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The Production Efficiency of Potato Farming in Batur Village Using the Stochastic Frontier Analysis Approach

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Abstract

This study aims to analyze the production efficiency of potato farming in Batur Village using the Stochastic Frontier Analysis (SFA) approach. The sampling of this study uses a random sampling method of 97 farmers. The research variables are land area (X1), seeds (X2), fertilizer (X3), pesticides (X4), labor (X5), and the dependent variable of potato production (Y). To analyze Cob-Douglas efficiency, the SFA method is used to measure technical efficiency, price efficiency, and economic efficiency of potato farming production units. The result of research on potato agricultural production in Batur Village is not technically efficient with a value of 0.999 < 1. In terms of price, it is also not efficient with a value of 1.79 > 1. Thus, from these two efficiencies cause economic efficiency is not achieved, namely with a value of 1.788 > 1. To overcome the inefficiency of potato farming production, the farmers must have the will to continue to develop by adding insight and knowledge such as participating in farmer counseling with related institutions in order to be able to solve production problems independently. The government can also help overcome farmers' problems by subsidizing fertilizers, seeds, and pesticides which can reduce the cost of agricultural production. With both efforts from both farmers and the government, it is certainly expected that agricultural production problems will be achieved in order to achieve production efficiency and can improve the welfare of potato farmers in Batur Village.

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INTRODUCTION

The agricultural sector is an important sector for the economy of a country, especially for developing countries. According to (Rini Sulistiyawati, 2021) agriculture plays a very important role and becomes a mainstay in the development of a country. it is also because according to (Ableeva et al., 2019) agriculture is the most strategic and significant economic activity in providing food for the population. The agricultural sector has multifunctions covering aspects of production or food security, increasing the welfare of farmers, or alleviating poverty and preserving life (Kusumaningrum S. I., 2019).

Based on data from BPS (Central Bureau of Statistics), agriculture contributes the second largest national income to the Indonesian economy as much as 13.28% in 2021. The data is as follows:

Table 1. The contribution of the agricultural sector to GDP in 2019-2021 (field of business at current prices)

Years	Contribution to GDP (percent)
2019	12.71
2020	13.7
2021	13.28

Source: Data of BPS

Based on the data in Table 1, in the last five years, the contribution of the agricultural sector to Indonesia's GDP has tended to be dynamic, which has tended to decrease in 2017-2019. However, it rose to 13.7% in 2021 and fell back to 13.28% in 2021. This decline occurred because there were still many people who preferred to work in the industrial sector rather than the agricultural sector.

According to (Nurul Awwaliyah, 2020), agriculture as the main point in development to improve people's welfare. Therefore, in terms of the employment field, agriculture has a large contribution to absorbing labor because the contribution to the Indonesian economy is also large (Kusumaningrum S. I., 2019). The contribution of the agricultural sector also has a contribution to income and employment in a region. According to (Budhiasa, 2017), the Gross Regional Domestic Product (GRDP) obtained from the agricultural sector makes a direct contribution, which is providing jobs and being a source of community income. From this explanation, it can be categorized that Indonesia is an agricultural country.

According to BPS, the agricultural sector has several sub-sectors, which are food crops, plantation crops, horticultural crops, forestry crops, fisheries, and livestock.

The six sub-sectors certainly have an important role in improving the economy and people's lives including horticultural crops which include fruits and vegetables. Besides being suitable for planting in tropical climates like Indonesia, these types of plants also have vital functions. According to (Pitaloka, 2017), horticultural crops have the function of improving people's nutrition, meeting the needs for environmental beauty and sustainability, increasing the country's foreign exchange in terms of sales, and expanding community job opportunities.

Central Java Province is one of the provinces that has the potential for horticultural crops. This is projected in table 2 below:

Table 2. Leading Vegetable Commodities of Central Java Province in 2019 – 2021 (Tons)

Years	Red Onion	Potatoes	Cabbage	Big Chilies
2019	481,890	294,015	274,487	164,906
2020	611,165	307,670	245,502	166,260
2021	564,255	277,725	193,026	169,282

Source: Data of Indonesian BPS

As seen from Table 2, the main commodity with the highest amount is red onion, followed by potatoes, cabbage, and big chilies. Potato production from 2019 rose to 307,670 tons in 2020 and fell in 2022, this was due to the influence of the pandemic that hit Indonesia. However, even though the potato commodity decreased, the position of potato remained number 2 in the leading vegetable commodity of Central Java.

One of the potato commodity-producing areas is Batur Village, Getasan Subdistrict, Semarang Regency. The agricultural potential in Batur Village, especially potatoes, is very high. This can be seen in the following table:

Table 3. Potato Production by Subdistrict in Semarang Regency in 2021 (Quintals)

Subdistricts	Years
Getasan	8,274
Banyubiru	2,765
Sumowono	275

Source: The data of BPS of Semarang Regency

Based on Table 3, the potato commodity in 2021 was produced the largest by Getasan subdistrict. As one of the villages in the subdistrict, Batur Village also contributes to potato production.

The production of potato farming in Batur Village is very high. This is due to most of the people working as farmers. This is also supported by its location at an altitude of 1,350 MASL with a slope-shaped topography and an average temperature of 30˚C, making the soil very fertile and suitable for planting various types of horticultural crops such as chili, cabbage, bitter gourd, tobacco, and potatoes.

However, cultivation which tends to be conventional makes agricultural production of potatoes tend to be constant and does not increase significantly which in turn can reduce potato production in Semarang Regency.

This is due to conventional farming uses chemical elements such as pesticides and chemicals which in the long term can reduce the level of soil fertility which certainly can affect the level of potato production produced by farmers. However, farmers are now increasingly aware of the impact of conventional agricultural use such as degraded land.

Meanwhile, the need for horticultural agricultural products, especially potatoes will continue to increase. Therefore, farmers must have a way to increase agricultural production of potatoes in order to keep up with market needs. Thus, farmers are required to use production factors efficiently to get maximum potato agricultural production.

Several previous studies that examine the efficiency of farming have different findings. Production efficiency can be affected by land area (Agatha & Wulandari, 2018), seeds (Laili, 2022), labor (Hutapea, 2021), farmer education (Arifin, 2021), and organic fertilizers (Fiatnasari, 2019). Then the cost of farming (Palullungan, 2022), pesticides (Ardiansah, 2022), and cost of production (Fadli, 2021)

This study would calculate whether potato farming in Batur village is efficient or not by using the Stochastic Frontier Analysis approach. The SFA method is used to measure the technical efficiency and

economic efficiency of potato farmers in Batur Village. A technical efficiency analysis would make it possible to know to what extent farmers are using their inputs (e.g., seeds, fertilizers, and labor) efficiently in potato production. Meanwhile, economic efficiency analysis would help researchers to find out how well farmers can produce potatoes with the most efficient cost.

Thus, the result of this study can provide new insights into how potato farmers in Batur Village can improve their production efficiency. The result of this study can also provide input for the government and other stakeholders to improve policies and programs that can help increase the productivity and welfare of farmers in the region.

Based on the background, this study aims to analyze the agricultural production of potatoes in Batur village.

METHOD

The concept of efficiency according to (Farress, 1957) is classified into three, which are technical efficiency, allocative efficiency, and economic efficiency. This study would examine the three efficiencies. This type of study is a quantitative descriptive research by analyzing data in the form of numbers which are then interpreted in a form that is easier to understand. The researchers used primary and secondary data types obtained by documentation, observation, interviews, and questionnaires. The research object is Batur Village, Getasan Subdistrict, Semarang Regency. Batur village becomes the research location because it is one of the villages that contributes the largest potato agricultural products in Semarang Regency. Where Batur Village has a total of 3,500 potato farmers. The population in this study are all potato farmers in Batur village. The number of samples was calculated using the Slovin formula and 97 samples were obtained from farmers. The sampling technique uses random sampling.

The variables in this study are the dependent variable (Y) which is potato production, while the independent variables (X) are land area, potato seeds, fertilizers, pesticides, and workers. The analytical method used is the Cobb-Douglas production function with the stochastic Frontier approach. There are two approaches according to (Farrell, 1957), namely the parametric approach and what is commonly called Stochastic Frontier Analysis (SFA), while the non-parametric approach is a linear approach commonly called the Data Envelopment Approach (DEA) (Chandio et al., 2019). In this study, SFA was used to identify factors that influence potato production and to analyze the level of production efficiency of potato farming in Batur Village, Getasan Subdistrict, Semarang Regency.

The method of collecting data in this study is first, the researchers make observations to analyze problems in the agricultural sector and collect initial data at the research location. The second is to do documentation by taking secondary data from articles, journals, publications, and other necessary reports. The third is distributing questionnaires to the respondents whose results are used as data to calculate the efficiency of potato agricultural production in Batur Village.

Mathematically, the cob-Douglas production efficiency function uses the Stochastic Frontier Analysis (SFA) approach, the research model is as follows:

$Y = aX_1^{b1}.X_2^{b2}.X_3^{b3}.\ldots.X_n^{bn}e^u$ ……………………………………………..(1)

Where:

Y : Production

X_1 : Type of i-th Production Factor, where i= 1,2,3….n

a : Intercept

bi : The regression coefficient of the i-th variable estimator

u : Error

e : natural logarithm E -2.178

The next step in facilitating estimation, the result of equation one is converted into logarithmic form. It aims to determine the optimal input used to determine the level of technical efficiency in potato farming in Batur village. The transformation model is as follows:

$Log\ Y = a + b_1 LnX_1 + b_2\ LnX_2 + b_3 LnX_3 + b_4\ LnX_4 + b_5 LnX_5 + e$.....(2)

Explanation:

Y : Logarithm of Potato Production

LnX1 : Natural logarithm of land area

LnX2 : Natural logarithm of seeds

LnX3 : Natural logarithm of fertilizer

LnX4 : Natural logarithm of pesticides

LnX5 : Natural logarithm of labors

b_1-b_5: coefficient value

e : error

The first efficiency analysis is technical efficiency. To measure technical efficiency, the formula used is as follows:

$TE = \exp\left(-E\left[\frac{u_i}{\varepsilon_i}\right]\right)$.....(3)

With known that:

$E\left[\frac{u_i}{\varepsilon_i}\right] = \left(\frac{\sigma_u \sigma_v}{\sigma}\right)\left\{\left[\frac{f(\varepsilon_i \lambda \sigma^{-1})}{1-F(\varepsilon_i \lambda \sigma^{-1})-(\varepsilon_i \lambda \sigma^{-1})}\right]\right.$.....(4)

Where :

ε = The sum of vi and ui

σ = Equation for $(\sigma_v^2+\sigma_u^2)^{1/2}$

λ = Ratio of σ_u with σ_v

f and F is the standard normal density and the distribution evaluation function of $(\varepsilon_i \lambda \sigma^{-1})$. The Technical Efficiency (TE) Value is in the range of 0 and 1, or 0 ≤ TE ≤ 1. If the TE value is close to 1, then the efficiency obtained is more technically efficient, if it is close to 0, it is more technically inefficient.

The second efficiency analysis is price efficiency. Price efficiency would be achieved if the ratio of the value of the marginal product of each input with price equals 1. Thus, the formula used is as follows

$NPM_x = P_x$, or

$\frac{NPMx}{Px} = 1$..... (5)

Or in another form as follows:

$\frac{b.Y.Py}{X} = Px$ ..... (6)

Atau

$\frac{b.Y.Py}{X.Px} = 1$ ..... .(7)

Information:

b = elasticity of production

Y = average potato production

Py= average production price Y

X = average production factor X

Px= average price of production factor X

The terms used are as follows :

a. If $\frac{NPMx}{Px} > 1$, then the use of the production factor x is inefficient, and to achieve efficiency, the factor of production x must be added.

b. If $\frac{NPMx}{Px} < 1$, then the use of the factor of production x is inefficient, and to achieve efficiency, the factor of production x must be reduced.

The third efficiency analysis is economic efficiency. Economic efficiency is a production condition that uses the minimum input and costs to be able to produce a certain amount of output or by using certain inputs and costs can produce maximum output. Economic efficiency can be achieved if technical efficiency and price efficiency have been achieved. Economic efficiency can be calculated in the following way:

EE = ET x EH……..(8)

Information :

EE = Economic Efficiency

ET = Technical Efficiency

EH = Price Efficiency

RESULT AND DISCUSSION

The respondents in this study are farmers in Batur Village, Getasan Subdistrict, Semarang Regency with an age range of 24 – 64 years. However, most of the farmers in Batur village are aged 40-60 years. Nevertheless, the farmers in Batur village are classified as productive age because they are above 16 years old and under 64 years old. The potato farmers in Batur village have mature experience because they have been working as farmers for more than 20 years. Most of the land cultivated is self-owned land and has an average land area of 1.25 Ha which is cultivated by the family themselves.

The potato farmers in Batur village sell or market their agricultural products with 2 choices, which are selling to middlemen or selling directly to the market. However, most potato farmers still sell potatoes to middlemen since they feel it is easier than having to sell them to the market as it requires transportation and additional costs to market them.

The result of data estimation using the Frontier 4.1 tool is shown in the following table

Table 4. The estimation result of the frontier stochastic production function

Variables	Coefficient	t-ratio
Constant	-0.172	-0.301
LnX1	-0.465	-0.329
LnX2	0.147	0.253
LnX3	-0.122	-0.737
LnX4	0.285	0.308
LnX5	0.221	0.102
Average Technical Efficiency Score	0.999	
n	97	

Source: Data processed, 2022

Estimation Model $LnY = \beta_0 + \beta_1 LnX_1 + \beta_2 LnX_2 + \beta_3 LnX_3 + \beta_4 LnX_4 + \beta_5 LnX_5 + \varepsilon$

Estimation Result: LnPr = -0.172 + -0.465LnLh + 0.147LnBb + -0.122LnPp + 0.285LnPt + 0.221LnTk

Information:

LnPr = Potato production

LnLh = Land area

LnBb = Seeds

LnPp = Fertilizer

LnPt = Pesticides

LnTk = Labors

The table describes the estimation result of the production function using frontier stochastic which is transformed into natural logarithm (Ln). then an explanation of the coefficients of each production factor or input used in the potato production of Batur village is as follows:

1. The input of land area has an elasticity coefficient of -0.465. This means that when the input of land area is added by farmers by 1%, the farmers will get an increase in production results of -0.465%.
2. The seed input has an elasticity coefficient of 0.147. This means that when the seed input is added by farmers by 1%, the farmers will get an increase in production results of 0.147%.
3. The fertilizer input has an elasticity coefficient of -0.122. This means that when the fertilizer input is added by farmers by 1%, the farmers will get an increase in production results of -0.122%.
4. Pesticide input has an elasticity coefficient of 0.285. This means that when the pesticide input is added by farmers by 1%, the farmers will get an increase in production results of 0.285%.
5. Labor input has an elasticity coefficient of 0.221. This means that when the labor input is added by the farmer by 1%, the farmer will get an increase in production by 0.221%.

The calculation of the technical efficiency of potato farming

Technical efficiency according to (Farrell, 1957) is the ability of a company, in this case a farming business, to obtain maximum output from the use of an input. As for this research, technical efficiency is measured using Frontier version 4.1 software. From the result of data processing in the table, it is obtained an average value of potato production efficiency of 0.999 means that the average productivity that can be achieved is 99.9%. The average value is less than 1 which means that the use of potato production factors is technically inefficient. This value also means that the use of production factors is still excessive so a reduction in the potato production factors is needed. As with the minimum land area that is worked on by laborers of more than 2 people. This should be able to be reduced to achieve efficiency.

The Calculation of Price Efficiency of Potato Farming

Price efficiency shows the relationship between costs and output (Vaulina et al., 2018). There are three possibilities that occur in price efficiency as follows:

1. If the efficiency value is less than 1, it means that the use of production factor x is inefficient. Thus, to achieve the efficiency of the production factor then x must be reduced.
2. If the efficiency value is more than 1, it means that the use of production factor x is inefficient. Thus, to achieve the efficiency of the production factor then x must be added.
3. If the efficiency value is equal to 1, it can be interpreted that the use of production factor x is efficient and maximum profit is obtained.

Table 5. The Calculation of the Price Efficiency of Potato Farming

No.	Production Factors	Price Efficiency Calculation Results	Explanation
1.	Land Area	-0.04	Inefficient
2.	Seeds	0.02	Inefficient
3.	Fertilizer	-0.02	Inefficient
4.	Pesticides	0.37	Inefficient
5.	Labors	1.46	Inefficient
	Price Efficiency	1.79	

Source: processed primary data, 2021

Table 2 explains that the use of production factors for potato farming in Batur village area shows that the overall results of the production factors that become variables have not fully achieved price efficiency. This is shown by each variable does not achieve a perfect score of 1.

1. Price Efficiency of Land Area Production Factor

The calculation result of the price efficiency of the land area production factor is -0.04 so it can be concluded that the use of land area production factor has not reached price efficiency. This can be seen from the result of price efficiency calculation which has a value of less than 1. Therefore, potato farmers must reduce the use of land area for potato farming.

2. Price Efficiency of Seed Production Factor

The calculation result of the price efficiency of the seed production factor is 0.02 so it can be concluded that the use of the seed production factor has not reached efficiency because its value is less than one. Therefore, the farmers need to add or reduce potato seeds for production.

3. Price Efficiency of Fertilizer Production Factor

The calculation result of the price efficiency of the fertilizer production factor is -0.02 so it can be concluded that the use of the fertilizer production factor has not reached efficiency because its value is less than one. Therefore, the farmers need to reduce the amount of fertilizer for production.

4. Efficiency of Pesticide Production Factors

The calculation result of the price efficiency of pesticide production factor is 0.37 so it can be concluded that the use of pesticide production factor has not reached efficiency because the value is less than one. Therefore, the farmers must reduce the amount of pesticides for production.

5. Price Efficiency of Labor Production Factor

The calculation result of the price efficiency of the labor production factor is 1.46 so it can be concluded that the use of the labor production factor has not reached efficiency because its value is more than one. Therefore, for production to achieve price efficiency, the potato farmers must increase the number of workers to work on potato farming.

The Calculation of Economic Efficiency of Organic Farming

Economic efficiency is when production can achieve a certain amount of output using lower inputs and production costs, or achieve maximum output with fixed inputs and production costs. This occurs when technical efficiency and price efficiency are optimally achieved. Then, to calculate the economic efficiency in this study is formulated as follows:

Economic Efficiency (EE)= Technical Efficiency (ET) x Price Efficiency (EH)

Economic Efficiency (EE) = 0.999 x 1.79

Economic Efficiency (EE) = 1.788

The calculation results obtained from the calculation of the economic efficiency of potato farming in Batur village is 1.788. This value is less than 1, which means that potato farming in Batur Village has not reached maximum economic efficiency, so it is necessary to increase the use of production factors for potato farming in Batur Village.

DISCUSSION

Efficiency in running farming is influenced by several production factors, such as land area, seeds, fertilizers, pesticides, labor, and others.

Land area is an important factor in the production process. This is because land area according to (Chenchen Ren, 2019) has a big influence on the sustainable ability of agriculture from the economic, environmental, and societal aspects. Meanwhile, the larger the land area, balanced with large inputs, will result in greater production (Utami & Mamilianti, 2021). The coefficient value of the land area on potato

farming is -0.465. The land area is certainly to be narrower because more and more agricultural land is being converted into people's homes. After all, according to Malthus' theory, population growth is relatively faster than the growth in food production capabilities. Thus, there is a need for efficient land use.

In potato farming, seeds play an important role in potato production. According to (Kiloes et al., 2019), the use of quality is one of the keys to the success of potato farming. This is evidenced by the seeds which have a coefficient value of 0.147. This means that the quality of seeds will have a positive effect on the quality and production of potato farming which leads to the efficiency of the potato production itself. Therefore, the selection of seeds must have superior quality.

According to (Agatha, 2018) the use of fertilizer is the most influential production factor in agricultural production. The use of organic fertilizers can increase the yield of potato tubers so that production can increase (Maryanto et al., 2018). The fertilizer used is definitely not inorganic fertilizer but manure which is more eco-friendly. Meanwhile, the value of the fertilizer coefficient on potato farming in Batur village is 0.122.

Pesticides are also an important factor in potato farming, this is since pesticides are used to reduce pests in plants that damage crops causing losses to farmers. According to (Manalu, 2019), the use of pesticides can kill the pests directly so that the yield is more satisfying. The pesticide coefficient value is 0.285. The use of pesticides on plants must also be organic.

In addition to land area, seeds, fertilizers, and pesticides. The production factor that is also important is labor. Where labor is an important production factor in farming (Gultom, 2018). Moreover, labor according to (Kenal Hutape et al., 2021) has a significant effect on income or in this case the production of farming. Labor has functions in the potato farming process because it is the subject of the running of agriculture. Labor has a coefficient of 0.221. The number of laborers is very influential in the potato farming of Batur Village.

Technically, potato farming production in Batur village has not reached efficiency. This is because the coefficient value obtained from running SFA is 0.999 which is less than 1.

The calculation result of technical efficiency using Frontier software obtains a value of $0.999 < 1$. The efficiency value is less than one which means that the use of inputs or production factors is inefficient because the inputs used are too excessive so it is necessary to reduce inputs so that efficiency is achieved.

The production factor that can be reduced in potato farming is labor. This is because the average agricultural land is cultivated by 2-4 people. So that the costs incurred to pay workers are bigger, while the land is relatively small which actually does not require a lot of labor.

This is also related to The Law of Demining returns, namely when a production has been optimal, the more or the addition of input can actually reduce production. The reduction in labor will certainly have a positive impact on other production factors, namely the use of land area. This is because the use of narrow land is used by excessive labor, which makes production inefficient. However, with the substitution of land, labor, and capital to a certain extent it can maximize the benefits for agricultural productivity (Hua Lu, 2018).

The next calculation is price efficiency, the value obtained is 1.79. This value is more than one, which means that the use of production factors in potato farming in Batur village has not yet achieved price efficiency. This is because the farmers have not been able to maximize the production factors of land area, seeds, and pesticides, and reduce the use of fertilizers and labor. However, this is not easy, in terms of labor and land use, basic needs nowadays continue to increase so that the salaries needed by farmers are also forced to continue to increase.

Meanwhile, in terms of land use which is narrower makes the production capacity is smaller as well. Then, in terms of fertilizer, the farmers in Batur village use Phonska fertilizer which is relatively expensive, namely 150/50 kg, whereas farmers should be able to make organic fertilizer independently if there is training from the relevant institution or government to save money on fertilizer. Likewise, with pesticides, farmers should also be able to save by making organic pesticides independently if farmers' innovation and creativity are high.

Furthermore, based on the value of economic efficiency, which is 1.788, the value is more than 1. This value means that potato agricultural production has not reached economic efficiency. A value of more than one means that additional factors of production are still needed in terms of land area, seeds, fertilizers, pesticides, and labor since they are inefficient. Economic efficiency cannot be achieved because technical efficiency and labor efficiency are not achieved.

CONCLUSION

Based on the result of the discussion, the research on the efficiency of potato farming in Batur village concludes that potato farming in Batur village is strongly influenced by several production factors of seeds, pesticides, and labor which have a positive effect on potato farming production in Batur village. Meanwhile, land area and fertilizer have a negative effect on potato farming in Batur village.

Then, the value of economic efficiency in potato farming in Batur village has not reached efficiency because the value is more than 1. Economic efficiency is inefficient because technical efficiency and price efficiency have not been achieved. Meanwhile, technical efficiency has a value of less than 1, which means that production factors still need to be reduced in potato farming in Batur village. Meanwhile, price efficiency has a value of more than 1, which means that production factors still need to be added to achieve price efficiency.

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