor hours per day | 19.8 | 1.83 | 1 | 6 |

Production function analysis aimed to determine how the use of production inputs such as land area, seeds, fertilizers, pesticides, and labor affected production and how the production response to the use of production factors was. The effects of the use of inputs on production can be seen in Table 2.

Table 2 shows an Adj. $R^2$ value of 0.8956. This means that 89.56 percent of the variation in the dependent variable could be explained simultaneously by the independent variables land area, seeds, fertilizers, pesticides, and labor, while the remaining10.44 percent was influenced by other factors outside the model. The effect of simultaneously using production factors on corn production can be determined using an F test. The analysis results showed F statistics of 73.54 with a probability of 0.0000 < (0.01), showing that the results had a very significant effect. This means that the independent variables contained in the model simultaneously had a very significant effect on corn production. The value of $\Sigma\beta_i$ = 0.987 > 1 means that the simultaneous use of production factors was in area II, which means that each increase in input proportion would result in an increasing in output. In other words, the corn farming was in the production stage of increasing return to scale.

With regard to best input practices and technical efficiency estimation, it was found that the sigma-squared value of 0.6231 was significant at the 1% level, indicating a good fit of the model, assuming that the compound error term was correct. The gamma (γ) value was close to one, meaning that the gap in corn production in Muaro Jambi Regency was due to technical inefficiency. According to [26], any random component of inefficiency effects has a significant contribution to the analysis of agricultural production. It provides information about the availability of the one-sided error factor in the model. Therefore, the traditional OLS model is an inadequate representation of the data. The mean technical efficiency rate in the research location was 74% (0.74), meaning that there is a possibility for producers to improve their efficiency by 26% with the present inputs and current technology being taken into consideration. Data showed that the rate of technical efficiency ranged between 0.67 and 0.98. Before evaluating the findings on the inefficiency components, it is good to know that a negative sign on an inefficiency parameter means that the group variable had a positive impact on technical efficiency or caused a decrease in inefficiency and that, on the other hand, a positive sign on an inefficiency parameter explains that the group variable had a negative impact on technical efficiency.

**Table 2** Corn estimation production function

| Variable | Coefficient | Std. Error | t-statistics | Probability |
|---|---|---|---|---|
| Land | 0.201 | 0.039 | 5.154 | 0.000 |
| Seed | 0.083 | 0.111 | 0.748 | 0.613 |
| Urea Fertilizer | 0.218 | 0.068 | 3.206 | 0.014 |
| NPK Fertilizer | 0.194 | 0.056 | 3.464 | 0.010 |
| Pesticide | 0.153 | 0.066 | 2.318 | 0.046 |
| Labor | 0.138 | 0.043 | 3.209 | 0.013 |
| Constant | 102.73 | | | |
| Adj. R-squared | 0.8956 | | | |
| Σ squared(v) | 0.0072 | | | |
| Σ squared(u) | 0.6231 | | | |
| Mean efficiency | 0.74 | | | |

**A. Estimation of Corn Farming Production Function**

The frontier productivity function model estimation was used to analyze the farm productivity function. The productivity variables used were land, seeds, urea fertilizer, NPK fertilizer, pesticide, labor, and frequency of attending counseling. The results of the estimation of the production function in the study area can be seen in Table 2.

Table 2 shows an Adj. $R^2$ value of 0.8956. This means that 89.56 percent of the dependent variable (output) could be explained jointly by the independent variables, while the remaining 10.44 percent was influenced by other factors outside the model. The productivity elasticity values of the variables land, seeds, urea fertilizer, NPK fertilizer, liquid pesticide, and labor were 0.201, 0.083, 0.218, 0.194, 0.153, and 0.138, respectively. If the independent variables increased by 10 percent *ceteris paribus*, the increase in productivity resulted by each would amount to 2.01 percent, 0.83 percent, 2.18 percent, 1.94 percent, 1.53 percent, and 1.38 percent, respectively.

The value of $\Sigma\beta_i = 0.987 < 1$ means that the use of production factors was in area II and that the stage of the production curve was in the area of decreasing return to scale, which means that each increase in the proportion of input would result in an increase in productivity output which is decreasing. The variables that significantly affected productivity (increasing) at the level of $\alpha = 0.05$ were land, urea fertilizer, NPK fertilizer, pesticide, and labor. Meanwhile, seeds had no significant effect on productivity.

### B. Farming Technical Efficiency

Technical efficiency is a reflection of the farmer's ability to get maximum output from a set of available inputs. In this study, the technical efficiency analysis used the following formula: $ET = E\ [\exp(-U_i) / \varepsilon_i)]$ $i = 1, 2, 3, \ldots, N$, where $TE_i$ is the technical efficiency of the $i^{th}$ farmer and $\exp((-U_i) / \varepsilon i)$ is the expected value (mean) of $U_i$, provided that $\varepsilon_i$ becomes $0 \leq ET \leq 1$. The ET value of farmers is said to be quite efficient if it is > 0.7 and inefficient if it is equal to or below 0.7. The results of technical efficiency analysis in corn farming in the research area can be seen in Table 2.

Table 2 shows that the average level of technical efficiency in corn farming was 0.74. This shows that the average productivity level achieved by corn farmers was around 74 percent of frontier production, meaning that the level of technical inefficiency was 0.26 (26 percent) or that the potential for production improvement was 26 percent. It was found that the lowest technical efficiency level of farmers was 0.56 and the highest was 0.81. In other words, the corn farming in the research location was on average technically efficient. The results of this study are in line with those of the research by [27], which also reported that most corn farmers were technically efficient. This can be caused by the use of production inputs that did not follow recommendations. This reflects that the opportunity to increase productivity is quite large because the gap between the maximum level of productivity that can be achieved with the best management system (best practice) and the current level is quite large. This implies that to increase farm productivity significantly more advanced innovations are needed. This would require technological breakthroughs derived from research activities.

## 4. Conclusion

This research investigated into the technical efficiency level of corn farming in Muaro Jambi, Indonesia, and the farm-specific components influencing it. Data were collected directly from farmers in the location of interest in Jambi using a survey method. A stochastic frontier model was applied to evaluate technical efficiency. The estimated coefficients for land, seeds, urea fertilizer, NPK fertilizer, and labor were positive, indicating that if any of these inputs increased, there might be an increase in crop yields and in returns of capital. The technical efficiency level of farmers in the location of interest was 74%. The implication is that technical efficiency in corn production could improve productivity by 74% through better use of available inputs and current technology.

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