Technical Efficiency of Catfish and Nile Tilapia Farming in Bangka Tengah Regency: A Stochastic Frontier Production Approach

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Abstract— Catfish and nile tilapia are food commodities which are important in fulfilling the need for nutrient consumption of most Indonesian people. In addition to domestic requirement, there is challenge of competitiveness at the level of ASEAN, namely the estabilishment of a free-market of ASEAN Economic Community (AEC). To increase the competitiveness, the quality of fishery product, particularly from catfish and nile tilapia farming, need to be improved. One effort to be performed is through the improvement of fingerlings and broodstock quality, as well as improvement in human resource and technology. Based on these reasons, research has been done and the purpose of this study was to analyze factors affecting catfish and nile tilapia production and to measure the level of technical efficiency. The study was conducted in Bangka Tengah Regency, Bangka Belitung Islands Province, Indonesia, based on the cross-sectional primary data collected from 71 catfish and nile tilapia farmers through of stratified random and systematic sampling methods. Furthermore, methods of analysis using the stochastic frontier production approach to look at the effect of inputs on catfish and nile tilapia production, followed by the analysis of technical efficiency (TE). Result showed that stochastic frontier Cobb-Douglas indicated that production input variables such as pond size, fingerlings, feed, labour, salt, lime and fuel pump statistically significant impacts on the catfish production, where the output elasticity associated with fingerlings is the highest (0.715), while, result of analysis showed that pond size, labour, salt, and fuel pump statistically significant impacts on the nile tilapia production, where the output elasticity associated with labour is the highest (1.005). The TE of catfish farming ranges between 0.130 and 0.999 with mean of 0.678, and the TE of nile tilapia farming ranges between 0.047 and 0.999 with mean of 0.221. The analysis of technical inefficiency aspect suggested that the length of formal education, and membership of fish farmer group in catfish farming were factors that contribute significantly and positively to technical efficiency of catfish farms. In the case of nile tilapia farming factors such as membership of fish farmer was factor that contribute significantly and positively to technical efficiency. By looking at these results, the government should optimize more intensive training workshops in fisheries for fish farmers, particularly fish farmers who have never participated in training workshops; in order to increase the knowledge and efficiency of catfish and nile tilapia farmers.

Index Terms— Catfish, nile tilapia, farming, stochastic frontier production, technical efficiency, Bangka Tengah Regency, Indonesia.

1 Introduction

CATFISH and nile tilapia production potential in Indonesia is quite high, production of catfish has reached 679 379 tonnes and nile tilapia has amounted to 999 695 tonnes, each production have grown significantly with average value of 3 percent of catfish farms and 7.06 percent of nile tilapia farms in 2010–14. Production and demand of catfish and nile tilapia commodity continue to grow with growth value from quarter I to quarter III in 2015 amounted to 11.53 percent (catfish) and 22.75 percent (nile tilapia). Domestic consumption of catfish and nile tilapia according to the national household preference in 2013 reached 3.30 percent for catfish and 4.90 percent for nile tilapia, it is estimated that consumption will continue to increase along with the increasing population (Pusdatin KKP 2015).

In addition to domestic requirement, there is competitiveness challenge at the level of ASEAN. To fulfill the domestic requirement and to anticipate free market of ASEAN economic community (AEC), effort in fish culture is needed, one of them is by performing efficient fish farming. Efficient condition needs minimum input and high production, thus resulting in competitiveness. Efforts requires to increase the quality of catfish and nile tilapia fishery products can be done by (i) increasing the quality of fingerlings and enhancing the use of other inputs, (ii) improvement in human resource, (iii) adopting new technology, and (iv) increasing the efficiency of farming operations (KKP 2016).

Statistically, efficiency can be conducted through many theorical approaches. One estimation method of efficiency level commonly used is through stochastic frontier analysis (SFA) model approach. SFA is applied with an emphasis on the condition of maximum output that can be produced (Coelli *et al*. 1998). Efficiency is composed of three parts, namely: 1) technical efficiency (TE), 2) allocative efficiency (AE), and 3) economic efficiency (EE). The economic efficiency is composed of technical efficiency (TE) and allocative efficiency (AE). Technical efficiency (TE) reflects the ability of

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a farm to obtain maximum outputs from a given set of inputs, and allocative efficiency (AE) reflects the ability to use inputs in optimal proportion given their respective prices (Farell 1957). However, increasing in fishery technical efficiency (TE) is an important factor in productivity growth in Indonesia. Low productivity is expected due to the reason that some of fish farmers do not have enough capital to buy fingerlings, low number of fish hatchery, and the lack of knowledge of fish farmers concerning fish farming technics. Furthermore, the price of local feed that is quite expensive also becomes a burden for fish farmers in fulfilling the need for fish feed.

Based on the problems found in catfish and nile tilapia farm, research of catfish and nile tilapia farm in Bangka Tengah Regency, Bangka Belitung Islands Province, Indonesia was conducted. Hence, the objective of this study was to analyze factors affecting the production of catfish and nile tilapia, as well as to determine the level technical efficiency and identify technical inefficiency factors affecting technical efficiency of catfish and nile tilapia farming.

2 Materials and Methods

2.1 Area and Time of Study

The study was carried out in Bangka Tengah Regency, Bangka Belitung Islands Province, Indonesia. Bangka Tengah Regency consists of 6 sub-districts, Koba Sub-district, Lubuk Besar Sub-district, Namang Sub-district, Simpang Katis Sub-district, Pangkalan Baru Sub-district and Sungai Selan Sub-district. This study was conducted from May-June 2017, through depth interview on sample of fish farmers, both using structured questionnaire and discussion. Research was done to obtain statistic data of production of catfish and nile tilapia farming identification which were selected based on category of one fish grow-out cycle, namely grow-out of catfish from November 2016 until May 2017 and grow-out of nile tilapia from October 2016 until May 2017, in which production data were selected based on the last harvest in one grow-out cycle of production.

2.2 Sampling Technique and Data Collection Method

The population of farmers cultivating patterns according the stratified sampling technique was initially used to divide the freshawater aquaculture into strata: catfish, nile tilapia or both. Calculation of the number of sample of each stratum concerning the number of unit in stratum resulted in catfish sample of 26 respondents, nile tilapia sample of 27 respondents, and catfish and nile tilapia sample of 18 respondents (each of them was classified, namely catfish of 18 respondents and nile tilapia of 11 respondents). Total number of respondent that will be analyzed for each instance of catfish sample was 44 respondents, while it was 38 respondents for nile tilapia sample. But in this study, there are 4 catfish farmers are just issued due to different characteristics with the other respondents. A pre-tested questionnaire was used to collect technical and economic data from the catfish and nile tilapia farmers, as well as socio-demographic enviromental characteristics.

2.3 Data Analysis Technique

Method of data analysis was performed based on stochastic frontier Cobb-Douglas production function approach, which is linear in log. The regression analysis was applied to identify factors affecting the production of catfish and nile tilapia. Moreover, value of technical efficiency (TE) of catfish and nile tilapia farms was also obtained by using software of Frontier version 4.1.

Regression function of stochastic frontier Cobb-Douglas was built into two models, namely regression function of stochastic frontier Cobb-Douglas of catfish and regression function of stochastic frontier Cobb-Douglas of nile tilapia, which used seven variables included pond size (X1), fingerlings (X2), feed (X3), labour (X4), salt (X5), lime (X6), and fuel pump (X7).

The model is specified as follow:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + V_i - U_i \quad (1)$$

Where:
Y = catfish/nile tilapia production (kg)
X_1 = pond size (m^2)
X_2 = fingerlings (number)
X_3 = feed (kg)
X_4 = number of labour use (hour)
X_5 = salt (kg)
X_6 = lime (kg)
X_7 = fuel pump (liter)
β_0 = intercept / constant
β_1, β_2, β_3, β_4, β_5, β_6 dan β_7 = coefficient parameter estimators
V_i-U_i = V_i is error and U_i technical inefficiency effect in the model.
The expected value was β_1, β_2, β_3, β_4, β_5, β_6 dan $\beta_7 > 0$.

The next stage was calculating the level of technical efficiency (TE) using the equation as follows:

$$TE_i = \exp(-E[U_i | \varepsilon_i]),\ i = 1,2,3,\ldots,n \quad (2)$$

TE_i is technical efficiency of fish farmer-i, $\exp(-E[Ui | \varepsilon_i])$ is the expected value for U_i with condition of ε_i, so that, $0 \leq TE \leq 1$. In this study, calculation method of technical efficiency referred to the model of Coelli (1996) which considered the effect of technical inefficiency (Ui) that was a reflection of social aspect of fish farmers. Variable of Ui was assumed as exponential of i.i.d (independently and identically distributed-i.i.d) or random variable with half-normal distribution or also called as truncated normal distribution (Schmidt and Lovell 1979), and used to measure the effect of technical inefficiency (Ui). The determinant factor of technical inefficiency is defined as:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + W_{it} \quad (3)$$

where:
U_i = technical ineficiency effect
Z_1 = age of the farmers (year)

Z_2 = formal education (year)
Z_3 = years of experience (year)
Z_4 = training in fisheries (1 if farmer got technical training, 0 otherwise)
Z_5 = access to fisheries officer (1 if access , 0 otherwise)
Z_6 = source of fingerlings (1 if private, 0 otherwise)
Z_7 = membership of farmer group (1 if member, 0 otherwise)
Z_8 = membership of cooperative (1 if member, 0 otherwise)
δ_0 to δ_8 = inefficiency parameters
The expected values were: $\delta_0>0$, $\delta_1>0$, $\delta_2,\delta_3,\delta_4,\delta_5,\delta_6,\delta_7,\delta_8 <0$.

The maximum likelihood estimate (MLE) was used to estimate the parameters of the the stochastic frontier Cobb-Douglas production function. The estimates for all the parameters of the stochastic frontier Cobb-Douglas production function and the technical inefficiency regression were simultaneously obtained using the FRONTIER Version 4.1 software (Coelli 1996). Thus, in the process, the variance parameter (σ_v^2 and σ_u^2) are given as follows:

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \quad (4)$$

and

$$\gamma = \sigma_u^2 / \sigma^2 \quad (5)$$

The value of the γ parameter ranges from 0 and 1 which determines the presence or absence of technical inefficiency. If γ = 0 then all deviations from the production frontier are because of no noise and the average response function is an adequate representation of the data. However, if γ = 1 it denotes that all deviations from the production frontier are exclusively a result of technical inefficiency (Battese & Corra 1977).

In addition, the technical inefficiency model in equation 3 can only be estimated if the technical inefficiency effect, U_i's are stochastic and have particular distributional properties (Coelli & Battese 1996). Therefore, it is of interest to test the null hypothesis that the technical inefficiency effect are absent: $\gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = \delta_8 = 0$ (where subscripts represent age, formal education, experience, training in fisheries, access to fisheries officer, source of fingerlings, membership of fish farmer group and membership of the cooperative, respectively). The stochastic frontier model reduces to a traditional average function in which the explanatory variables in the technical inefficiency model are included in the production function. Failure to reject the null hypothesis $H_0 : \gamma = 0$ implies that the existence of stochastic frontier. Similarly, γ = 1 implies that all the deviation from the frontier are due to the technical inefficiency (Coelli *et al.* 1998).

Following Battese and Coelli (1995), these and related null hypothesis can be tested using the generalized likelihood-ratio statistic (LR), given by:

$$LR = -2[\ln\{L(H_0)\} - \ln\{L(H_1)\}] \quad (6)$$

where $L(H_0)$ and $L(H_1)$ denote the maximized values of the likelihood function under the restricted (H_0) and unrestricted (H_1) models respectively. However, if the given null hypothesis is true, then the LR statistic has approximately χ^2 distribution or mixed χ^2 distribution with a degree of freedom equal to the number of parameters, assumed to be zero in the constrained model. On the other hand, if the hypothesis one side (γ = 0), Coelli (1995) proposed the use of Table 1 Kodde and Palm's (1986) critical values rather than χ^2 distribution for the LR test.

3 Results and Discussion

3.1 Summary Statistics

Table 1 presents the summary statistics of the data collected in the study with independent and response variables of catfish and nile tilapia culture. The table shows that the average production of catfish farming (7.17 kg m^{-2}) is comparatively larger compared with nile tilapia farming (1.79 kg m^{-2}). The average pond size of catfish farms is 372.12 m^2 which is lower compared with nile tilapia farms is 570.03 m$^{2.}$ Stocking density of catfish farms on average (number of fingerlings released per m^2) is 110.45 pieces while stocking density of overall nile tilapia farms on average is 24.74 pieces, which has considerable variation in the two farm types as catfish farmers used more fingerlings compared with nile tilapia. Based on Shafrudin *et al.* (2006) if stocking density is too low, the growth of fish not too rapidly, so production is not maximum. However, some of the catfish farmers have a hatchery unit on their farm, and hence produce their own seed. Feed is one of the important components in aquaculture and contributes more than 50% of the poduction cost. Thus, some catfish and nile tilapia farmers used commercial feed, supplementary feed available in the market such as rice bran, chicken intestine, and water spinach. The average feed applications in the catfish system is 12.25 kg m^{-2} which is higher compare to earlier studies as the average feed application in the nile tilapia system is 4.27 kg m^{-2}. In catfish farming, farmers used more feed compared to nile tilapia. The average labour use in the catfish and nile tilapia farming is 0.64 hours m^{-2} and 0.52 hours m^{-2}, respectively. Catfish farmers used more salt (0.17) and lime (0.18) compared with nile tilapia farmers used salt (0.05) and lime (0.16), indicating that farmers of both production systems use almost the same quantity of lime. The average fuel pump of nile tilapia farms is 12.25 liter which is higher compared with catfish farms is 5.56 liter. It is due to the reason that most Nile

TABLE 1
SUMMARY STATISTICS OF VARIABLES USED IN COBB-DOUGLAS *STOCHASTIC FRONTIER* PRODUCTION FUNCTION

Variables	Catfish farmers		Nile Tilapia farmers	
	Mean	Standard deviation	Mean	Standard deviation
Fish production (kg/m^2)	7.17	7.91	1.79	2.55
Pond size (m^2)	372.13	396.28	570.03	1054.71
Fingerlings (number/m^2)	110.45	143.64	24.74	36.06
Feed (kg/m^2)	12.25	15.17	4.27	5.65
Labour (hours/m^2)	0.64	0.73	0.52	0.52
Salt (kg/m^2)	0.17	0.29	0.05	0.07
Lime (kg/m^2)	0.18	0.34	0.16	0.16
Fuel pump (liter)	5.56	14.37	12.25	17.50
Age (years)	39.88	10.90	44.74	12.06
Education (years)	9.08	3.53	7.13	3.49
Experience (years)	5.51	3.86	5.82	2.93

kg = kilogram, m = meter

tilapia farmers still perform the fish farming in artificial earthen pond which usually requires fuel (gasoline) for the operation of water pump that is used to drain or empty the water pond after harvest. Furthermore, fuel is also used in feed machine to make artificial feedIt is due to the reason that most Nile tilapia farmers still perform the fish farming in artificial earthen pond which usually requires fuel (gasoline) for the operation of water pump that is used to drain or empty the water pond after harvest. Furthermore, fuel is also used in feed machine to make artificial feed. The average age of the sample catfish and nile tilapia farmers are 39.88 and 44.74 years respectively. This indicates that the both respondents are middle age. The average experience of farmers vary from 5.51 years in catfish to 5.82 years in nile tilapia. The educational level of most of the sample catfish farmers is high school and nile tilapia farmers is elementary school, indicating that they are literate.

3.2 Parameter Estimates of Stochastic Frontier

The maximum likelihood estimations (MLE) of the parameter in the Cobb-Douglas stochastic frontier production function and those in the inefficiency function are presented in Table 2. The value of coefficient of β parameter estimate obtained was its elasticity of frontier production (output).

The empirical results in Table 2 revealed that in the overall catfish farming the elasticity of output with respect to pond size, fingerlings, feed, labour and fuel pump are estimated to be 0.039, 0.715, 0.159, 0.086 and 0.004 respectively and statistically significant at 5% level of significance. The elasticity of output associated with fingerlings is the highest (0.715), indicating that, if the number of catfish fingerlings is increased by 10% increase, the catfish return is estimated to increase by 7.15% with assumption *cateris paribus*. The increase in the use of catfish fingerlings is expected to have positive effect on catfish production, unless the quality of fingerlings is very poor or diseased. The output elasticity with respect to salt and lime in overall catfish farming were estimated to be -0.028 and -0.006 respectively and are statistically significant at 5% level of significance which are unexpected but might be due to over use of input. This indicates that, if the salt and lime are increased by 10%, then the return from catfish are estimated to decrease by 0.28% or 0.06%, respectively. In the case of nile tilapia farming, the elasticity of output with respect to pond size, labour and fuel pump are estimated to be 0.199, 1.005 and 0.127, respectively, and have a positive impact on the outputs in nile tilapia culture and are all statistically significant at 5% level of significance. The output elasticity associated with labour is the highest (1.005). Based on the law of dimishing return, the productivity are decrease if the labour increase continously. The labour would added at certain conditions that increase in production, but, when the labour continuously will be added, otherwise, then it would be decreased in production. Chaudry and Amjad (2009) reported the large amount of labour needs also to be supported by the master of skill and has sufficient knowledge so as to maximize the improvement of agricultural productivity. Further, elasticity of frontier production with respect to salt is -0.044 and significant at the 10% level. This indicates that if the salt is increased by 10%, then return from nile tilapia is estimated to decrease 0.44%.

Most catfish and nile tilapia farmers applied lime and salt both as effort to maintain the stability of acidity (pH) of soil and water and to eradicate pest and disease. The type of lime used by fish farmer was dolomite agricultural lime. The salt used by fish farmer was NaCl that is coarse salt which has different purity from table salt in general and does not contain iodine, thus it is safe for fish. Excessive use of salt leads to fish dehydration which further results in death even though high concentration salt may have function to eradicate diseases, mainly those that caused by bacteria and fungi.

Furthermore, the return to scale (RTS), computed as the summation of output elasticities, are estimated to be 0.969 for catfish culture and 1.698 for nile tilapia culture. These denote catfish farmers have a constant return to scale (CRS) and nile tilapia farmers have an increasing return to scale (IRS). The implication are that if the sample fish farms increase all the combination of inputs production by 1%, the output of catfish would also increase by highest 1%, while the output of nile tilapia would also increase by another 1.70%.

Parameter of gamma (γ) value describes the variance of different output/production due to the influence of technical inefficiency effect or noise effect which are not included in the model (Ojo *et al.* 2009). According to the result of calculation, γ values obtained for catfish and nile tilapia farming were similar, namely 0.999 and it was statistically significant at 5% level. This indicates that the influence of inefficiency effect dominantly affected the model built, conversely, noise effect did not affected the model dominantly. The estimated γ is similar to those reported by Begum *et al.* (2016) respectively. The same research results indicate that the effects of the inefficiency of the more dominant effect of noise is the research conducted by Alawode and Jinad (2014) as well as Crentsil and Essilfie (2014).

3.3 Factors of Technical Inefficiency

The results from the technical inefficiency model indicate that the farm-specific variables have either a positive or a negative impact on technical efficiency, both as a group and several of them individually, as reported in Table 2. Those factors with a positive (negative) coefficient will have a negative (positive) influence on technical efficiency. In overall catfish farming, formal education, experience, source of fingerling, membership of fish farmer group and membership of cooperative have positive impact on technical efficiency (negative impact on technical inefficiency) and age, training in fisheries and access to fisheries officer have negative impact on technical efficiency (positive impact on technical inefficiency).

The coefficient of formal education and membership of fish farmer group are both negative and statistically significant at 5% improve technical efficiency of catfish farming. The coefficient of formal education has a positive impact on technical efficiency, supporting that education increases the ability to perceive, interpret and respond to new technology

and thereby enhances the farmer's managerial skills to make judicious use of the agricultural inputs. The estimated formal education is similar to those reported by Begum *et al.* (2015); Iliyasu *et al.* (2014); and Singh *et al*. (2009) respectively. The membership of fish farmer group be positively related to

TABLE 2
MAXIMUM LIKELIHOOD ESTIMATES OF PARAMETERS OF THE COBB-DOUGLAS STOCHASTIC FRONTIER PRODUCTION FUNCTION

Parameter	Variable	Catfish farmers (n=40)			Nile Tilapia farmers (n=38)		
		Coefficients	Standard error	p-value	Coefficients	Standard error	p-value
	Stochastic frontier						
β_0	Constant	-1.199	0.071	0.000	-1.150	1.362	0.203
β_1	Ln pond size (X_1)	0.039**	0.017	0.028	0.199**	0.081	0.010
β_2	Ln fingerlings (X_2)	0.715**	0.012	0.000	0.249	0.203	0.115
β_3	Ln feed (X_3)	0.159**	0.013	0.000	0.149	0.126	0.122
β_4	Ln labour (X_4)	0.086**	0.028	0.004	1.005**	0.544	0.037
β_5	Ln salt (X_5)	-0.028**	0.001	0.000	-0.044*	0.029	0.070
β_6	Ln lime (X_6)	-0.006**	0.002	0.003	0.013	0.258	0.308
β_7	Ln fuel pump (X_7)	0.004**	0.001	0.012	0.127**	0.024	0.000
	Inefficiency function						
δ_0	Constant	-0.394	0.872	0.327	-0.975	0.671	0.078
δ_1	Age	0.024*	0.014	0.050	0.028**	0.009	0.002
δ_2	Formal education	-0.124**	0.054	0.014	0.044	0.034	0.102

technical efficiency. It is assumed that catfish farmers who belong to fish farm group are likely to benefit from better access to input and to information on improved farming practices, and to get donations from government such as fingerlings and feed machine. Being a member in farmers' group may lead sharing of infromation on farming technologies, which tends to influence the production practices of members through peer learning. The estimated membership of fish farmer group is positively significant with technical efficiency in catfish farming, which consistent with Crentsil and Essilfie (2014).

In the case of nile tilapia farming factor such as age, formal education, access to fisheries officer, source of fingerlings and membership of cooperative were positively related to technical, while the coefficient of experience, training in fisheries, and membership of farmer group were negatively technical inefficiency. The coefficient of membership of fish farmer group is negative and statistically significant at 5% improve technical efficiency of nile tilapia farming.

3.4 Distribution of Technical Efficiency Scores

The distribution of technical efficiency scores of the catfish and nile tilapia farms is shown in Table 3. Results show that the mean technical efficiency of the catsfish farmers in Bangka Tengah Regency is 68±26% (Mean ± Standard deviation), ranging from 13% to 99%, and the mean technical efficiency of the nile tilapia farmers in Bangka Tengah Regency is 22±21%, ranging from 5% to 99%. This implies that, on average, the sample of catfish and nile tilapia farmers in Bangka Tengah Regency incurred output loss of about 32% and 78%, respectively by due to technical inefficiency, given the current technological state and inputs level. In other words, there exist 32% and 78% potential for increasing output by the catfish and nile tilapia farms. There is therefore room for improvement in catfish and nile tilapia production in Bangka Tengah Regency given the available resources and available technology.

In addition, the results from the analysis of frequency distributions of the TE scores reveal that 42.5% of the catfish farmers and 5.26% of the nile tilapia farmers in the study area have TE scores equal to or more than 70%, as presented in Table 3. The indices of TE level indicate that if the average catfish farmers of the sample could achieve the TE level of its most efficient counterpart, then average catfish farmers could increase their return by 31% [1-(68/99)]. Similarly, the most technically inefficient catfish farmers could increase the return by 87% [1-(13/99)] if he/she could increase the level TE to his/her most efficient counterpart. On the other hand, the indices of TE indicate that if the average nile tilapia farmers of the sample could achieve the TE level of its most efficient counterpart, then average nile tilapia farmers could increase their return by 78% [1-(22/99)]. Similarly, the most technically inefficient nile tilapia farmers could increase the return by 95% [1-(5/99)] if he/she could increase the level TE to his/her most

efficient counterpart.

The mean technical efficiency of catfish and nile tilapia farms is 68% and 22% respectively, which is quite similar to the estimates of average agricultural farms (aquaculture and livestock/dairy farms) in the world, such as reported by Rahman *et al.* (2011) found the technical efficiency of prawn farming in Bangladesh to be 68%. Other studies such as Alam *et al.* (2011) found the TE of tilapia in Bangladesh farmers at 78%. Singh *et al.* (2009) estimated the TE of freshwater aquaculture in India to be 67% for one-stage procedure and 47% for two-stage procedure. Alawode and Jinad (2014) found the TE of catfish production in Nigeria at 52.9%. Begum *et al.* (2016) estimated the TE of freshwater prawn farming in Bangladesh to be 65%. Iliyasu *et al.* (2014) found the TE of cage fish farming in Malaysia at 79%. Crentsil and Essilfie (2014) estimated the TE of smallholder fish production in Ghana to be 73.88%. The wide inefficiency spectrum in this study is therefore not surprising and is similar to those reported in literature.

TABLE 3
FREQUENCY DISTRIBUTION OF TECHNICAL EFFICIENCY IN CATFISH AND NILE TILAPIA PRODUCTION

Technical efficiency range	Catfish farmers		Nile Tilapia farmers	
	Frequency	Percentage	Frequency	Percentage
0.00-0.10	0	0.00	9	23.68
0.11-0.20	2	5.00	18	47.37
0.21-0.30	2	5.00	3	7.90
0.31-0.40	2	5.00	4	10.53
0.41-0.50	3	7.50	0	0.00
0.51-0.60	7	17.50	0	0.00
0.61-0.70	7	17.50	2	5.26
0.71-0.80	4	10.00	1	2.63
0.80-0.90	1	2.50	0	0.00
0.91-1.00	12	30.00	1	2.63
Total	40	100.00	38	100.00
Mean	0.68		0.22	
Minimum	0.13		0.05	
Maximum	0.99		0.99	
Standard deviation	0.26		0.21	

Most inefficient nile tilapia farmers were in the position of increasing return to scale (IRS). This finding is in line with the study of Gunden *et al*. (2010) who stated that the majority of inefficient fish farmers fell into the category of IRS. According to Mussa (2011), small scale fish farmers in general were not in the optimal condition of business scale, thus resulted in low efficiency level achieved.

3.5 Test of Hypotheses

The generalized likelihood ratio test of various null hypotheses involving the restriction on the variance paramater, γ, in the stochastic production frontier and δ coefficient in the technical inefficiency model are presented in Table 4. The first hypothesis is tested for the presence of inefficiencies in the model. The test of significance of the inefficiencies in the model ($H_0 : \gamma = \mu = 0$) was rejected at the 5% significance level, indicating that the maximum likelihood estimation (MLE) is a significant improvement over an ordinary least squares (OLS) and inefficiencies are present in the model. The calculated value of statistic is 32.96 for catfish farms and 39.05 for nile tilapia farms, which is greater than the critical value (Table 4). In other words, hypothesis (1): the inefficiency effects are not present, symbolically,

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$$H_0: \gamma = \delta_0 = \delta_1 = \delta_2 = \dots\dots\dots = \delta_8 = 0$$

where the null hypothesis is rejected for the catfish and nile tilapia farming indicating the significant presence of inefficiency effects on catfish and nile tilapia farming. Thus the traditional average response function is not an adequate representation for catfish and nile tilapia production, given the specification of the stochastic frontier and inefficiency model, defined by Equation (1) and (3).

The second null hypothesis H_0: $\delta_0 = \delta_1 = \delta_2 = \dots = \delta_8 = 0$ were tested using the generalized likelihood-ratio statistic, *LR*, defined by Equation (3), specifies that technical inefficiency follows a half-normal distribution with zero mean originally proposed by Aigner *et al*. (1977). This null hypothesis is rejected at 10% level of significance for catfish farming suggesting that, and the null hypothesis is not rejected at 10% level of significance for nile tilapia farming. For in the case of catfish farming, given the stochastic frontier with the model for technical inefficiency effects, the standard stochastic error component model is not appropriate for the half-normal distribution, and in the case of nile tilapia farming *vice versa*.

TABLE 4
LIKELIHOOD RATIO TESTS OF HYPOTHESES FOR PARAMETERS OF THE STOCHASTIC FRONTIER

Null hypothesis	Test statistic (*LR*)	DF	Critical χ^2 value	Decision
1. No inefficiency effect (H_0 : $\gamma = \delta_0 = \delta_1 = \dots = \delta_8 = 0$)				
Catfish farming	32.964	10	17.67	Reject H_0
Nile tilapia farming	39.048	10	17.67	Reject H_0
2. Technical inefficiency effects have a half normal dsitribution with mean zero (H_0 : $\delta_0 = \delta_1 = \dots = \delta_8 = 0$)				
Catfish farming	13.33	9	12.74	Reject H_0
Nile tilapia farming	0.00	9	12.74	Cannot reject H_0

Note: The critical values for the hypotheses are obtained from Table 1 of Kodde and Palm (1986, p. 1246), whereas the other value in this column represents chi square values.

4 Conclusion

This study examines the factors affecting catfish and nile tilapia production and to measure the level of technical efficiency, which analyzed using the stochastic frontier production approach, including a model for the technical inefficiency effects. The results showed that pond size, fingerlings, feed, labour, and fuel pump are statistically significant factors contributing positively to the production of catfish, where the output elasticity associated with fingerlings is the highest (0.715). In the case of nile tilapia, pond size, labour and fuel pump are statistically significant factors contributing positively to the production of nile tilapia, where the output elasticity associated with labour is the highest (1.005). The mean technical efficiency level of catfish and nile tilapia farming were 68% and 22% respectively impliying that a substantial 32% and 78% of the potential for increasing output from the catfish and nile tilapia farming system by eliminating inefficiency. There is therefore room for improvement in catfish and nile tilapia production in Bangka Tengah Regency given the available resources and available technology. Another that, our estimates suggest that these efficiency gains could mainly come from increased production intensity, from the improvement in the adoption of management practices, and making better use of other inputs. The quality, quantity of feeds, and frequency of feeding are important considerations in catfish and nile tilapia farming management, which will increase the productivity of catfish and nile tilapia farming. Finally, the length of formal education, and membership of fish farmer group in catfish farming are significant determinants of technical inefficiency of catfish farms. In the case of nile tilapia farming factors such as membership of fish farmer is significant determinants of technical inefficiency of nile tilapia farms. By looking at these results, the government should optimize more intensive training workshops in fisheries for fish farmers, particularly fish farmers who have never participated in training workshops; in order to increase the knowledge and efficiency of catfish and nile tilapia farmers. The catfish and nile tilapia seed industry also need to be standardized and regulated. Government needs to establish an agency to certify the quality of catfish and nile tilapia seeds. This will go a long way in helping newly estabilished hatcheries to secure market for their products as potential customers will have little fear in certified fingerlings.

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