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Productive Efficiency of Fish Production as a Panacea for Economic Recession among Farming Household in South-West, Nigeria

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Abstract: This study investigates production and cost efficiency as well as economic efficiency of fish farming. The study is based on primary cross sectional data collected from 6 Local Government Area (LGAs) selected from the 6 states that make up the of South-Western zone of Nigeria, on a representative basis of one local government per state. The farmer's economic efficiencies are estimated as the product of TE and AE. The production technology of the farmers is assumed to be specified by the Cobb-Douglas frontier production function. Findings from the results indicate that a unit increase in use of feed, high stock density, quantity of lime and organic fertilizer used will increase fish output by 3.37, 0.75, 0.06 and 0.69%, respectively. The study reveals that fish farming operation in the study area is yet to achieve the maximum possible efficiency level. The results indicate that involvement in fish farming under high level of productive efficiency will increase fish supply in Nigeria, thereby reducing fish importation with an attendant improvement in the value of Foreign reserve and by extension stability in the Foreign exchange value.

Key words: Fish, production-efficiency, cost-efficiency, economic-efficiency, stochastic frontier, organic fertilizer

INTRODUCTION

The contribution of fish farming to national development is palpable. This is evident through provision of essential services such as supporting nutritional well-being, providing feedstock for the industrial sector, making contributions to rural development increasing export opportunities, facilitating effective administration of natural resources and conservation of biological diversity (Ajao, 2011). The assertion by Ajibefun and Daramola (1999), holds that developing economies rely mainly on fish farming as the major avenue to generate protein. This predicts the viability of fish farming in Africa, especially in Nigeria where population is constantly on the increase. This portends high profitability for fish farming in Nigeria where supply of protein appears inadequate based on cursory observation. It is also pertinent to note that health challenges have conditioned individuals to adhere strictly to consumption of fish at the expense of meat. This realisation may serve as a fulcrum for conclusion that fish farming has greater percentage of yielding maximum profits. Experienced and established fish farmers could also explore opportunities embedded in new trends at occasions and recreation centres where fish barbeque has become a delicacy sought after by many. The market is ripe but the challenge of finance and managerial incapability may be the major encumbrances confronting the Nigerian fish farmers (FAO., 2014).

MATERIALS AND METHODS

Stochastic frontier modelling is popular because of its flexibility and ability to closely combine the economic concepts with modelling reality. Based on this, the model is employed in this study to provide the basis for measuring farm-level technical efficiency and allocative efficiency which are the basis for estimating the economic efficiency of fish farming in the study area. The modelling, estimation and application of stochastic frontier production function to economic analysis assumed prominence in econometrics and applied economic analysis following Farrell (1957)'s, seminal paper where he introduced a methodology to measure the technical efficiency, allocative efficiency and economic efficiency of a firm. According to Farrell, the TE is associated with the ability of a firm to produce on the isoquant frontier while the AE refers to the ability of a firm to produce at a

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given level of output using the cost-minimizing input ratios. Thus, EE is defined as the capacity of a firm to produce a pre-determined quantity of output at a minimum cost for a given level of technology (Bravo-Ureta and Pinheiro, 1997). However, over the years, Farrell's methodology had been applied widely while undergoing many refinements and improvements. Aigner *et al*. (1977), Meeusen and van den Broeck (1977) were the first to propose stochastic frontier production function and since, then many modifications had been made to stochastic frontier analysis. The model used in this study is based on the one proposed by Battese and Coelli (1995) and Battese *et al*. (1996) in which the stochastic frontier specification incorporates models for the inefficiencies effects and simultaneously estimate all the parameters involved in the production and cost function models.

The stochastic frontier function model of Cobb-Douglas functional form is employed in this study to estimate the farm level TE and AE of the farmers in the study area. The Cobb-Douglas functional form is used because of the following: the functional form has been widely used in farm efficiency both for the developing and developed countries, the functional form meets the requirement of being self-dual, allowing an examination of EE and Kopp and Smith (1980), suggested that the functional form has limited effects on empirical efficiency measurement. The Cobb-Douglas production functional form which specifies the production technology of the farmers is expressed as:

$$Y_i = f(X_i; \beta) \exp V_i - U_i$$

where, Y_i represents the production of the ith farm which is measured in kg; X_i represents the quantity of fish inputs used in the production. The V_I are assumed to be independent and identically distributed random errors, having normal N $(0, \sigma_v^2)$ distributional and independent of the U_i technical inefficiency effects which are assumed to be Non-negative truncation of the half-normal distribution N $(\mu, \sigma u^2)$. The TE of individual farmers in the study area is defined in terms of the ratio of observed output to the corresponding frontier's output, conditional on the level of input used by the farmers. Hence, the TE of the farmer is as:

$$TE_i = {Y_i}/{Y_i^*} = (X_i; \beta) \exp(V_i - U_i) / f(X_i; \beta)$$

$$\exp V_i = \exp(-U_i)$$

Where:

Y_i = The observed output of fish

Y_i^* = The frontier's output

The cost frontier of Cobb-Douglas functional form which is the basis of estimating the AE of the farmers is specified as:

$$C_i = g(Y_i, p, \alpha) \exp(V_i + U_i)$$

where, C_i represents the total input cost of the ith farm; g is a suitable function such as the Cobb-Douglas function; Y_i represents production of the ith farm; P_i represents input prices employed by the farm in fish production and measured in Nigerian Naira (N), α is the parameter to be estimated, V_i and U_i are random errors and assumed to be independent and identically distributed truncations (at zero) of the N $(0, \sigma^2 v)$ distribution. U_i provides information on the level of allocative efficiency of the ith farm. The AE of individual farmers is defined in terms of the ratio of the predicted minimum Cost (C_i^*) to observed Cost (C_i) as:

$$AE_i = C_i^* / C_i = \exp(U_i)$$

The farm-specific EE is obtained as the product of TE_i and AE_i. Given the assumptions of the stochastic frontier models, the inference about the parameters of the model can be based on the Maximum Likelihood Estimates (MLE) because the standard regularity conditions hold. Aigner *et al*. (1977) suggested that MLE of the parameters of the model can be obtained in terms of parameterization $\sigma^2 u + \sigma^2 v = \sigma^2 s$ and $\lambda = (\sigma^2 u \div \sigma^2 v)$. Battese and Corra (1977), replaced $\sigma^2 u$ and $\sigma^2 v$ with σ^2 (variance of composite term) $= \sigma^2 v + \sigma^2 v$ and $\gamma = \sigma^2 u \div (\sigma^2 u + \sigma^2 v)$. The parameter γ must lie between 0 and 1. In the case of $\sigma^2 v = 0$, γ would be equal to 1 and all the differences in error terms of the frontier production function are the results of management factors under the control of the producer (Coelli *et al*., 1998). When $\sigma^2 u = 0$, γ would be = 0 which means all the differences in error terms of the frontier production function are the results of the factors that the producer has no control on them, i.e., random factors. This also implies the existence of a stochastic production frontier. The value of γ close to 1 indicates that the random component of the inefficiency effects makes a significant contribution to the analysis of production system. The term γ statistic is used for hypothesis testing concerning the existence of inefficiencies. If $(H_0: \gamma = 0)$ is rejected it means that there are inefficiencies and the function could be estimated using MLE method. If H_0 is not rejected ordinary least squares method gives the best estimation of the production function.

The study is based on the primary cross sectional data collected from 6 states of Nigeria which include Lagos, Ogun, Oyo, Osun, Ekiti and Ondo. A multi-stage sampling techniques was used to select the respondents. The first stage, involved the purposive selection of Lagos Ogun and Oyo States from the 6 states in the zone. The three states were selected because they had the highest number of fish farms in the zone in year 2018. The second stage of the sampling involved, a purposive selection of four Local Government Areas (LGAs) in each of the 3 states where fish farmers are predominant. The 12 LGAs selected were identified to have the highest number of fish farms in the respective states. In the third stage, 4 communities from each of the selected LGAs were randomly selected to give a total of 48 communities. The number of fish farmers in each communities were used in the fourth stage where 4 or 5 respondents were randomly selected from each of the selected communities making a total of 240 respondents.

Method of data analysis: Stochastic frontier production and cost functions were used to analyze TE and AL of the farmers. The farmer's economic efficiencies are estimated as the product of TE and AE. The production technology of the farmers is assumed to be specified by the Cobb-Douglas frontier production function which is defined as:

$$\text{In } Y = \alpha+\beta_1 \text{ In } X_1+\beta_2 \text{ In } X_2+\beta_3 \text{ In } X_3+ \beta_4 \text{ In } X_4+\beta_5 \text{ In } X_5+\beta_6 \text{ In } X_6+(V_i-U_i)$$

Where:

- Y = Fish output (kg)
- $\alpha, \beta_1, \ldots, \beta_7$ = Parameters to be estimated
- X_i = Pond size (acre)
- X_2 = Stock density (No. of fingerlings per unit area)
- X_3 = Feed (kg)
- X_4 = Lime (kg)
- X_5 = Labor (man-days)
- X_6 = Fertilizer (kg)
- V_i = Random error having zero mean which Associated with random factors
- U_i = One-sided inefficiency component
- In = Symbol of natural logarithmic

The Cobb-Douglas cost frontier function for the fish farmers is specified and defined as follows (Ojo, 2003):

$$\text{In } C = \alpha+\beta_i \text{ In } Y+\beta_2 \text{ In } PX_1+\beta_3 \text{ In } PX_2+ \beta_4 \text{ In } PX_3+\beta_5 \text{ In } PX_4+\beta_6 \text{ In } PX_5+(V_i-U_i)$$

Where:

- C = Total production Cost in N
- Y = Fish output, $\alpha, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$ are parameters that was estimated
- PX_1 = Average Price of fingerlings (N)
- PX_2 = Average Price of feed (N/kg)
- PX_3 = Average in Price of fertilizer (N/kg)
- PX_4 = Price of pesticide
- PX_5 = Average wage rate V_i, U_i and In are as defined earlier

The model is estimated using the maximum likelihood method which gives the estimates of parameters $\lambda = (\sigma^2u \div \sigma^2v)$, σ^2u, σ^2v and σ. The γ is estimated from the estimates of σ^2u and σ^2v as $\gamma = \sigma^2u \div (\sigma^2u+\sigma^2v)$.

RESULTS AND DISCUSSION

The results in Table 1 show that most of coefficients have positive value except stock density under OLS estimation. There are only 4 variables that significantly influence fish output, namely: feed, stock density, lime and organic fertilizer. The implication of this result is 1% increase in use of feed, increase in stock density, use of lime and organic fertilizer will increase the fish production each 3.37, 0.75, 0.06 and 0.69%, ceteris paribus.

Most of the independent variables considered have positive significant coefficients up to 10% level of significance which indicate that there is a scope for increasing fish output by increasing the level of these inputs. The estimated elasticities of production of all the inputs are <1 indicating prevalence of "increasing returns to scale" in the study area. This shows that efforts should be made to expand the present scope of production to actualize the potential in it that is more of the variable inputs could be employed to realize more output in the study area.

The coefficients of MLE estimation explains that the stochastic production frontier function has the characteristic of increasing return to scale. It means that increasing use of inputs will proportionally increase the

Table 1: OLS and MLE estimation result of the stochastic production frontier function showing average product estimate's

	OLS estimation		MLE estimation	
Parameters	Coefficient	SE	Coefficient	SE
β_0	0.045***	0.07370	0.0538***	0.0104
β_1	0.0237	0.01490	0.0644	0.7510
β_2	3.337***	0.72100	0.851***	0.1440
β_3	0.746***	0.08370	0.541***	0.1050
β_4	0.0615***	0.00103	0.716***	0.0850
β_5	-0.0886	0.09110	0.996	0.9410
β_6	0.687***	0.10700	2.041*	0.9290
Sigma-square (δ^2)	0.0453	-	0.0447***	0.0068
Gamma (γ)	-	-	0.910***	0.0016
Log likelihood function	43.087		42.852	-
LR test	-		46.967	-

***Significant at α = 1%, **Significant at α = 5%, *Significant at α = 10%; Field data, 2018

Table 2: Frequency distribution, Technical Efficiency (TE) value in fish farming in South-West Nigeria

Efficiency range	Frequency	Relativefrequency
0.50-0.59	4	1.66
0.60-0.69	10	4.17
0.70-0.79	34	14.17
0.80-0.89	82	34.17
0.90-1.0	110	45.83
Total	240	100.00

Mean, 0.8330; Minimum, 0.5146; Maximum, 0.9823; SD, 0.1634; Field data, 2018

Table 3: OLS and MLE estimation result of the stochastic production frontier function showing average cost estimate's

	OLS estimation		MLE estimation	
Parameters	Coefficient	SE	Coefficient	SE
α	0.223****	0.149	6.041****	0.8620
α_1	0.447	0.737	0.201	0.2540
α_2	0.337	0.725	-0.802	-0.6110
α_3	7.46****	0.834	1.116****	0.3010
α_4	0.615****	0.103	0.417****	0.0046
α_5	0.886	0.911	0.351	0.3720
α_6	0.687****	0.107	-0.590****	0.1460
δ^2	0.0453	-	0.010	0.1010
γ	-	-	0.999****	0.1580
Log likelihood function	43.087		40.508	
LR test	-		51.576	

***Significant at α =1%, **Significant at α = 5%, *Significant at α = 10%. Field data, 2018

fish output to achieve maximum profit (Adeyonu *et al*., 2017). The value of γ is 0.910 and significant at 1% level of significant, implying that 91% of the random error is mostly influenced by inefficient factor outside stochastic model. The value of γ which approaching 1 also remain 1 side error where U_i dominated the symmetry error distribution from V_I. The explanation of 1 side error also strengthens by the value of likelihood ratio. It also reveals that the value of LR test is 46.85 which is greater than the LR function of 42.85. Since, the observe LR>LR function, we can conclude that the assumption that fish farming in South West Nigeria is 100% efficient.

According to Table 2, the average technical efficiency ranges between 0.515 and 0.982 with a mean value of 0.833. If the farmers with the minimum efficiency are able to achieve the maximum level of efficiency, they would be able to save as more cost as 47.56%. With the similar formula, the efficient farmers (farmers with mean efficiency) will be able to save 14.74% of their usual production cost (Adeyonu, 2015). The value (47.56%) saved cost for farmers with minimum efficiency was computed as 1-0.515 and 0.982 and likewise for those with mean efficiency level.

The technical efficiency distribution estimates shows that 98% of the farmers in the study area already operate at efficient level of production with a minimum efficiency gap as indicated by the value of the of standard. This

Table 4: Frequecy distribution, Cost Efficiency (CE) value in fish farming in South West

Efficiency range	Frequency	Relative frequency
0.50-0.59	4	1.67
0.60-0.69	14	5.83
0.70-0.79	40	16.67
0.80-0.89	86	40.00
0.90-1.0	96	35.83
Total	240	100.00

Mean, 0.825; Minimum, 0.505; Maximum, 0.937; SD, 0.192; Field data, 2018

Table 5: Decile ranges of frequency distribution, Economic Efficiency (EE) value in fish farming in South West Nigeria

Efficiency range	Technical Efficiency (TE)	Cost Efficiency (CE)	Economic Efficiency (EE)
0.50-0.59	0.522	0.512	0.267
0.60-0.69	0.641	0.645	0.413
0.70-0.79	0.750	0.767	0.575
0.80-0.89	0.831	0.818	0.679
0.90-1.0	0.982	0.938	0.921
Maximum	0.982	0.938	0.921
Minimum	0.522	0.512	0.267
Mean	0.745	0.572	0.571

Field data, 2018

result implies that resource management approach has successfully increased the technical efficiency of fish farming in South-West Nigeria.

The estimates of stochastic frontier cost function are presented in Table 3. The estimated values of all the parameters of price variables are positive. Most of the coefficients are significant at 1% level of significance. From the result of the maximum likelihood estimation procedure, the production cost, price of feed, price of fertilizer, price of pesticide and labor cost are significant implying that a little increase in those variables will increase the total cost of production.

This condition reflects that fish farming in this study area is very sensitive with the switch in production and input price. Since, incremental growth in fish output is greater than incremental growth in total cost of production, unit cost will decrease as the total output increases. The estimated values of δ^2 and γ are due to technical inefficiencies of the fish farms. The estimates indicate the presence of inefficiency effect over random error in fish farming.

The distribution of farms in decile ranges of predicted Cost Efficiency (CE) is in Table 4. The highest number of fish farmers have CE between 0.80-0.89 with a maximum efficiency of 0.94 and 0.51 minimum. It can be estimated from the mean and maximum levels of CE that the average farmer can realize a 46% cost saving. The minimum efficient farmers can earn additional 12.3% profit, if they can achieve the minimum cost efficiency. The Economic Efficiency (EE) has been estimated as the product of farm AE and TE. The distribution of fish farmers is shown in Table 5. The mean of EE is 57% as against 82 and 83% for

TE and CE, respectively. The TE appeared to be more significant than AE as a source of gains in EE. The result of the analysis indicated that TE and AE have effects on fish production as depicted by the estimated γ coefficient of the models and by the predicted TE and AE within the farms.

CONCLUSION

The study used a stochastic model to estimate TE, CE and EE of fish farming in South-West, Nigeria. The estimated mean TE, AE and EE levels fall within the range of 0.50 and 0.89. The corresponding mean TE, AE and EE values are estimated at the levels of 0.83, 0.86 and 0.57, respectively.

This study confirms that fish farming in South-West Nigeria can still increase output with the available resources until it attain an optimal level of production. According to the production and cost efficiency estimates, fish farming system is efficient in technical and cost. This is supported by the results which showed 83% of fish farmers in the study are efficient in technical and cost effectiveness, going by the findings from the study. On this premise, farmers in the study area can still increase their productivity and profit level.

The study, however, revealed that fish farming in the study area is yet to achieve maximum output level. Also, it is evident from this study that the EE of the farmers can be improved substantially and that AE constitutes relatively more serious problem than TE as judged by the average AE and TE estimated in the area. The results indicate that involvement in fish farming with high level of productive efficiency will increase fish supply in Nigeria, thereby reducing fish importation and stabilizing the nation's Foreign exchange value.

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