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Firm Efficiency and Returns to Scale in Catfish Production among Smallholders

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Abstract

Firm efficiency and productivity analyses are important considerations in measuring performance of a farm business. Despite its potentials, the level of catfish production has failed to meet domestic demand in Nigeria. This study analyzes the determinants and returns to scale in catfish production among smallholders in Ekeremor, Bayelsa State, Nigeria. Primary data collected via random sampling were evaluated using descriptive statistics, regression and elasticity of production analysis. The results revealed the estimated mean for farming experience, average feed quantity per cycle, stocking density per average pond size, quantity of labour and average pond size; were 9 years, 3000kg, 1020 fingerlings per 482 sq.m and 300 man-days respectively. The coefficient of multiple determination (R^2) was 0.787, implying that 79% variation in catfish output among smallholders was accounted for by the variables in the regression model The estimated value of returns to scale was 0.743($\sum\rho<1$); indicating a decreasing return to scale. Moreover, the major constraints of catfish production include high feed cost (95%), inadequate capital (80%), pond construction cost (73.3%), poor market linkages (70%) and poor access to modern technologies (65%). Alternative feed sources, adoption of practices and technology, financial and credit information, feed, construction materials and equipment subsidy, improved market linkages, extension contact, access to and adequate supply of water, production inputs, technological innovations and cooperative formation are strongly recommended.

Keywords**:** Catfish, constraints, determinants, elasticity of production, farm output, smallholders

1.0 INTRODUCTION

The aim of fish farming (husbandry) or aquaculture is generally for fish production for human consumption. The term fish is a diverse group of animals that live and breathe in water by means of gills (https://manoa.hawaii.edu/exploringourfluidearth/biological/fish/what-fish). Aquaculture continues to grow rapidly. Understanding the general aspects of aquaculture is of increasing importance for all those working in this industry. Aquaculture requires specific knowledge and skills on general aspects of fish production (Emokaro, 2010). In the past, rural fish farming in Africa concentrated on tilapia fish production however catfish production is also on the rise (Olagunju *et al.*, 2007). Population growth is usually accompanied by increase in demand for basic necessities of life (i.e. food, clothing and shelter). This is the case with the unrestricted increases in the demand for protein rich food items of animal origin (Ugwumba and Chukwuji, 2010). However, the ability of catfish production to reach optimal level has been on the decline, yield (output per unit water area) for catfish farmers and the profit margins have decreased overtime. The Food and Agriculture Organization (FAO), (2006), recommended that an individual takes 35g (grams) of animal protein per day for sustainable growth and development. However, the animal protein consumption in Nigeria is less than 8g (grams) per day per person, which is a deficit from the FAO minimum recommendation (Amao, *et al*., 2009). Fish especially the catfish species are widely consumed in Nigeria. Currently, domestic fish production is put at 600,000 metric tonnes as against the present national demand of about 1.5 million metric tonnes per annum; over 50% of fish supply requirement is met through importation, which constitutes a huge and avoidable drain of foreign exchange resources. As such there is a demand deficit of 900,000 metric tons per annum in a population growing at an estimated 2.5% annually (Asa and Obinaju, 2014). The shortfall is said to be bridged by the importation of 700,000 metric tonnes annually. Increased awareness of the need for adequate fish protein in human diets, assessment of productivity, management practices and constraints are approaches of improving production so as to achieve self-sufficiency in catfish production (Okwu and Acheje, 2011). The government at various occasions have adopted different programs and policies aimed at improving firm efficiency and fish productivity. These programs and policies place the smallholders in central focus; hence, this subsector is particularly dominated by the smallholders who represent a substantial proportion of the total fish farmers and contribute to over 80% of the total output. Animal protein sources include cattle, goats, sheep, poultry and fish. According to Ocmer (2006) fish and fish products constitute more than 60% of the total protein intake especially in rural areas. Therefore, the importance of fish farming particularly catfish production, to the sustainability of animal protein supply cannot be over-emphasized (FAO, 2006). Smallholder farmers are facing new barriers in both their production and returns on investment. Despite its potentials, the level of catfish production has failed to meet the country domestic demand (FAO, 2007). Catfish farming remains a viable investment in Nigeria; with proper management (Oguntola, 2006). The ability of catfish farmers to reach optimal production level has been on the decline over the years, despite the efforts of government and other interventions from stakeholders, yield has remained low in the country and particularly in the study area; there is still a deficit in the supply and demand for catfish (Dada, 2004). This has been attributed to inadequate supply of production inputs, poor quality of fingerlings, inadequate extension services, high cost of feeds, poor adoption of improved techniques, prevalence of smallholder fish farmers, poor infrastructural facilities and low capital investment. These factors account for the decline in the fish population dynamics and therefore the need to increase fish production through intensification of aquaculture systems. The contribution of domestic fish farming cannot be over emphasized; catfish farming has the potential of contributing to domestic fish production and reducing expenditures on fish importation. Hence, this research will fill the gap and provide empirical information on the determinants and returns to scale in catfish production; within this framework this study will seek to provide answers to the following research questions;

1. What are the factors of catfish production?
2. What is the input and output relationship?
3. What is the elasticity of catfish production?
4. What are the constraints of catfish production in the study area?

Research Hypothesis

H_0: There is no input and output relationship in catfish production.

2.0 METHODOLOGY

Study Area

The study was carried out in Ekeremor Local Government Area (LGA), Bayelsa State, Nigeria. The LGA is one out of the eight in Bayelsa State; its headquarters is in the town of Ekeremor. It has an area of 1,810 km^2 and lies on the geographical coordinates of latitude 5^{o}3' N and longitude 5^{o}47'E (NBS, 2012). Mean annual rainfall of the area is 2,200mm for upland or dry regions where water bodies are few and 3,500mm for wetland or lowland regions which comprises of land areas being surrounded by water bodies. Temperature range is between 23-31°C and vegetation found in the area includes saline water swamp, mangrove swamp and rain forest (NBS, 2012). The seasonal condition of the area presents a healthy environment for fish production; hence adequate supply of water for catfish ponds in the study area. The inhabitants of the LGA are predominantly fish farmers.

Fig.1. Ekeremor LGA: Google Map Data (2022)

Sampling Technique

Random sampling technique was employed for this study. At constant proportionality of 0.15 (15%); which is the constant ratio or fraction of variable quantity to another to which it is proportional, sixty (60) respondents were selected for the study from a sample frame of 402 catfish farmers using a compiled list from the Bayelsa state Agricultural Development Program (BYADEP) in synergy with local enumerators and validated using raosoft sample size calculator at 90% confidence level and 10% margin error.

Method of Data Collection

Data was collected using structured questionnaire designed in line with the objectives of the study.

Analytical Techniques

Descriptive and inferential statistics were used to analyze the primary data collected. Regression analysis was used to estimate the determinants of catfish production in the study area. The return to scale of catfish production was estimated using the elasticity of production factors.

Regression Analysis

Multiple regression analysis was used to estimate the input and output relationship in catfish production and hence ascertain the factors influencing catfish production in the study area, a structural relationship was specified, and it showed a relationship between dependent variable (Y) and independent variables (X_i). Four functional forms (linear, semi-log, double log and exponential) were specified and fitted to the data. The double-log function gave the best fit and was chosen as the lead equation. The choice of the production function is predicated on its conformation to a priori expectation in terms of signs and magnitude of the coefficients, the number of significant variables, the coefficient of multiple determination, the economic rationale, and the significance of the coefficients and the overall performance of the model and was used to analyze objective ii. The model in its explicit form is presented in equation (1):

$$Log\,Y = b0 + b1logX_1 + b2logX_2 + b3logX_3 + b4logX_4 + b5logX_5 + e_i \qquad \ldots (1)$$

Where:

Y = Catfish output (kg/400 square meter (sq.m); X_1 = farming experience (years); X_2 = Feed (kg/400 sq.m), X_3 = Stocking capacity (number of fingerlings/400 sq.m); X_4 = Labour (man-days); and X_5 = Pond size (400 sq.m); e_i = Error term; and b_0 = Intercept term showing the value of Y when X_1, X_2, X_3, X_4, X_5 is zero. The a priori expectation is that X_1-X_5 will have a positive effect on production

Returns to Scale

It refers to the change in output as a result of a given proportionate change in all the factors of production simultaneously. It is a long run concept as all the variables are varied in quantity. Returns to scale are increasing or constant or decreasing depending on whether proportionate simultaneous increase of input factor's results in an increase in output by a greater or same or small proportion. Elasticity of production is used to estimate returns to scale and presented in equation (2):

$$Elasticity\ of\ production\ (\sum\rho)\ =\ \%change\ in\ output\ (\%\Delta\Upsilon)\ /\ \%change\ in\ input\ (\%\Delta\chi)\ldots\ (2)$$

It can also be estimated in terms of the relationship between Marginal Physical Product (MPP) and Average Physical Product (APP) and presented in equation (3):

$$\sum\rho = \frac{\Delta\Upsilon}{\Upsilon} \div \frac{\Delta\chi}{\chi} \qquad \ldots (3)$$

Written as;

$$\sum\rho = \frac{\Delta\Upsilon}{\Delta\chi} \div \frac{\chi}{\Upsilon} \qquad \ldots (4)$$

Given that;

$$\frac{\Delta\Upsilon}{\Delta\chi} = MPP;\ \text{and}\ \frac{\chi}{\Upsilon} = 1/\ APP \qquad \ldots (5)$$

Therefore;

$$\sum\rho = MPP\ /\ APP \qquad \ldots (6)$$

However, in production function the return to scale is obtained by the summation of elasticity coefficients of the independent variables (Reddy *et al*., 2004).

$$\sum\rho^k = RTS^k \qquad \ldots (7)$$

Where;

$\sum$ = Summation sign
$\sum\rho^k$ = Elasticity coefficient of k variable
RTS = Returns to scale
If $\sum\rho^k > 1$ it is increasing returns to scale
If $\sum\rho^k = 1$ it is constant returns to scale
If $\sum\rho^k = < 1$ it is decreasing returns to scale.

3.0 RESULTS AND DISCUSSION

Production Factors

Table 1: Summary Statistics of Production Factors

Factors	Mean
Experience(years)	9
Feed (kg)	3,000
Stocking density (fingerlings/pond)	1020
Labour (man-days)	300
Pond size (sq.m)	482

Table 1 revealed that the mean farming experience was 9 years; implying that the catfish farmers had adequate farm experience as such they are expected to adjust and adopt new technologies that would stimulate increased production. This corroborates with Wurts (2004), who also posited that efficient pond management has significant correlation to the years of farming experience. Average feed quantity utilized per cycle was 3000kg; implying that feed is an important component in catfish production; feed therefore is an essential production input. The average stocking density per fish pond in the area was 1020 fingerlings per average pond size. This is not unconnected to the average pond size of the farmers; that enables sustainable and optimum catfish production. This result is in line with Esu *et al* (2009) who also reported similar results in their study of catfish production. The average quantity of labour per production cycle was 300 man-days; implying that catfish production is relatively labour intensive. The average pond size in the study area was 482 square meters, with an average depth of 3 meters. This conforms to the FAO, 2007 submission that ponds as small as 1-400 sq.m range are suitable. However, ponds in the 401-800 sq.m range are more practical (https://www.ijaar.org/articles/ajsad/v1n4/ajsad-v1n4-oct-dec20-p1261.pdf).

Regression Analysis

Table 2: Factors Influencing Catfish Production

Variable	Coefficients	Standard Error	T-value
Constant	4.581***	1.346	3.403
Farm experience (X_1)	0.417**	0.165	2.527
Feed (X_2)	0.302***	0.091	3.319
Stocking capacity (X_3)	-0.465***	0.114	-4.079
Labour (4_5)	0.489**	0.178	2.747
Pond size (X_5)	$0.265^{n.s}$	0.196	1.352
R^2	0.787		
F-value	29.13		

The regression analysis presented in Table 2 revealed the determinants of catfish production in the study area. The estimated coefficient of determination (R^2) was 0.787 implying that 79% of the variation in the output of catfish was explained by the independent variables in the regression model, while the remaining 21% are exogenous to the system, i.e. unexplained and attributable to the random stochastic error term (e_i); thus, the null hypothesis is rejected. The coefficient of farming experience (0.417) was positive and statistically significant 5% level of significance. It could be deduced that the more experienced farmers were more productive; through experience the gain more in-depth knowledge of management practices that enhances farm productivity. In addition, the coefficient of feed quantity (0.302) was positive and statistically significant 1% level of significance, implying that adequate feed supply enhances gross output; feed is very critical in catfish production. Feed therefore is an essential production input. Also, the coefficient of stocking capacity (-0.465) was negative and statistically significant 1% level of significance. This implies that high stocking density results to reduced output as the space occupied by each catfish in terms of water volume is reduced. Cannibalism becomes frequent and struggle for feed is increased and consequently, high mortality rates and decline in output. Furthermore, the coefficient of labour (0.489) was positive and statistically significant 5% level of significance, suggesting that labour supply is a key component of catfish production; it is major requirement for carrying out the various farm operations. These findings corroborates with the work of Olasunkanmi and Yusuf (2013) who reported similar results on firm Efficiency and Returns-to-Scale in catfish production.

Elasticity of production

Table 3: Elasticity of Factors of Production and Returns to Scale

Factors of Production	Elasticity of production ($\sum\rho^k$)
Farm experience (X_1)	0.417
Feed (X_2)	0.302
Stocking capacity (X_3)	-0.465
Labour (4_5)	0.489
Returns To Scale	0.743

Table 3 revealed that the value of elasticity of production($\sum\rho^k$). The estimated value of returns to scale is 0.743, thus, $\sum\rho < 1$ which indicates a decreasing return to scale. Decreasing returns to scale is due to the operation of diseconomies of scale.i.e, the technical efficiency of variable and fixed resources declines. Variable resources are abundant relative to fixed resource. The additional productivity of variable resource becomes negative hence increase in the use of variable factors yields less additional output. Thus, addition of successive units of variable factors to fixed factors in the process of honey production adds less to the gross output of honey produced. This value represents stage III of the production function; which is regarded as an irrational (supra-optimal) stage of production. This stage offers the opportunity of reorganization of fixed and variable resources; it also correlates with the Law of Negative marginal returns. This result corroborates with the findings of Asa, *et al*. (2012): who posited similar results in their study on Economic Analysis of catfish Production.

Constraints of Catfish Production

Table 4: Constraints of Catfish Production among Smallholders

Constraints	Frequency	%
1. High cost of feed	57	95.0
2. Inadequate capital	48	80.0
3. High cost of pond construction	44	73.3
4. Poor market linkages	42	70.0
5. Poor access to modern technologies	39	65.0
6. High labour cost	31	51.7
7. Fish mortality	28	46.7
8. Water pollutants	23	38.3
9. Scarcity of seeds (Fingerlings)	18	30.0
10. Inadequate extension contact	15	25.0

Table 4 revealed the most prevalent constraints of catfish production in the study area were; high cost of feeds (95%), the result corroborates with Ohen and Abang (2009) who reported that high cost of feeds is a major constraint to catfish farming in Nigeria. Inadequate capital (80%), the result corroborates with Kudi *et al* (2008) who also reported that inadequate capital was a major production constraint; also Olasunkanmi and Yusuf (2013) identified inadequate finance as a serious problem in catfish production. High cost of pond construction (73.3%); the respondents revealed that catfish farming requires a huge initial capital outlay especially for pond construction, catfish farming requires a huge capital outlay especially for pond construction, this results corroborates with Ohen and Abang (2009) and Kudi et al (2008). Poor market linkages (70%), poor access to modern technologies (65%), high labour cost (51.7%), fish mortality (46.7%), water pollutants (38.3%), Seed (fingerling) scarcity (30%) and inadequate extension contact (25%). This corroborates with the findings of Olasunkanmi and Yusuf (2013) who also reported similar results in their respective studies on catfish production.

4.0 CONCLUSION AND RECOMMENDATIONS

This study analyzed firm efficiency and returns to scale in catfish production in Ekeremor, Bayelsa State, Nigeria. It was revealed that the factors of production affected farm productivity among respondents. Moreover, the variables in the regression model were significant determinants of catfish production in the study area. The estimated elasticity of catfish production indicated a decreasing return to scale .i.e., the technical efficiency of variable and fixed resources declines. All the constraints identified by the farmers were economically important and significantly affected catfish production in the study area; hence effort should be made to minimize these constraints. Based on the findings of this study, the following recommendations are made for policy actions to improve output and income derivable. Based on the findings of this study, the following recommendations are hereby made to improve firm efficiency and catfish productivity in the study area:

1. Research funding to explore alternative feed sources and adoption of practices and technology that automates production; mitigates fish mortality, minimizes labour costs and optimizes productivity.
2. Provision of financial and credit information to farmers to avail them opportunities to capital required to expand their scale of production.
3. Policy formulation to subsidize feed cost, pond construction materials and equipment.
4. Improved market linkages to increase farm profitability.
5. Improve farmer's access to and supply of adequate water, modern production inputs, technological innovations (fingerlings, feeds, pond fertilizers, etc.) to ensure sustainable production.
6. Catfish farmers should form cooperatives that will enable them pool their resources together to boost their level of productivity and increase their economies of scale.
7. Provision of incentives and interventions by improving farmer's access to extension services.

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