Technical Efficiency Analysis with a Frontier Approach in Milkfish Farming in Demak Regency

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***Abstract*— This study aims to analyze the factors that influence the level of production and the level of production efficiency of the milkfish pond farming in Demak Regency, Central Java Province, Indonesia. The research sample was 160 milkfish farmers who were selected by survey method through interviews with respondents using structured questionnaires to obtain primary data. Data analysis used stochastic frontier production function analysis. The results of the research analysis showed that the production factors of land area, milkfish seeds, feed, labor, and fertilizer had a significant effect on production yields. Lime production factor has no significant effect on production yield. The average technical efficiency of milkfish pond farming is 0.69. The production of milkfish pond culture is technically not efficient, but it is worth cultivating. This study suggests that improving technical efficiency can be done by optimizing the milkfish pond farmers' production factors which significantly affect production yields.**

***Keywords*—** *Technical efficiency, Stochastic Frontier Production Function, Production*

1. Introduction

Indonesia is an archipelago that has the largest number of islands compared to other countries, namely more than 17,500 islands with a coastline of 99,093 km. The vast sea area has provided benefits in the form of abundant fishery resource content so that Indonesia is able to become the world's fishery processing center [1]. The coastal area has significant potential which has provided employment opportunities for the community for many years, and is able to absorb a workforce of no less than 16 million people [2].

The potential area for brackish water aquaculture is located along the north coast of Central Java with a coastline of ± 453.9 km. The available coastal cultivation area is estimated at 40,000 ha, while the current utilization and production area is only 38,910 ha [3]. Several commodities that have been cultivated and have the potential to be further developed include milkfish, tiger prawns, white shrimp, vannamae shrimp, crabs, groupers and seaweed [4].

Milkfish (chanos chanos) is one of the fishery resources produced from pond cultivation. Advances in maintenance techniques have developed rapidly, so that milkfish production in the ponds has reached 2,000 kg/ha/year. Milkfish is a popular food fish in Southeast Asia including Indonesia. This fish is the only species that still exists in the chanidae family [5].

National milkfish production currently ranks sixth among other fishery commodity types such as seaweed, catfish, tilapia, catfish and shrimp. Milkfish production on average has increased by 17% each year. On the other hand, the level of fish consumption in Indonesia has also increased. In 2010 the level of fish consumption reached 30.48 kg/capita/year, in 2011 it was 32.25 kg/capita/year, while in 2012, the level of fish consumption reached 33.89 kg/capita/year [6].

The increase in the value of national milkfish production is also inseparable from the potential for fishponds in Indonesia, one of which is from Demak Regency. The ecological and geographical conditions of Demak Regency, which are located on the coast and directly adjacent to the North Coast of Java, are very supportive for the development of marine and fisheries businesses. The temperature, climate, and topography owned by Demak Regency are very suitable for the development of marine and fisheries potential, this is evidenced by the existence of aquaculture in Demak Regency spread over four districts, namely Karangtengah, Sayung, Bonang,

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and W Gedung Subdistricts with a total area of 7,945.97 Ha [3].

Among the pond culture fish species whose production can be increased for the domestic market is milkfish which is a potential commodity. Therefore, many cultivators have switched to the milkfish cultivation business or undertake polyculture cultivation, including cultivators in Demak Regency. Milkfish and tiger prawns (vannamei) are coastal aquaculture fisheries commodities that can be cultivated in ponds [7, 8].

Based on the level of importance of milkfish farming, a research was conducted with the question whether the use of input is significant in explaining the variation in output of milkfish pond farmers, and is technically the milkfish pond farmer's business efficient? The importance of research information for milkfish ponds: (1) can optimize the land in the right planting season; (2) in order to obtain optimal production results; and (3) can make a profit.

2. Theoretical Review

2.1 Cultivation of fishpond

Fishpond is a brackish water cultivation habitat located in a coastal area. In general, ponds are used to raise tiger prawns, milkfish, tilapia, and grouper fish. Ponds are an alternative to finding land use by the coast, because ponds are land fisheries that can only be done in areas that are supported. The ease of obtaining sea water as a means of living fish one of the fish cultivation that is cultivated in the pond is milkfish, which is one of the fish that has high protein and economic value [9].

Milkfish is a stubborn aquatic animal, which means that milkfish can live in fresh, salt and brackish water. Milkfish is a type of consumption fish that is familiar to the community, relatively resistant to various types of diseases that usually attack aquatic animals [4].

People living in coastal areas generally take advantage of fisheries business as employment because the fisheries sector is very supportive and has a strategic role in ensuring food security, besides that the fisheries sector is a business field to improve the quality of nutrition for the community so that one of the businesses that the coastal community is engaged in is fish farming milkfish. Milkfish is the product of a pond, this fish farming was originally a side job for fishermen who could not go to sea. Pond cultivation activities are aimed at achieving the welfare of pond farmers which cannot be separated from the efficient use of existing resources and their limitations.

The increase in milkfish pond production is related to the technology being cultivated. Changes in pond technology require large planning and capital, so that in the short term the amount of production that can be achieved by milkfish farmers is determined by the efficient use of production factors at a fixed technological level.

Increased efficiency in the use of production factors can increase the productivity of the milkfish pond business. Increased efficiency will increase the income of the milkfish pond farmers by increasing the productivity of the pond business, expanding job opportunities and cultivator household business opportunities.

Murillo-Zamorano [10] states that the measurement of production efficiency was developed by Farrell [11], which in essence, the efficiency of production units can be decomposed into components of technical efficiency and allocated efficiency through efficient isoquant units and cost minimization of the input price ratio which is the slope of the isokos line.

Technical efficiency was first defined by Koopman [12] referred to in Kumbhakar & Lovell [13] that producers achieve technical efficiency if and only if it is no longer possible to produce more output without reducing a number of other outputs or increasing the number of inputs used. The measurement of technical efficiency also depends on the production concept used. The measurement of technical efficiency can be differentiated into the single-output production frontier concept, namely one input with one output and the multiple-output distance function concept, in which several inputs produce multiple outputs.

2.2 Stochastic Frontier Production Function

The production function describes the maximum amount of output that can be obtained from a package of inputs with fixed technology, and econometricians have guessed the production function by its average. Furthermore, Aigner et al., [14] simultaneously developed the Stochastic Frontier Model which allows for statistical disturbances. The stochastic frontier function model integrates a random disturbance structure of two components, namely components that reflect inefficiencies and components that capture disturbances that come from outside that cannot be controlled by the production unit. With the stochastic production function method, both internal and external factors that are thought to affect the level of technical efficiency of production to be achieved can be captured and explained with the help of econometric models. Meanwhile, the factors that cause inefficiency can also be captured at the same time. In addition, it can also be estimated whether inefficiency is caused by random errors in data collection and the nature of some variables which are external factors or caused by internal factors that cause inefficiencies in the production process.

Farrell [11] argues that there are serious considerations of the possibility of estimation which is called the frontier production function, this attempt to bridge the gap between theory and empiric. Furthermore, Coelli et al., [15] explained that the frontier production function can be used to measure production efficiency. The frontier production function can be estimated from the data sample. To estimate the production function required information on the number of inputs and outputs of the farm production function.

Technical efficiency is the ability of a farm to get maximum output from the use of a set of inputs. Technical efficiency is related to the ability of a farm to produce on the isoquant frontier curve.

Another definition shows that technical efficiency is the ability of the farm to produce a certain level of output by using the minimum input at a certain level of technology. The frontier production function shows a farm's ability to produce maximum output with the use of certain inputs and at a certain level of technology.

According to Partomo [16], studies related to pond cultivation research emphasize the economic theory of neoclassical production. Timmer [17] defines technical efficiency as the ratio of input actually used to available output. In other words, the quantity that shows the ratio between actual production and maximum production.

Several studies that use the frontier production function (FPF) are by Farrell [11], he explains that the frontier production function in its operations represents the broad use of technology by companies (including aquaculture). Kumbhakar & Lovell [13] say that there are three ways to maximize the benefits of farming. The method of (i) maximizing output at the use of certain inputs or what is often called technical efficiency; (ii) maximum profit can be obtained from a suitable combination of inputs at a given input price level (allocated efficiency); and (iii) produce the right production combination at a certain production price level. Understanding the definition of efficiency means that efficiency (technical, allocated, economic) is an indicator of the performance of farming, including aquaculture. The achievement of technical efficiency, especially how farmers minimize the use of high input factors aim to increase competitiveness and profit.

Efficiency has attracted many policy makers and economists, efficiency can be interpreted as the right way, time-saving, energy-saving, and cost-effective (Indonesian dictionary), while there is no waste. Efficiency is the transformation of certain inputs (labor, finance, and tools/technology) to get the maximum output. Technical efficiency is one component of overall economic efficiency [18].

According to Adiyoga [19] basically pond farmers want to maximize profits, but in their behavior, pond farmers cannot be separated from the changes that occur in their daily work environment. Managing pond farming, farmers may make deviations with consequences. The dynamics of aquaculture can continuously change the technical and economic environment, making it difficult for farmers to adjust their cost allocation decisions in response to changes in their production environment.

3. Research Methods

3.1 Research Model

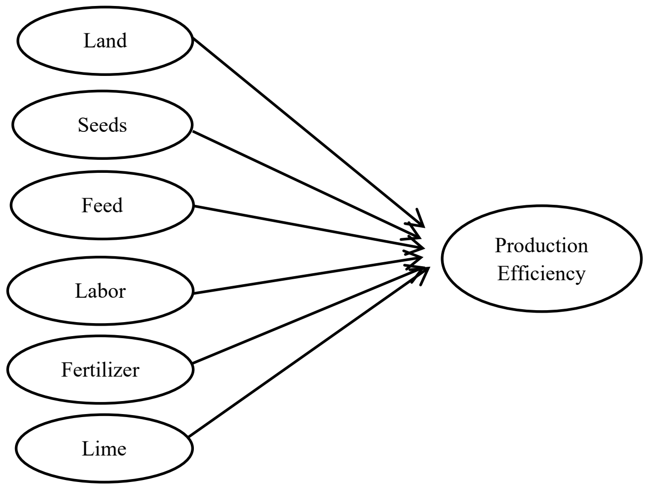

Figure 1. Research Model

3.2 Research Design

This type of research includes explanatory research, which is research that highlights the relationship between research variables.

3.3 Sampling and Location

This research was conducted in North Coast, Demak Regency, Central Java Province on milkfish fishpond farmers in 5 (five) districts, namely: Bonang District, W Gedung District, Karangtengah District, Sayung District and Demak District. The location of the research was determined purposively with the consideration that this district has various conditions for aquaculture exploitation.

Sampling/respondents in this study were carried out by random sampling method. The first stage of data collection was from March to July 2019 and the second stage was carried out from November 2019 to March 2020. Primary data for the production aspect were collected from 160 pond farmers. The data collection technique is done through observation, in-depth interviews, and conducting literature studies.

3.4 Data analysis

The analysis of the stochastic frontier production function is used to measure the technical efficiency of the milkfish pond farming in terms of output and the factors that affect technical efficiency. To analyze the efficiency of the technique in this study, the Cobb Douglas Stochastic Frontier production function model was used:

$$\ln Y = \beta 0 + \beta 1 \ln X1 + \beta 2 \ln X2 + \beta 3 \ln X3 + \beta 4 \ln X4 + \beta 5 \ln X5 + \beta 6 \ln X6 + vi - ui$$

Information:
Y = Milkfish output (yield) (Kg)
X_1 = Land area (Ha)
X_2 = Seed (Tail)
X_3 = Feed (Kg)
X_4 = Labor (Hours)
X_5 = Fertilizer (Kg)
X_6 = Chalk (Kg
β_o = intercept
βj = Estimator parameters (1,2,3,4,5,6)
v_i-u_i = *error term* (u_i = effects of technical inefficiency in the model)

To define distribution parameters (u_i) the effect of technical inefficiency in this study used the following equation:

$$\mu_i = \delta_0 + Z_1\delta_1 + Z_2\delta_2 + \omega_{1t}$$

In this study, the factors or variables that are thought to affect the level of technical inefficiency of milkfish farmers are Z_1, Z_2.

Information:
μ_1 = Technical inefficiency effects
Z_1 = Work experience as a milkfish pond farmer
Z_2 = Income outside of milkfish pond farming

Estimation of production function parameters and inefficiency function was carried out simultaneously with the FRONTIER 4.1 program. Testing of stochastic frontier parameters and technical inefficiency effects is carried out by estimating all parameters β_o, β_j, variants u_i and v_i using the Maximum Likelihood (MLE) method. At a confidence level of 1% - 10%, while the test criteria used is the one-way generalized likelihood ratio test.

4 Results and Discussion

4.1 Characteristics of Sample Farmers

The total sample of milkfish farmers in this study was 160 people, spread over five sub-districts within the Demak Regency area.

Table 1. Classification of Sample Farmers by region of origin

sub-district	amount	%
Wedung	37	23
Bonang	36	22
Karangtengah	32	20
Demak	19	12
Sayung	36	23
Total	160	100

4.2 The Use of Production Factors in Milkfish Farming

Production results are output obtained from a production process. The quality and quantity of the product produced depends on the factors of production and the technology used. The average use of production factors in milkfish pond farming in Demak Regency includes land area, seeds, feed, labor, fertilizer, and lime.

Table 2. Use of Production Factors and Yield/Hectares

No	Production Factors	amount	Unit
1	Land area	1	hectares
2	Seeds	4000	tail
3	Feed	90	Kg
4	Labor	187	HOK
5	Fertilizer	500	Kg
6	Chalk	100	Kg

4.3 Analysis of Estimation of Stochastic Frontier Functions

This study uses a stochastic frontier model with the Maximum Likelihood Estimator (MLE) estimation method. The MLE estimation for the Cobb Douglas production function parameter and the technical inefficiency effect model was carried out simultaneously from Coelli [20]. The analysis of the production function describes the relationship between the output produced in the production process and the use of its inputs.

The production function used in this analysis is a Cobb-Douglas production function with a stochastic frontier model based on the Maximum Likelihood (MLE) method to estimate the overall parameters of production factors (β_m), intercept (β_0), and variance of the two error components v_i and u_i (σv^2 and σu^2). Table 3 displays the results of the stochastic frontier production function estimation using six independent variables. The estimation result of the stochastic frontier production function has the following equation:

$$\ln Y = \ln 3.572 + 0.364 \ln X1 + 0.251 \ln X2 + 0.490 \ln X3 + 0.522 \ln X4 + 0.018 \ln X5 -0.523 \ln X6 + 0.061\ v_1 - 0.053\ u_1$$

Table 3. Estimation of the Stochastic Frontier Production Function

No	Variable	Coefficient	t-ratio
1	Constant	3.572	1.679
2	Land area	0.364	2.037**
3	Seeds	0.251	1.992**
4	Feed	0.490	2.041**
5	Labor	0.522	2.837***
6	Fertilizer	0.018	1.658*
7	Chalk	-0.523	-0.065
8	*Log Likelihood* OLS	-19.275	
9	*Log Likelihood* MLE	-5.149	
10	∑ß	1.122	
11	LR	21.36	
12	N	160	

Information:

*** is significant at α 1 percent; ** is significant at 5 percent α; * is significant at α 10 percent; t-table (α = 1 percent) = 2.167; t-table (α = 5 percent) = 1.96; t-table (α = 10 percent) = 1.64

Based on this equation, it is known that the return to scale is as follows:

$$\sum ß = X_1^{0.364} X_2^{0.251} X_3^{0.490} X_4^{0.522} X_5^{0.018} X_6^{-0.523} = 1.122$$

Table 3 shows the results of the estimation that the value of the generalized likelihood ratio (LR) of the stochastic frontier function of this model is 21.36 and is greater than the table value. The table value is statistically significant at α = 5% (12,405) which is obtained from the $\chi 2$ distribution table for the mixture of Kodde & Palm [21]. This means that the stochastic frontier production function can explain the existence of technical efficiency and inefficiency of farmers in the production process.

Table 3 above also shows that the log likelihood value in the Maximum Likelihood Estimation (MLE) method with a value of - 5,149 is greater than the log likelihood value in the Ordinary Least Square (OLS) method, which is - 19,275. This means that the production function with the MLE method is good and in accordance with the conditions in the field.

The estimated parameter of the Cobb-Douglas stochastic frontier production function shows the boundary elasticity of the production of the inputs used. The estimation results in Table 3 show that the elasticity value of the land area (X1) was found to have a significant effect on the production of milkfish pond farming with a value of 0.364. This figure shows the additional land area of 1%, still able to increase milkfish production in the research area with an additional production of 0.364%.

Variable seed (X2) was found to have a significant positive effect on milkfish production with a value of 0.251. This figure shows that the addition of 1% seedling cater is paribus can still increase milkfish production in the study area with an additional production of 0.251%. This elasticity value occupies the second stage in the production function, namely the rational stage. The addition of seeds is one of the right ways to increase milkfish production. From the results of this analysis, it can be seen that the use of seeds in Demak Regency per unit area of land can be continuously increased to obtain higher fish yields. The average of milkfish seeds that are spread by pond farmers in the research area in one hectare is 4000 heads/ha with a prediction of 50% life, so it is expected to harvest 2000 heads.

The number of milkfish seeds recommended for distribution by local fishery extension agents is 2,000-2,500 fish/ha for traditional fish farming. Traditional milkfish cultivation, the number of logs can be sown is around 3,000-5,000 heads/ha to produce an average production of 300-1,000 kg/ha/season.

Meanwhile, the limit production elasticity of the feed variable (X3) was found to have a significant effect on milkfish production with a value of 0.490. This figure shows that the addition of feed by 1% cater is paribus, can still increase milkfish production in the research area by 0.490%. This means that the amount of feed used is still possible to increase seeing changes in the increase in milkfish production is very small.

The labor variable (X_4) has a significant effect on milkfish production in the study area with a value of 0.522. This figure shows that the addition of labor has an effect on increasing milkfish production. Adding the workforce by 1% increases production by 0.522%. It is estimated that fertilization performed by pond farmers in the study area is less than ideal as suggested.

The value of the fertilizer variable (X_5) was found to have a positive coefficient value of 0.018, which means that an increase in fertilizer use by 1% will increase milkfish production by 0.018%. In the research area, the application of fertilizers is intended to grow moss as natural food in the pond which is the main feed for milkfish so that the amount of cost is relatively higher than the cost of buying artificial feed. The statistical test of the five variables, namely land area, seeds, feed, labor, and fertilizer, obtained a t ratio value that was greater than the t table with an error rate of 1% - 5%. This shows that the five variables statistically have a significant effect on the production of milkfish cultivation.

The lime variable (X_6) was found to have no significant effect on milkfish production with a value of -0.523. The use of lime in the research area is intended to clean ponds and purify water.

4.4 Return to Scale

The results of the calculation of the elasticity of each production factor based on the results of the estimation of the stochastic frontier production function with the MLE method can be seen in Table 3. Based on the results of the calculation of Table 3, it is known that the amount of elasticity/regression coefficient is 1.122. This value shows the return to scale (RTS) which is greater than 1 so that the milkfish pond farming is in a condition of increasing return to scale. This means that the production process of milkfish pond farming is at a production stage with an increasing scale or the proportion of increasing use of production factors gives a greater proportion of the output proportion increase. To calculate the Technical Efficiency (ET) of pond culture farmers, it can be done by comparing the actual production with the maximum production.

Table 4. Frequency Distribution of Technical Efficiency of Bandeng Fish Farmersg

No	Efficiency Level	amount	%
1	≤ 0.70	87	54
2	0.71 – 0.80	38	24
3	0.81 – 0.90	35	22
Total		160	100
Average		0.69	
Maximum		0.90	
Minimum		0.54	

By tracing the distribution of technical efficiency per individual milkfish pond farmer, it was found that the majority of 54% of the milkfish pond farmers were still at the level of technical efficiency ≤ 0.7. Farmers are categorized as efficiency if they have an efficiency level of more than 0.7.

Based on Table 4, it shows that the average technical efficiency value of the stochastic frontier function is 0.69 or 69%. The results of the estimation of the average efficiency level show that there is still a 31% chance for the average milkfish pond farmer to increase his production. The highest level of efficiency is 0.90, this means that farmers can reach at least 90% of the potential production obtained based on the combination of inputs used in milkfish pond farming activities. While the lowest level of efficiency is 0.54, this figure shows that in order to increase production, pond farmers must have effort and hard work by applying skills, cultivation techniques used by farmers who are the most efficient and the application of more advanced technology.

4.5 Sources of Technical Inefficiency

The factors that influence the efficiency level of milkfish pond farmers using the technical inefficiency effect model of the stochastic frontier production function are described in Table 5.

Table 5. Estimation of the Technical Inefficiency Effects of the Stochastic Frontier Production Function

Variable	Parameter	Estimated Value	t-Ratio
Constant	δ_0	2,154	1,362
Work experience	δ_1	2,793**	2,096
Income outside the milkfish ponds	δ_2	2,549**	2,436

The results of the inefficiency effect model estimation in Table 5 show that the working experience of milkfish pond cultivation and income outside the milkfish pond cultivation have a significant effect on $\alpha = 5\%$ in explaining technical inefficiencies in the production process of the pond farmers.

In several previous studies, experience is considered as a proxy for the age of the pond farmers, especially in traditional agriculture. The Farmers who are relatively old do not always have more experience than younger farmers, so the separation of age and experience variables as independent variables is considered relevant.

The income variable outside the farm has a significant effect on technical inefficiency. This condition indicates that an increase in income outside of farming will increase the level of inefficiency. This is very possible because if the income outside the milkfish pond business increases, it means that more time for the pond farmers is spent outside the pond business if the farmers are more ponds, because not all income is earned from outside the business.

4.6 Recommendation

The difference in the level of technical efficiency achieved by each aquaculture cultivator indicates that there are different levels of mastery and application of aquaculture technology. Improvement of management capability factors for milkfish pond cultivators such as education can reduce the inefficiency of the pond business.

The production of milkfish pond culture is technically not efficient, but it is worth cultivating. This study suggests improving technical efficiency to a higher level by optimizing the milkfish pond farmers the production factors that significantly affect the production yield.

Increasing the technical efficiency of the milkfish pond business in the short term can be done through improving education, the status of pond land ownership, easy access to finance and improving the sales pattern of the fishpond business harvest.

Increasing formal education for pond cultivators is directed at the specialization of the pond business, such as Vocational High Schools for Fisheries and Aquaculture. Meanwhile, non-formal education for pond cultivators is directed at training in farming skills such as replacing urea fertilizer with organic fertilizers, closed system technology, bioremediation and so on. It is necessary to carry out supervision by the Department of Fisheries and Livestock of Demak Regency on the pond business in using excessive urea.

4.7 Research Limitations

This research was only conducted in five sub-districts out of 14 sub-districts in the Demak Regency area, thereby reducing the generalization of findings related to the management context of the milkfish farming with those in various other regions in Indonesia. Another limitation is that the variable lime application has no effect on the yield, this requires a more in-depth analysis in future studies.

5 Conclusion

From the estimation results using the stochastic frontier production function, it was found that the area of land, milkfish seeds, feed, labor, and fertilizer had a significant effect on milkfish production. Meanwhile, the lime variable statistically does not significantly affect the milkfish pond farming production.

Statistically, work experiences in the milkfish pond business and the income of farmers outside the milkfish pond business have a significant effect on the technical inefficiency of milkfish farming.

The return to scale (RTS) value of the MLE production function in milkfish pond farming is greater than one, which is equal to 1.122, this indicates that the milkfish pond farming is in a condition of increasing return to scale, which means that the proportion of increasing the use of production factors appropriately will result in additional production with a larger proportion.

The average technical efficiency value of milkfish pond farming is 0.69. This value indicates the achievement of inefficient input use performance, because the technical efficiency value is below the critical value of 0.70.

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