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APPLICATION OF A STOCHASTIC FRONTIER PRODUCTION FUNCTION FOR MEASUREMENT AND COMPARISION OF TECHNICAL EFFICIENCY OF MANDARIN FISH AND CLOWN FISH PRODUCTION IN LOWLANDS RESERVOIRS, PONDS AND DAMS OF CROSS RIVER STATE, NIGERIA

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ABSTRACT

This study compared technical efficiency of mandarin fish and clown fish production in Cross River State, Nigeria. Data were obtained from 240 respondents including 120 mandarin fish farmers and 120 clown fish farmers, which were randomly selected from villages in the study area by means of structured and semi-structured questionnaire. Data collected were analyzed using descriptive statistics and stochastic frontier function that incorporated inefficiency effects that were estimated using the Maximum Likelihood Estimate (MLE). The result showed that the sum of elasticity for mandarin fish and clown fish were found to be 1.36 and 1.25, respectively implies that both production systems were operated in inefficient stage (technically inefficient). The result also showed that fish farmers' educational level, access to credit, farm size and feed positively influenced their levels of efficiency in mandarin fish and clown fish production systems in Cross River State. Extension agents should guide fish farmers on levels of inputs combination that would ensure efficient production of fish. Regular awareness campaign about new technologies in fish production should be embarked on by extension agents; this will enable fish farmers adopt new technologies in fish production. Extension agents should train fish farmers on improved production technique while banks should give loans to fish farmers and strictly monitor all her loan beneficiaries to ensure loan repayment. The study also recommends efficient policy formulation and implementation that will encourage fish farmers and unemployed youth in Cross River State to join fish producers cooperative(s) to enable them obtain loans at low interest rate from banks for increase in their capital base for higher output.

Key words: Analysis, Efficiency, Fish, Production, Resource, Use.

INTRODUCTION

Fish production is associated with rapid returns per unit investment. The two most important factors responsible for the credit supply increase in fish production has been profitability and quick returns on invested capital which encourages formal and informal credit institutions to provide needed capital more readily for fish production than other agricultural productions (Adinya and Ikpi, 2008; Offem *et al*, 2008).

According to Adinya and Ikpi (2008) Cross river State has the potential to be self- sufficient in fish production because of the presence of river and suitable ecological zone for its production either in ponds, dams or rivers. They further maintained that fish production in Nigeria has been inadequate to bridge the demand-supply gap because of non –optimal use of resource and enormous post –harvest losses. Farrel (1957) revealed that there are three important production efficiencies namely: technical, allocative and economic efficiencies. Technical efficiency is the measure of the farms success in producing maximum output from a given set of resources or is the ability of producing a given level of output with a minimum quantity of inputs under a given technology. Allocative efficiency is the ability of the farmer to use the inputs in optimal proportions given their respective prices and the production technology. Economic efficiency is the product of the technical and allocative efficiencies (Adinya *et al*, 2008). However, given the low rate of adoption of fish technologies by fish farmers, improvement in resource use efficiency remains the most cost effective way in enhancing productivity. From both theoretical and applied perspectives, measurement of efficiency is important because it might lead to resource saving, more profit from investment, effective loan repayment and also have important implication on both policy formulations and firm management (Bravo-Ureta and Rieger,1991; Egbetokun and Ajijola, 2008; Enya and Adinya, 2008).

METHODOLOGY

A multi stage sampling procedure involving simple random sampling techniques were used to select the respondents. At the first stage, 12 local government areas were selected from18 local government areas. Then two (2) fish producing/ farming communities were randomly chosen from each of the local government area (24 fish farming communities were randomly chosen from (12) local government areas). One village was randomly chosen from each of the communities (24 villages were taken from 24 fish farming communities). Ten respondents (5 mandarin fish and 5 clown fish farmers) were randomly selected from each of the selected villages in the study area. In all, 240 questionnaires were distributed to 240 respondents (120 mandarin fish farmers and 120 clown fish farmers. Data for the study were elected from primary source. Mainly from field survey.

The analytical tools that were employed in this study include: descriptive statistic and Cobb-Douglas functional form of the stochastic frontier analysis. The Cobb-Douglas functional form of the stochastic frontier was used to determine the technical efficiency or in efficiency of fish farmers in study area:

Model specification the stochastic frontier production function, (Coelli, 1996) is specified as follows:

Y = f (Xi, âi) + Vi – Ui …equation (1)

where Y = observed output of the ith fish farmer in kg

F(.) = an appropriate function (e.g. Cobb-Douglas, Trans slog, etc)

Xi = vector of inputs (known functions of factor inputs (fish pond size, labour, capital and quantity of feed applied) and their relevant explanatory variables associated with the production of the ith fish farmer

Âi = vector of unknown parameters associated with explanatory variables in the production function

Vi = random error term

Ui = non-negative one sided error term that measures inefficiency

Using the method of Jondrow *et al,* (1982), technical efficiency can be measured using the adjusted output as shown:

Y* = f(Xi âi) – Ui …equation (2)

where Ui can be estimated as

äë[F* (åië/ä)- åië]
E(Ui /åi) = -------------------------------- equation (3)
1+ $ë^2$ [1-F* (åië/ä)- ä

where F* and F*(1) are standard normal density and cumulative distribution functions respectively.

ë = äu/ äv åi = Vi-Ui $ä^2$ = äv ^{2}+ $äu^2$

V* is the observed output adjusted for statistical noise

When åi ä and ë estimates were replaced in equation (2) and (3), the estimates of Vi and Ui were obtained.

In this study Cobb-Douglas production function was fitted to the frontier model of the two species of fish production systems and estimated using the maximum likelihood method. This is specified as follows:

$$Ln\ Yi = Lnb_o + b_1 LnX_{1i} + b_2 LnX_{2i} + b_3 LnX_{3i} + b_4 LnX_{4i} + b_5 LnX_{5i} + åi … \text{equation (4)}$$

where: Y= output of fish (kg)

X_1 = fish pond size (hectares)

X_2= labour used in fish production in (man-days)

X_3 = feed (kilogram)

X_4 = fingerlings(kilogram)

X_5 = capital (naira)

Ln = natural logarithm

b_o - b_5 = Regression coefficients to be estimated

åi =composite error term(Vi- Ui)

Technical efficiency is the measurement of fish farm success in producing maximum output from a given set of resources (Farrel, 1957).

Determinants of technical efficiency

This is defined mathematically as:

$$TEi= a_o + a_1Z_1 + a_2Z_2 + a_3Z_3 + a_4Z_4 + a_5Z_5 + a_6Z_6 + a_7Z_7 + a_8Z_8 + e \text{ …equation (5)}$$

where TEi = technical efficiency of the i-th fish farmer

Z_1=farmer's educational level(years of schooling)

Z_2= farming experience (years)

Z_3=age of farmer (years)

Z_4= credit access, (a dummy variable) which takes the value of unity(1) if the fish farmer has access to credit and zero(0) otherwise

Z_5=extension visit, (a dummy variable) which takes the value of unity(1) if the fish farmer was visited by extension agent and zero(0) otherwise(not visited by extension agent)

Z_6=gender, (a dummy variable) male = 1, female=0

Z_7=fish specie used, tilapia(mandarin fish (= 1), clown fish = 0)

Z_8= member of cooperative; member= 1, non -member=0

e = error term

a_o = intercept

a_1- a_5 = parameters to be estimated

Each resource was measured using the formula

The average physical product (APP) was derived by dividing total output by total input

$$APP = \frac{Y}{X}$$

MVP = MPPx P

$$\text{Allocative efficiency (AEI)} = \frac{MVP}{p} = 1$$

Allocative efficiency is the ability of a fish farmer to equate marginal value

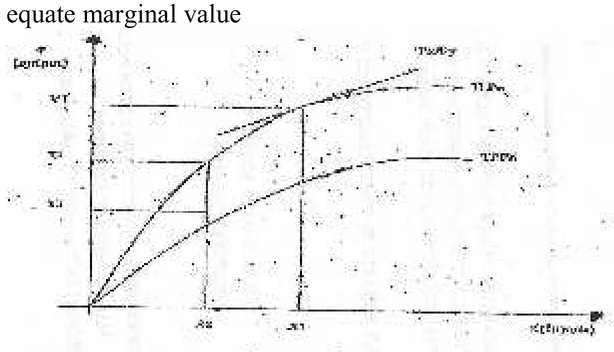

Figure 1: Graphical representation of technical and allocative efficiencies

product (MVP) of a factor to its price(p).
decision rule
if AEI = 1(fish farmer is efficient)
if AEI is not equal to 1(fish farmer is inefficient)
if AEI is less than 1(fish farmer over utilized productive resource)
if AEI is greater than 1 (fish farmer under utilized productive resource)

$$\text{Economic efficiency of resource use(r)} = \frac{MVP}{MFC} = 1$$

r= ratio use to estimate relative efficiency of resource use
where: MVP = value added to rice output due to the use of an additional unit of input, it was calculated by multiplying MPP by the price(MPPxi x po) decision rule
if r = 1(fish farmer is efficient)
if r is not equal to 1(fish farmer is inefficient)
if r is less than 1(fish farmer over utilized productive resource)
if r is greater than 1 (fish farmer under utilized productive resource) (Awoke, 2000; Adinya and Ikpi, 2008).

RESULTS AND DISCUSSION

The socio-economic characteristics of fish farmers in Cross River State are presented in Table 1. Table 1, shows that about 75% of the fish farmers attended upto Junior Secondary School Certificate (JSSC)/ Senior Secondary School Certificate (SSSC). This result corroborate with Boonchuwong *et al*., (2007).

Table 1: Distribution of respondents according to socio-economic characteristics of mandarin and clown fish farmers in Cross River State, Nigeria

Educational attainment	**Mandarin fish Frequency**	**Percentage (%)**	**Clown fish Frequency**	**Percentage (%)**
First school leaving certificate	60	50	55	45.83
Junior secondary school/ Senior secondary school	30	25	32	26.67
Tertiary institution	10	8.33	11	9.17
No formal education	20	16.67	22	18.33
Total	120	100	120	100
Age of fish farmers				
21-40	22	18.33	20	16.67
41-60	68	56.67	65	54.16
61years and above	30	25	35	29.17
Total	120	100	120	100
Gender				
Male	118	98.33	116	96.67
Female	2	1.67	4	3.33
Total	120	100	120	100
Marital status				
Married	88	73.33	90	75
Single	32	26.67	30	25
Total	120	100	120	100
Fish pond size(farm size in hectares)				
0.1-5	90	75	116	96.67
6 hectares and above	30	25	4	3.33
Total	120	100	120	100
Credit				
Access to credit	28	23.33	22	18.33
No access to credit	92	76.67	98	81.67
Total	120	100	120	100
Adoption of improved production technologies in fish production				
(a) Improved water quality	50	41.67	32	26.67
(b) Vaccination	30	25	50	41.67
(c) Industrial feed (35-44% protein diet)	27	22.50	22	18.33
(d) Improved management practices	7	5.83	4	3.33
(e) Only a, b and c	3	2.50	7	5.83
(f) all of the above	3	2.50	5	4.17
Total	120	100	120	100

Source: Field survey, 2010.

Table 2: Distribution of mandarin and clown fish farmers in Cross River State by constraints militating against fish production

constraints	Mandarin fish Frequency	Percentage (%)	Clown fish Frequency	Percentage (%)
Lack of credit	32	26.67	30	25
High cost of industrial feed	22	18.33	27	22.50
Lack of extension agents	7	5.83	6	5
Lack of veterinary doctors	55	45.83	50	41.67
Lack of fish production equipment	4	3.33	7	5.83
Total	120	100	120	100

Source: Field survey, 2010

Table 3: Maximum Likelihood Estimate of Stochastic Frontier Production Function for mandarin and clown fish in Cross River State, Nigeria

Variables	Mandarin fish	Clown fish
Constant	3.26 (4.21)	2.23 (3.42)
Fish pond size(X_1)	0.06 (2.95)*	0.04 (1.52)*
Labour(X_2)	0.08 (3.20)	0.06 (2.43)
Feed (X_3)	0.09 (1.89)*	0.07 (1.57)
Fingerlings(X_4)	0.49 (3.89)*	0.02 (9.22)
Capital($X_{5)}$	0.03 (8.60)*	0.02 (9.22)
Sum of elasticities	1.36	1.25
Diagnostic statistics		
Gamma (γ)	0.73 (3.02)	0.61 (2.89)_
Sigma-squared(δ^2)	0.50 (2.90)	0.43 (3.43)
Log-likelihood function	-52.83	-33.21
Log-likelihood Ratio-test	29.61	24.62

Source: Field survey, 2010 Data analysis using frontier 4.1
*significant at (P<0.05) Figures in parentheses are standard errors

Data in Table 1 also reveals that mandarin fish (98.33%) (96.67%) and clown fish farmers respectively were males. Table 1 also reveals that 73.33% and 75% of mandarin fish and clown fish farmers respectively were married. Table also reveals that 75% and 96.67% of mandarin fish and clown fish farmers respectively had fish pond size between 0.1-5hectares. While 25% and 3.337% of mandarin and clown fish farmers respectively had farm sizes ranging from 6 hectares and above. These result confirms similar findings by Adinya and Ikpi (2008) that fish farmers in Cross River State had fish pond size of 2-5 hectares and majority of the farm mainly to augment family income and nutrition supply. The results in Table 1 shows that 56.67% and 54.66% of mandarin fish and clown fish fish farmers respectively were aged between 41-60 years. While 18.33% and 16.67% of mandarin fish and clown fish farmers respectively were aged between 21-40 years. The implication of the results is that majority of the respondents were within the economically active age. These findings are synonymous with Asa (2003) that people in age group of 41-60 years are more economically active and independent than those in age group of less than 20 years.

Table 4: Technical efficiency level of mandarin and clown fish farmers in Cross River State, Nigeria

Efficiency Class	mandarin percentage	Clown percentage
<0.50	16.07	11.61
0.51-0.60	14.29	13.39
0.61-0.70	22.85	28.79
0.71-0.80	15,99	15,69
0.81-0.90	15.60	15.52
0.91-100	15.20	15.00
Total	100	100
Mean	0.73 ± 0.13	0.61 ± 0.11

Source: Field survey, 2010 Data analysis using frontier 4.1
* significant at (P<0.05).

Table 5: Determinants of Technical efficiency level of mandarin and clown fish farmers in Cross River State, Nigeria

Variables	mandarin coefficient	mandarin t-ratio	clown coefficient	clown t-ratio
Constant	**3.26**	**0.33**	**2.23**	**0.40**
Education	**0.13**	**1.66**	**0.12**	**1.83**
Farming experience	0.65	2.66	0.59	2.34
Age	0.11	1.81	0.34	1.13
Credit access	2.02	2.57	0.81	2.90
Extension visit	0.57	2.12	0.07	2.64
Gender	0.31	2.10	0.52	1.20
Marital status	0.11	1.81	0.08	0.62
Member of cooperative	0.12	1.83	0.65	2.66

Source: Field survey, 2010. Data analysis using frontier 4.1 * significant at 5%

The study revealed that several constraints militating against the efficient production of fish in Cross River State, Nigeria. These constraints or variables are presented on Table 2. From the table, the constraint of lack of credit, high cost of industrial feed, lack of extension agents, lack of veterinary doctors and lack of fish production equipment occupied 26.67%, 18.33%, 5.83%, 45.83%and 3.33 % respectively for mandarin fish farmers. While the corresponding were 25%, 22.50%, 5%, 41.67% and 5.83 % respectively for Clown fish farmers. The result of the study agrees with the findings of Olopade (2010) which revealed that same constraints are militating against the efficient production of fish.

Table 3 reveals that the coefficients of fish pond size, feed, fingerlings and credit were significant at 5% level for mandarin and clown fish. Labour was not significant for both mandarin and clown fish. Feed appears to be one of the important variables with elasticity of 0.09 and 0.07 for mandarin and clown respectively. It implies that increasing feed by 10 percent will lead to about 0.9 and 0.7 increase in output in mandarin and clown. The sum of elasticity of 1.36 and 1.25 for mandarin and clown respectively indicates that mandarin and clown fish farmers in the study area were operating in the inefficient stage (ΣP is greater than 1; increasing return to scale region). The gamma (γ) were 0.73 and 0.61 for mandarin and clown respectively ($P<0.05$). It is an indication that 73 and 61 percent variation in output of mandarin and clown fish respectively are attributed to technical inefficiency. The sigma-square (δ^2) on the other hand were 0.50 and 0.48 for mandarin and clown fish respectively ($P<0.05$)h. The Likelihood Ratio Test (LRT) for mandarin (29.61) and clown (24.62) were technically inefficient.

Table 4 reveals that a technical efficiency range from 0.48-0.99 and 0.55-0.99 for mandarin and clown fish farmers, respectively. The mean estimates were 0.73 and 0.61 for mandarin and clown fish respectively. The efficiency distribution had shown that mandarin (16.07%) and clown (11.61%) had less than 0.50 efficiency level. The result of the study shows that mandarin fish farmers were more efficient than clown fish farmers.

Table 5 shows that the coefficient of fish farmers' educational level, farming experience, credit access, member of cooperative have the expected positive signs and significant at 5% in both mandarin and clown fish farmers. This implies that fish farmers' efficiency will increase with increase in their years of schooling, farming experience, member of cooperative and access to credit.

Conclusion and Recommendations: The study shows that mandarin and clown fish farmers were technically inefficient in the use of productive resources in fish production. The study recommend capacity building of fish farmers through regular training by extension agents on efficient use of resources. This study also shows that fish farmers are facing several problems in their production activities. These problems or constraints negatively affect the efficient production of fish in the study area. This suggests that a considerable fish yield potential remain to be exploited through better use of available production resources in the study area. The constraints associated with fish production as highlighted in this research work if tackled could pave a way to increase production, technical efficiency and farm income of stakeholders. Hence, for efficient production of fish in the study area, these constraints must be reduced to the barest minimum. This can be done through good policy formulation, implementation, proper supervision of fish production programme, effective extension services and proper agricultural financing. In order to stimulate local fish production, government should make a policy that will motivate fish farmers to optimally allocate productive resources to achieve optimum production. This measure will also encourage unemployed youth in Cross River State, Nigeria to join fish producers cooperatives and enable them obtain loans at low interest rate from banks for increase fish production in the state.

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