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Measurement of Technical Efficiency of Catfish Farmers in Benin Metropolis, Edo State, Nigeria

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ABSTRACT

Despite the importance of fish in the diet of Nigerians, supply is below demand. Amongst other problems, technical inefficiency among farmers is seen as one of the cause of short supply. This study, therefore, examined the technical efficiency of catfish farmers in Benin Metropolis, Edo State, Nigeria. The specific objectives were to describe the socioeconomic characteristics of the respondents, determine the individual farm efficiency level of catfish farmers, and identify the factors that influence their technical efficiency or inefficiency and their returns to scale. Primary data were obtained with the use of copies of questionnaire from 100 respondents using two-stage sampling technique. Data were analysed with the use of frequencies and percentages and the Stochastic Frontier Production Function model. Results showed that the estimated farm level efficiency ranged from 57.10% to 97.50% with a mean of 88%. Pond size, quantity of fingerlings and feeds had positive and significant effect on output at 5%, 1% and 1% level of significance respectively, while farming experience had negative and significant effect on technical inefficiency at 5% level of significance. The result also showed the return to scale of 1.35 indicating increasing return to scale and that catfish production in the study area was in stage one of production. This implies underutilization of inputs. The result concluded that the farmers were underutilizing their inputs and some level of technical inefficiency exists among them, hence, more room for output expansion. It therefore means that there is a need for farmers to be educated on how to maximize output from their available inputs and technology so as to increase supply of catfish production in the study area.

Key words: Technical efficiency, catfish farmers, stochastic frontier, production function model

INTRODUCTION

Fish is a global food which serves as an important source of animal protein, both to humans and in the diet of some animals. In Nigeria, fishery in the agricultural sector is important (Kudi *et al*., 2008). It serves as a source of income and job creation for a good number of people, most especially in the rural areas where agriculture is their major source of livelihood. Also, fish is a source of protein, minerals and vitamins in the diet of Nigerians (Kingdom and Alfred-Ockiya, 2009). Despite the importance of fish in the diet of Nigerians, supply is far below that required to meet the dietary needs of the teeming populace, thereby exposing them to dangers of malnutrition and other resulting health implications (Oyakhilomen and Zibah, 2013). This shortage in supply is seen in the importation and consumption rates of animal protein in Nigeria. Animal protein consumption is 8grams per *caput* per day (Ugwumba, and Chukwuji, 2010), a far cry from the Food and Agriculture Organization (FAO, 1991), minimum recommendation of 35 grams of animal protein per *caput* per day for sustainable growth and development. Fish importation in Nigeria from other countries in order to meet demand is to the tune of over 900,000 metric tonnes of fish (Ozigbo *et al*., 2014) and Benin City, Edo state is not in any way excluded from the imported fish products. Nigeria is thereby regarded as one of the largest importers of fish among the developing countries (Olagunju *et al*., 2007). Importation, however, has its economic implications on the nation. It leads to great loss in foreign exchange earnings; hinders the creation of more jobs in the industry which could improve the economic livelihood of those engaged in it amongst others. Hence, there is a need to encourage raising fishes locally so as to limit its importation.

The raising of fish in Nigeria cuts across both the extensive and intensive system of farming and the rearing of different species. However, catfish is among the most commonly cultured species of fish (Issa *et al*., 2014). Catfish commands very good commercial value in the market (Ugwumba, 2011). Consequently, it is vital to the sustainability of the aquaculture industry in the country, it grows very fast, has high fecundity and adapted to supplement feed (Osawe, 2004 as cited in Ugwumba and Okoh, 2010). However, its supply has still not met demand.

Some of the problems leading to supply below demand amongst others are inadequate finance, lack of skilled manpower, and high cost of inputs. Most studies have reported the cost of fish feed to be high and always a significant variable, and also the unavailability of good quality fingerlings (Kudi, *et al*., 2008; Oladejo, 2010; Ugwumba and Chukwuji, 2010; Omobepade *et al*., 2015). Hence, there is a need given these inputs and available technology to maximize output, which invariably helps bridge the gap between supply and demand. This study therefore sought answers to the following research questions: what are the socio economic characteristics of fish farmers in Benin Metropolis? What are the technical efficiency levels of the farmers? What are the factors that influenced the farmers' technical efficiency or inefficiency levels? What is their return to scale of production?

MATERIALS AND METHODS

The Study area

The study was carried out in Benin metropolis, Edo State. The State is located in the South – South geopolitical zones of Nigeria. Edo state lies within longitude 06°04´ E and 06°43´ E and latitude 05°44´N and 07°34´N. Edo State which has a total land area of 17,802km^2 and an estimated population of over three million people. It has a tropical climate characterized by wet and dry seasons having mean annual temperature of about 25°C in the rainy season and 28°C in the dry season. The State is made up of 18 Local Government Areas (LGAs). It is bounded by Delta State in the South, by Ondo State in the West, by Kogi State in the North and by Kogi and Anambra States in the East.

Benin City is the capital of Edo State. It is bounded by latitude 6° 34´ North and longitude 5° 63´ East. The major occupations of the people are trading, farming, metal and wood work, carving, other related artisanal activities, and a good number are civil servants. The climate and soil condition favours the growth of plants. The type of soil found in Benin City is a sandy loam soil and it is made up of Benin formation. Catfish production as an agricultural enterprise employs a good number of the populace in the study area and also serves as source of food (protein).

Sampling and Data collection Procedure

The population of the study consisted of catfish farmers in Benin Metropolis. A two stage sampling procedure was used to select respondents in the study area. Two (2) LGAs in Benin City (Oredo and Egor LGAs) were purposively selected because of the high concentration of fish farming enterprise in the areas. This was followed by the selection of fifty (50) catfish farmers from each LGA employing simple random sampling technique, making a total of 100 respondents for the study. Primary data were obtained using open and close ended questionnaire and interview schedule.

Data analysis

The stochastic frontier production function model which was first developed by Aigner *et al*. (1977) and Meeusen and van den Broeck, (1977) was adapted. It is specified as:

$Y_i = X_i\beta + V_i - U_i$

This model, has also been used by Udoh and Oluwatoyin (2006), Erhabor and Emokaro (2007), Udoh and Etim (2008), Emokaro and Ekunwe (2009), Etim *et al*. (2014). The technical efficiency model is specified as:

$$\text{TE (technical efficiency)} = \frac{Y_i}{Y_i^*} = \frac{f(X_i\beta)\exp(V_i - U_i)}{f(X_i\beta)\exp(V_i)} = \frac{f(X_i\beta)\exp(-U_i).\exp(V_i)}{f(X_i\beta)\exp(V_i)} = \exp(-U_i)$$

Where Y_i is the observed fish output of the ith farm, X_i is a vector of inputs used by the ith fish farmer and β is a vector of parameters to be estimated, that together with X_i define the frontier. V_i and U_i stand for the error components, with $V_i \backsim$ iid $N(0, \sigma_v^2)$ as stochastic noise, $U_i \backsim$ iid $N^+(0, \sigma_U^2)$ as a measure of the inefficiency of the ith farmer; Cov $(V_i, U_i) = 0$, Cov $(U_i, X_i) = 0$, and Cov $(X_i, V_i) = 0$; σ_V^2, σ_U^2 and σ^2 are unknown scalar parameters to be estimated; $\sigma^2 = \sigma_V^2 + \sigma_U^2$ indicates the goodness of fit of the model used; and γ (gamma) $= \sigma_U^2 / \sigma_V^2 + \sigma_U^2 = [0, 1]$ (Battese and Corra, 1977) measures the deviation of the output from the frontier due to technical inefficiency. If $\gamma = 0$, it implies that there are no effects of technical inefficiency, and all deviations from the frontier are due to noise (Aigner *et al*., 1977). A value greater than zero implies that there are technical inefficiency effects. Thus, TE has values that range between 0 and 1, with 1 defining efficient catfish farmers and 0 defining inefficient catfish farmers.

The null and alternative hypotheses being H_0: $\gamma = 0$ and H_1: $\gamma > 0$. The null hypothesis was tested using the log likelihood ratio test, given by:

$\lambda = -2[\ln\{L(H_0)\} - \ln\{L(H_i)\}]$

Where, $L(H_0)$ and $L(H_1)$ are values of likelihood function under the null hypothesis (H_0) and alternative (H_1)hypothesis, respectively (Danwand *et al*, 2011).

Frontier Model Specification

The Cobb-Douglas form of the stochastic production frontier was used to analyse the production (output) and technical efficiency of the catfish farmers. The Cobb-Douglas form of the stochastic production frontier is specified as:

$\ln Y_i = \beta_0 + \sum_{j=1}^{6} \beta_j \ln X_{ji} + V_i - U_i$ and stated in explicit form as:

$\text{Ln } Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + V_i - U_i$

Where Y_i is fish output of the i^{th} farmer, and X_{ji} is the j^{th} input for the i^{th} farmer.

Where:

Y = Fish output(Kg)

X_1= Pond size (m^2)

X_2 = Fingerlings (number)

X_3 = Labour (man days)

X_4 = Fertilizer (kg)

X_5 = Fish feed (kg)

X_6 = Medication (litres)

β_0 = intercept

$\beta_1 - \beta_6$ = unknown parameters to be estimated.

V_i and U_i stand for the error components, with $V_i \backsim$ iid $N(0, \sigma_V^2)$ as stochastic noise, $U_i \backsim$ iid $N^+(0, \sigma_U^2)$ as a measure of the inefficiency of the i^{th} farmer.

The inefficiency (U_i) of production was modeled in terms of factors that are assumed to affect the efficiency of production of the farmers. It is defined as:

$U_i = \delta_0 + \sum_{i=1}^{5} W_i\delta + e_i \geq 0$ and stated in explicit form as:

$U = \delta_0 + \delta_1 W_1 + \delta_2 W_2 + \delta_3 W_3 + \delta_4 W_4 + \delta_5 W_5 + e$

Where:

U = technical inefficiency

W_1 = Age of famer (years)

W_2 = Sex of farmer (male = 1; female = 0)

W_3 = Educational level (No formal education (1); primary education (2); secondary education (3); Tertiary education (4).

W_4 = Household size (number)

W_5 = Farming experience (Years)

e =error term

δ_0 = intercept

$\delta_1 - \delta_5$ = inefficiency parameters to be estimated; and e $\backsim N(0, \sigma_\zeta^2)$.

RESULTS AND DISCUSSION

Socio economic Characteristics of Respondents

The socio economic characteristics of catfish farmers in the study area are presented in Table 1. The Result shows that male catfish farmers constituted about 81% as compared to the female farmers that represent 19% of the respondents. This indicates the dominance of men in fish production in the study area. Most of the catfish farmers fell within the age group of 31 – 50 years indicating that most of them were within the economically active age group. On marital status, the result shows that majority (60%) were separated and most of the respondents (59%) had household sizes of four persons or less. Majority (99%) of the catfish farmers had one form of education with 51% having tertiary education. This indicates that a good number of the respondents were literate. The result further shows that the nature of farm ownership was mainly in the form of sole proprietorship (88%), and most of the respondents (68%) were part time farmers with farming experiences of between 1 – 4 years (65%).

Table 1: Socio economic characteristics of respondents

Socio Economic Characteristics	Frequency	Percentage (%)
Sex		
Female	19	19
Male	81	81
Age		
≤ 30	7	7
31 – 40	33	33
41 – 50	24	24
> 50	36	36
Marital Status		
Single	26	26
Married	10	10
Separated	60	60
Divorced	4	4
Household Size		
≤ 4	59	59
5 – 8	30	30
> 8	11	11
Educational Level		
No Formal Education	1	1
Primary	21	21
Secondary	27	27
Tertiary	51	51
Nature of Farm Ownership		
Sole Proprietorship	88	88
Family	8	8
Cooperative	4	4
Nature of Farming		
Part time	68	68
Full time	32	32
Farming Experience (Years)		
1 – 4	65	65
5 – 8	31	31
9 – 12	4	4

Farm Inputs Used By Catfish Farmers

The various farm inputs used by catfish farmers in the study area as identified by the respondents are presented in Table 2. The result shows that majority (70%) utilised concrete ponds for their production. A larger proportion (72%) relied on only family labour as their source of labour, while 20% of the respondents utilised a combination of family and hired labour. The farmers who used fingerlings as their stocking materials constituted the highest percentage (97%) as against those that use juvenile (3%). Majority (96%) of the respondents utilised compounded or local feeds, while only about 3% and 26% used fertilizer and medication respectively for their production.

Table 2: Input used by catfish farmers

Input	Frequency	Percentage (%)
Type of Pond used		
Earthen	20	20
Concrete	70	70
Plastic tank	5	5
Tarpaulin	5	5
Source of Labour		
Family	72	72
Hired	8	8
Family/Hired	20	20
Stocking Material		
Fingerling	97	97
Juveniles	3	3
Feeding Material		
Compounded feeds	96	96
Phytoplankton's	4	4
Fertilizer Application		
Yes	3	3
No	97	97
Medication		
Yes	26	26
No	74	74

Stochastic Frontier Production Function (SFPF) Analysis

The estimated results of the ordinary Least Squares (OLS) and Maximum Likelihood Estimates (MLE) for catfish production is Benin Metropolis is presented in table 3. The OLS model provides an average production function while the MLE model provides estimates of the Stochastic frontier production function (SFPF).

The log-likelihood function for catfish production in the city was 0.22. These gave the log-likelihood ratio tests of 0.85 significant at 5% level of significance, suggesting the presence of the one-sided error component. This indicates inadequacy in use of OLS and adequacy in use of MLE. The sigma squared of 0.13 significant at 1% indicates a 'good fit' and the correctness of the specified distributional assumptions of the composite error term. The gamma estimate of 0.49 significant at 5% indicates that 49% of error variations are due to the inefficiency error term and not due to the random error term. That is 49% variation in output of catfish farmers in the study area is due to the inefficiency factor. This indicates that 51% of the deviation in output of catfish farmers was occasioned by noise.

Table 3: Ordinary Least Squares (OLS) and Maximum Livelihood Estimates (MLE) Functions for Catfish Production in Benin Metropolis

Variable	Parameter	Average function (OLS)	Frontier function (MLE)
Constant	β_0	5.01 (10.24)*	5.05 (8.91)*
Pond size	β_1	0.71 (2.68)*	0.72 (2.44)**
Medication	β_2	-0.07 (-1.61)	0.01 -1.14
Labour	β_3	-0.18 (-0.19)	-0.07 (-1.20)
Fingerlings	β_4	0.48 (3.04)*	0.57 (3.70)*
Fertilizer	β_5	0.23 -1.21	0.01 -0.03
Feed	β_6	0.15 (3.54)*	0.13 (4.03)*
Sigma square	σ^2	0.09	0.13 (4.20)*
Gamma	Γ		0.49 (2.26)**
Log likelihood function			0.22
Log likelihood ratio			0.85

Source: Field data. Figures in parenthesis are t-ratio. * estimate is significant @ 1% level and ** estimate is significant @ 5%

The combined estimates of the production function for catfish in Benin metropolis based on the MLE of the SFPF showed that pond size, number of fingerlings and feed were positive and significant at 5 %, 1% and 1% level of significance respectively with coefficients of 0.72, 0.57 and 0.13 respectively. This suggests that a 1% increase in pond size will lead to 0.72% increase in output, 1% increase in the number of fingerlings will lead to 0.57% increase in output and a 1% increase in feeds will lead to 0.13% increase in output. This indicates that pond size, number of fingerlings and feed had positive and significant effect on the output.

In the findings of Itam *et al*. (2014) and Yisa *et al*. (2015); feed, number of ponds and number of fingerlings had significant effect on output of catfish. The significance of these variables could be attributed to their importance in fish production and also confirms the result in Table 6 on return to scale of 1.35, it shows that the farmers were still operating in stage 1 of the production cycle and that increasing either pond size, fingerlings or feed holding other factors of production constant will increase the total physical product (output)

Technical Efficiency Distribution of Catfish Farmers

Table 4 shows that the estimated technical efficiency of the farmers ranged from 0.57 to 0.98 with an average technical efficiency of 0.88. This suggests that the least technically efficient farmer could increase his technical efficiency by an additional 43.00% and produce on the frontier, while the best technically efficient farmer given available technology and inputs could improve production by an additional 2.00% and produce on the frontier. Also, the average technical efficiency of 0.88 indicates the capacity of an average catfish farmer to increase technical efficiency by an additional 12% to the maximum possible level and by 10% to the level of the best technically efficient farmer by adopting the technology and techniques used by the best practiced catfish farm.

Table 4: Distribution of Technical Efficiency Indices among Catfish Farmers in the Study Area

Technical Efficiency Range	Frequency	Percentage
0.51 - 0.60	1	1
0.61 - 0.70	8	8
0.71 - 0.80	10	10
0.81 - 0.90	30	30
0.91 -1.00	51	51
Mean efficiency	0.88	
Maximum	0.98	
Minimum	0.57	

This suggests that some level of technical inefficiency still exists among the respondents. Some level of technical inefficiency was reported by Onoja and Achike (2011) in their study carried out in Rivers State and Itam *et al*. (2014) in their study carried out in Cross River State. Table 4 further shows that 81% of respondents had technical efficiency above 0.81. This suggests that majority had relatively high technical efficiency level in the study area. However, there still exist efficiency gaps in the production of catfish in the study area and room for efficiency improvement among catfish farmers. This compares favorably with the findings of Emokaro and Ekunwe (2009), Onoja and Achike (2011), and Ugwumba (2011) that observed efficiency gap from the optimum efficiency level and that the efficiency of catfish farmers could be increased in Kaduna Metropolis, Kaduna State, Rivers State, and Anambra State respectively.

Determinants of Technical Efficiency or Inefficiency

The estimated inefficiency parameters of the catfish farmers in the study area as presented in Table 5 shows that the estimated coefficients for age, sex, educational level, household size, and farming experience were 0.01, -0.28, -0.07, 0.02 and -0.01. Positive relationship indicates that increase in the variable in question increases inefficiency while the reverse is the case for negative relationship. However, only farming experience was significant at 5% level of significance.

Table 5: Determinants of Technical Efficiency or Inefficiency

Variable	Parameter	Coefficient	t-value
Constant	δ_0	-1.47	1.04
Age	δ_1	0.01	0.83
Sex	δ_2	-0.28	1.96
Educational level	δ_3	-0.07	1.17
Household size	δ_4	0.02	1.12
Farming experience	δ_5	-0.01	2.25**

Source: Field data. **estimate significant at 5% level of significance

The negative sign and significance of farming experience indicates that as catfish farmers' farming experience increases, their inefficiency in catfish production decreases. This is in consonance with a priori expectation for the farmers because over time they would have learnt on the job how to better combine their resources efficiently. In a study carried out in Cross River State by Itam *et al*. (2014) farming experience was also a significant determinant of technical inefficiency, however was positive, implying that the more experience the farmer the higher their inefficiency level.

Production Elasticity and Return to Scale

The production elasticity and return to scale of catfish production in the study area is presented in table 6. The elasticity of pond size was 0.71, meaning that a 100% increase in pond size will lead to 71.00% increase in output of catfish production. Medication cost had an elasticity of 0.01 meaning a 100% increase in medication cost will lead to 1% increase in output of catfish. Fingerling input had an elasticity of 0.57 meaning a 100% increase in the quantity of fingerlings will lead to 57% increase in output. Fertilizer had an elasticity of 0.00 meaning that a 100% increase in quantity of fertilizer will lead to no percent increase in output of catfish. Feed had an elasticity of 0.13 meaning that a 100% increase in feed intake will lead to 13% increase in output of catfish. The elasticities of the individual inputs was less than one indicating that the percentage change in the inputs was greater than the percentage change in the output of catfish in the study area.

Table 6: Production Elasticity and Return to Scale

Input (Variables)	Production elasticity coefficients
Pond size	0.71
Medication	0.01
Labour	-0.07
Fingerlings	0.57
Fertilizer	0
Feed	0.13
Return to scale (Total)	1.35

Labour had elasticity of -0.065, meaning that a 100% increase in labour input will bring about 6.5% reductions in output of catfish production in the study area. Similar result of a negative elasticity of labour in catfish production was seen in the work of Itam *et al.* (2014). Positive elasticity for pond size and fingerlings, were reported by Emokaro and Ekunwe (2009) in a study carried out in Kaduna State but it was different for labour which had positive elasticity and feed which had a negative elasticity. The result further shows the return to scale of 1.35 indicating increasing return to scale and that catfish production in the study area was in stage one (irrational) of production, implying the underutilization of inputs. This suggests that production could be increased by using more of the inputs with positive elasticities. Similar result was reported by Onoja and Achike (2009), they reported that catfish farmers were in stage one of their production cycle in a study carried out in Rivers State. Also study carried out by Itam *et al*. (2014), the farmers were in stage one of their production. However, in the work of Emokaro and Ekunwe (2009) and Yisa *et al.* (2015) the total sum of elasticities of variables of production was less than one indicating the farmers were in stage two of production cycle, that is the rational stage of production.

CONCLUSION

The study concluded that some gaps exist in the farm level technical efficiencies of catfish farmers in Benin metropolis in Edo State. It was also noted that technical efficiency of the catfish farmers varied due to the presence of technical inefficiency. Pond size, fingerlings and feeds statistically and positively influenced catfish production, while farming experience negatively and significantly influenced the technical inefficiency of the farmers. Fish production was in stage 1 of the production stages indicating under-utilization of the inputs by the farmers giving room for future expansion in output and productivity. The study therefore recommends that, in order to further bridge the gap between supply and demand in the study area, farmers should be encouraged to operate in stage 2 of their production by increasing their efficiency in the use of their variable inputs. .

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