SUB-THEME 7: AGRIBUSINESS: PRODUCTIVITY, EFFICIENCY AND OTHER EMERGING ISSUES.

PRODUCTIVE EFFICIENCY OF FISH PRODUCTION: A PANACEA FOR ECONOMIC RECESSION AMONG FARMING HOUSEHOLD IN SOUTH-WEST, NIGERIA

Ajiboye, B. O.[1*], Bamiro O. M.[1], Adeyonu A. G.[1], Adigun G.T.[1]

[1]Department of Agricultural Economics, Landmark University, Omu-Aran, Kwara State, Nigeria
*CORRESPONDENCE E-MAIL: ajiboye.babatunde@lmu.edu.ng, G.S.M: 08034454153

ABSTRACT

This study investigates the level of production and cost efficiency as well as economic efficiency of fish farming. The study is based on primary cross sectional data collected from six local government area (LGAs) selected from the six(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 indicated that a unit increase in use of feed, high stock density, quantity of lime and organic fertilizer used will increase fish output. The study revealed that fish farming operation in the study area is yet to achieve its 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.

KEYWORD: Fish, Production efficiency, Cost efficiency, Economic Efficiency, Stochastic frontier

INTRODUCTION

Fish farming provides important services including 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). According to Ajibefun *et al* (2000), the most reliable source of protein for many people in the developing economies. Fish farming is potentially profitable because there is a ready market for fish due to the increasing population of Nigeria and the desire to meet the protein need of the people. Also, the preference of people for fish rather than meat, due to health challenges, makes fish farming a promising venture. Fish farmers who are established and are well experienced can be suppliers of fish to recreation centers such as restaurants, fast food joints and bars because fish barbeque is one of the favorite meal on people's menu.

Nigerian fish farmers are expected to tap into this opportunity, yet there is the lingering problem of financial and managerial incapability.

THEORETICAL FRAMEWORK

Stochastic Production and Cost Functions

The stochastic frontier modelling is becoming increasingly popular because of its flexibility and ability to closely combine the economic concepts with modelling reality. And, based on this, the model is employed in this study to provide the basis for measuring farm-level TE and AE, which are the basis for estimating the EE 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's (1957) 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 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) and Meeusen and Van de 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 to estimate the farm level TE and AE of the farmers in the study area. The Cobb-Douglas functional form is used because of: (a) the functional form has been widely used in farm efficiency both for the developing and developed countries, (b) the functional form meets the requirement of being self-dual, allowing an examination of EE, and (c) 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 follows:

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

Where, Y_i represents the production of the i^{th} farm, which is measured in kg; X_i represents the quantity of inputs used in the production. The Vis 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 (μ, σu2). The TE of individual farmers 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 expressed as:

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

Where, Y_i is the observed output and Y_i^* is 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 follows:

$$C_i = g(Y_{i,}p_i\alpha)\exp(V_i + U_i)$$

Where, C_i represents the total input cost of the i^{th} farm; g is a suitable function such as the Cobb-Douglas function; Y_i represents production of the i^{th} farm; P_i represents input prices employed by the i^{th} farm in fish production and measured in Indian Rupees (INR); 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, σ2v) distribution. Ui provides information on the level of allocative efficiency of the i^{th} 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 follows:

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

The farm-specific EE has been obtained as the product of TE_i and AE_i.

Given the assumptions of the above stochastic frontier models, the inference about the parameters of the model can be based on the maximum likelihood (ML) estimation because the standard regularity conditions hold. Aigner et al. (1977 suggested that ML estimates of the parameters of the model can be obtained in terms of parameterization $\sigma^2u + \sigma^2v = \sigma^2s$ and $\lambda = \sqrt{}\,(\sigma^2u \div \sigma^2v)$. Battese and Corra (1977) replaced σ^2u and σ^2v with σ^2 (variance of composite term) = $\sigma^2u+\sigma^2v$ and $\gamma = \sigma^2u \div (\sigma^2u + \sigma^2v)$. The parameter γ must lie between 0 and 1. In the case of $\sigma^2v = 0$, 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 $\sigma^2u = 0$, γ would be equal to zero, 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. γ close to 1 indicates that the random component of the inefficiency effects makes a significant contribution to the analysis of production system. 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 ML estimation method. If H_0 is not rejected, ordinary least squares method gives the best estimation of the production function.

METHODOLOGY

Study Area

The study area is Southwest Nigeria comprising of Lagos, Ogun, Oyo, Osun, Ondo and Ekiti States. Southwest Nigeria is within the tropical rainforest, the area has bimodal rainfall distribution. The area lies between longitude $2^0\ 31^1$ and $6^0\ 00^1$ East and Latitude $6^0\ 21^1$ and $8^0\ 37^1$N (Agboola, 1979) with a total land area of 76,852km^2 and a population of 27,722,432 (National Bureau of Statistics, 2011). The study area is bounded in the East by Edo and Delta States, in the North by Kwara and Kogi States, in the West by the Republic of Benin and in the South by the Gulf of Guinea.

The vegetation in Southwest Nigeria is made up of fresh water swamp and mangrove forest, the low land forest stretches inland to Ogun State and part of Ondo State while secondary forest is towards the northern boundary where derived and southern Savannah exist (Agboola, 1979).. There are distinct dry and rainy seasons. The wet season is associated with the Southwest monsoon wind from the Atlantic Ocean while the dry season is associated with the northeast trade wind from the Sahara desert. The region has an average annual rainfall and temperature of 1486mm and 26.70C respectively (Omotosho, 2009). The region has high density of human population with rain-fed agriculture as primary occupation of the people. The states are known for the cultivation of food crops such as maize, cocoyam, cassava, vegetable and yam (Oyekale, 2009).

Sampling Procedure/Sample Size

The study is based on the primary cross sectional data collected from six States in the South-west Nigeria. Primary data were collected through the use of well-structured questionnaire. The questionnaire covered socio-economic characteristics and fish production variables.

A proportionate sample of fish farmers were selected from one Local Government Area (LGA)) per state, namely Ikorodu (Lagos) 10%; Yewa North (Ogun) 30%; Ibarapa Central (Oyo) 10%; Obokun (Osun) 10%; Akure South (Ondo) 20% and Ido-Osi (Ekiti) 20% leading to 240 respondents whose data were used for this study.

Method of Data Analysis

Stochastic frontier production and cost functions were used to analyze the technical and allocative efficiency 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:

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

Where, Y = Fish output (kg); $\alpha, \beta_1 .....\beta_7$ = parameters to be estimated; X_1 = 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 is associated with random factors; U_i = one-sided inefficiency component; and ln = symbol of natural logarithmic. The Cobb-Douglas cost frontier function for the fish farmers is specified and defined as follows (Ogundai and Ojo, 2006):

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

Where, C = Total production cost in ₦; Y= Fish output, α, β_1, β_2, β_3, β_4, β_5, β_6 are parameters to be estimated; PX_1 = average price of fingerlings (₦); PX_2 = average price of feed (₦ per kg), PX_3 = average price of fertilizer (₦ per kg), PX_4 = Price of pesticide, PX5 = 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 λ (= $\sqrt{}$ ($\sigma^2u \div \sigma^2v$), σ^2u, σ^2v, and σ. 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 four variables that significantly influence fish output, namely: feed, stock density, lime and organic fertilizer. The implication of this result is that a unit 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 independent variables considered have positive significant coefficients up to 10 per cent 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 less than one, 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

Table 1: OLS and MLE Estimation Result of the Stochastic Production Frontier Function Showing Average Product Estimates'

Parameter	OLS estimation		MLE estimation	
	Coefficient	Standard error	Coefficient	Standard error
β_0	0.045***	0.0737	0.0538***	0.0104
β_1	0.0237	0.0149	0.0644	0.751
β_2	3.337***	0.7210	0.851***	0.144
β_3	0.746***	0.0837	0.541***	0.105
β_4	0.0615***	0.00103	0.716***	0.085
β_5	-0.0886	0.0911	0.996	0.941
β_6	0.687***	0.107	2.041*	0.929
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	-

*Note *** Significant at α=1%, ** Significant at α=5%, * Significant at α=10%*
Source: Computed from Field Data, 2017

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 fish output to achieve maximum profit.

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 one side error, where U_i dominated the symmetry error distribution from V_i. The explanation of one 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 are greater than the LR function, we can conclude that the assumption that fish farming in South West Nigeria is100% efficient.

Table 2: Frequency Distribution, Technical Efficiency (TE) value in Fish farming in South-west Nigeria.

Efficiency Range	Frequency	Relative Frequency	Mean	0.8330
0.50-0.59	4	1.66	Minimum	0.5146
0.60-0.69	10	4.17	Maximum	0.9823
0.70-0.79	34	14.17	Standard Dev.	0.1634
0.80-0.89	82	34.17		
0.90-1.0	110	45.83		
Total	240	100		

Source: Computed from Field Data, 2017

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.

The value (47.56%) saved cost for farmers with minimum efficiency was computed as $1-\frac{0.515}{0.982}$, 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 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 percent 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 σ^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

Table 3: OLS and MLE Estimation Result of the Stochastic Production Frontier Function Showing Average Cost Estimates'

Parameter	OLS estimation		MLE estimation	
	Coefficient	Standard error	Coefficient	Standard error
α_0	0.223***	0.149	6.041***	0.862
α_1	0.447	0.737	0.201	0.254
α_2	0.337	0.725	-0.802	-0.611
α_3	7.46***	0.834	1.116***	0.301
α_4	0.615***	0.103	0.417***	0.0046
α_5	0.886	0.911	0.351	0.372
α_6	0.687***	0.107	-0.590***	0.146
Sigma-square (δ^2)	0.0453	-	0.010	0.101
Gamma (γ)	-	-	0.999***	0.158
Log likelihood function	43.087		40.508	
LR test	-		51.576	

*Note *** Significant at α=1%, ** Significant at α=5%, * Significant at α=10%*

The distribution of farms in Decile ranges of predicted Cost Efficiency (CE) is presented 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.

Table 4: Frequency Distribution, Cost Efficiency (CE) Value in Fish farming in South west Nigeria.

Efficiency Range	Frequency	Relative Frequency	Mean	0.825
0.50-0.59	4	1.67	Minimum	0.505
0.60-0.69	14	5.83	Maximum	0.937
0.70-0.79	40	16.67	Standard Dev.	0.192
0.80-0.89	86	40		
0.90-1.0	96	35.83		
Total	240	100		

Source: Computed field Data, 2017

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.

Table 5: Decile Ranges of Frequency Distribution, Economic Efficiency (EE) Value in Fish farming in South west Nigeria

Efficiency Range	Technical Eff. (TE)	Cost Eff. (CE)	Economic Eff. (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

Source: Computed from Field Data, 2017

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 had 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.

Fish farming system in South-west Nigeria can increase output 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.

REFERENCES

Aigner, D.J.; C.A.K. Lovell and P. Schmidt (1977), "Formulation and Estimation of Stochastic Frontier Production Function Models", *Journal of Econometrics*, Vol.6, No.1, July, pp.21-37.

Ajao A.O (2011): Comparative Technical Efficiency of Concrete and Earthen Fish Pond in Oyo State, Nigeria, *Journal of Science Frontier Research*, 11: 35-41

Ajibefun I.A and Daramola A. G, 2000: Measurement and Sources of Technical Inefficiency in Poultry Egg Production in Ondo State, Nigeria.,*Journal of Rural Ecology* 10:85-93

Bravo-ureta, B.E. and R.E. Evenson (1994), "Efficiency in Agricultural Production: The Case of Peasant Farmers in Eastern Paraguay", *Agricultural Economics*, Vol.10, No.1, pp.27-28.

Bravo-ureta, B.E. and E. Antonio Pinheiro (1997), "Technical, Economic and Allocative Efficiency in Peasant Farming: Evidence from the Dominican Republic", *The Developing Economics*, Vol.35, No.1, pp.48-67.

Battese, G.E. and G.S. Corra (1977), "Estimation of Production Frontier Model with Application to the Pastoral Zone of Eastern Australia", *Australian Journal of Agricultural Economics*, Vol.21, No.1, pp.169-179.

Battese, G.E.and T.J. Coelli (1995), "A Model of Technical Inefficiency Effects in a Stochastic Frontier Production for Panel Data", *Empirical Economics*, Vol.20, pp.325-345.

Battese, G.E.; S.J. Malik and M.A. Gill (1996), "An Investigation of Technical Inefficiencies of Production of Wheat Farmers in Four Districts of Pakistan", *Journal of Agricultural Economics*, Vol.47, pp.37-49.

Coelli, T.J.; D.S.P. Rao and G.E. Battese (1998), *An Introduction to Efficiency and Productivity Analysis*, Kluwer Academic Publishers, Boston, U.S.A.

Food and Agriculture Organization of the United Nations (2014): The State of World Fisheries and Aquaculture: Opportunities and Challenges. *Food and Agriculture Organization*: 3-22

Farrell, M.J. (1957), "The Measurement of Production Efficiency", *Journal of Royal Statistical Society*, Series A (General), Vol.120, Part 3, pp.253-290

Kopp. R.J. and V.K. Smith (1980), "Frontier Production Function Estimations of Steam Electric Generation: A Comparative Analysis", *Southern Econometric Journal,* Vol.47, pp.1049-1059.

Meeusen, W. and J. Van den Broeck (1977), "Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error", *International Economic Review*, Vol.18, No.2, June, pp.435-444.

Omotosho, J.B. (2009) Pre-rainy SeasonMoisture Build-up and Storm Precipitation Delivery in the West Africa Sahel. *International Journal of Climatology*. DOC:10.1002/joc.1548

Ojo, S. O. 2003: Productivity and Technical Efficiency of Poultry Egg Production in Nigeria. *International Journal of Poultry Science* 2:459-464

Oyekale, A., Bolaji, M. and Olowa, O. (2009). The Effects of Climate Change on Cocoa Production and Vulnerability Assessment in Nigeria. *Agricultural Journal*. Retrieved from http://www.medwelljournals.com/fulltext/?doi=aj.2009.77.85