APPLICATION OF STOCHASTIC FRONTIER ANALYSIS ON CATFISH (Clarias gariepinus) PRODUCTION SYSTEMS IN DELTA STATE, NIGERIA

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Abstract
The study applied Stochastic Frontier Analysis on catfish production systems in Delta State of Nigeria to determine the farmers’ levels of technical efficiency under the production systems adopted in the study area. Structured questionnaire were used to elicit responses from 538 catfish farmers who provided suitable information from the 561 sampled farmers. Descriptive statistics was used to describe the socioeconomic characteristics and for the production systems, stochastic frontier production function was used to estimate the technical efficiency of farmers. Results from the study shown that about 61.71% of the farmers were male, married (86.62%) and 52.97% of them operating on full time. The pond systems used are as follows: earthen pond (27.51%), concrete pond (33.83%) and plastic/tarpaulin pond (38.66%) respectively by the farmers with an average pond size of 629.63m² in the study area. The mean levels of technical efficiency (TE) of the farmers under the production systems were earthen pond (0.77), concrete pond (0.76) and plastic/tarpaulin pond (0.73) respectively. The average TE level in the study area was 0.84; operating about 16% below the frontier. The results further revealed the returns to scale (RTS) of the farmers under production systems as earthen pond (0.086), concrete pond (0.089), plastic/tarpaulin pond (0.099) and the study area was 0.070 respectively. The results from the inefficiency model estimated showed that age, household size, educational level and catfish production experience were the major factors that influenced the technical inefficiency of the catfish farmers. The study concludes that the technical efficiency levels could be improved and maintained if the inefficiencies accounted for by the socio-economic conditions of the catfish farmers are addressed. The right and supporting policies to minimize inefficiencies resources use and improve catfish production should be put in place by the authorities concerned.

Keywords: stochastic frontier, production function, technical efficiency, inefficiency model, factors, catfish, farmers, nigeria

Introduction
Catfish majorly culture in Nigeria include Clarias gariepinus, Heterobranchus bidorsalis and Clarias heterobranchus hybrid (heteroclarias). Clarias gariepinus is regarded as an excellent aquaculture species because it grows fast and feeds on a variety of agricultural by-products, it is hardy and can tolerate extreme temperature, easy to produce in captivity with high annual production and good feed conversion rate (Ahmadu & Egbodion, 2017). Catfish as a species of fish is healthy for human consumption and Fishery is an important sector in the economic development of many developed and developing countries. It is impossible to farm meat to meet the protein requirement of everyone in the world due to the large resource consumption for its production (Imade & Ahmadu, 2022). Catfish is a source of high-quality protein that can be produced more cheaply than any other animal protein for human consumption. It is also medically recommended for
pregnant women, children and adults because of its high-level protein, digestibility and lack of cholesterols, and constitutes a preventive resource for heart attack or failure and stroke (Kareem, 2011). In effect, meeting the demand for fish using catfish production under different ponds system (concrete pond, earthen pond and plastics tank pond) offers a profitable and ecologically viable alternative to the oceans-as-deserts scenario we are currently facing (FAO, 2010).

The Nigerian vast aquatic medium comprising numerous water bodies like rivers, streams, lake reservoirs, flood plains, irrigation canals, and coastal swamps offer great potentials for aquaculture production in Nigeria (Source?). The United Nation (UN) noted in its 2016 State of World Fisheries and Aquaculture report that nearly a third of wild stocks are overfished (FAO, 2016). Thus, there is need to annexed the potentials of catfish production to fill this gap. Catfish farmers need to be adequately equipped with the necessary production skills to be able to exploit the immense potentials of catfish production and sustaining efficiency under diverse production system. Catfish production is a subset of aquaculture which involves the rearing of catfish under controlled conditions for economic and social benefits, and there are three major groups of activities that contribute to food production namely; agriculture, aquaculture and fisheries (FAO, 2015). Catfish has the potential to contribute to sustainable development and poverty reduction in Nigeria as a whole, Delta State in particular by generating income and employment (Imade & Ahmadu, 2022).

Nigerian governments had at various times, adopted different agricultural development programmes, policies, and institutions aimed at raising the production, efficiency and productivity of farmers to help combat food insecurity (Iwuchukwu & Igbokwe, 2012). Given these various agricultural programmes and policies implemented over the years, the Nigerian catfish farmers are still not able to meet the fish needs of the populace. This then makes it imperative to quantitatively measure the current level of production performance, and to identify the policy options available for raising the present level of performance. These measures are intrinsically related; productivity is reduced in the presence of inefficiency, whereas the more technically efficient a farm is, the higher the productivity, Ceteris paribus (Erhabor & Emokaro, 2007). The success of any nation’s development programme is dependent on the human resources which must be provided with adequate diet in order for the teeming populace to function efficiently. Thus, production of food rich in protein such as those from animal sources like catfish requires efficient harnessing of all production resources. This study therefore examines the application of Stochastic Frontier analysis on catfish production systems with the view to estimate the technical efficiency levels of catfish farmers in Delta State of Nigeria.

Against this backdrop, this research sought to answer the following questions: describe the socio-economic and production characteristics of the catfish farmers, estimate the level of technical efficiency of the farmers; and identifies the factors influencing the technical inefficiency of the farmers in Delta State, Nigeria.

**Methodology**

**Study Area**

The research was conducted in Delta State of Nigeria. The state consists of twenty-five Local Government Areas (LGAs) which are grouped into Delta North, Delta Central and Delta South Agricultural Zones by the Delta State Agricultural
Development Programme (ADP). The state lies between latitudes 05° 00’N and 06° 30’N of the Equator and longitudes 05° 00’E and 06° 45’E of Greenwich Meridian. It covers a total land area of 17,698km² with a projected population in 2016 of 5,663,400 people (National Population Commission, 2006). Delta State is generally low-lying without remarkable hills. The state has a wide coastal belt interlace with rivulets and streams, which form part of the Niger Delta (National Population Commission, 2006).

Sampling Procedure and Data Collection

A three-stage sampling procedure was carryout for the study (Ref?). The first stage involved the purposive sampling of two Local Government Areas (LGAs) from the three Agricultural Zone to make a total of six LGAs sampled in Delta State. From Delta South Zone, Warri South West and Warri South LGAs were selected, Udu and Uvwie LGAs in Delta Central, while Ndokwa West and Ukwuani LGAs in Delta North Agricultural Zone. Identifications of catfish farmers in the LGAs were done using snowballing sampling technique at the second stage that gave 667 population of catfish farmers. According to Ryan (2013), the formula for determining the sample size was used to select the farmers at the third stage. This formula is expressed as:

\[ n = \frac{N}{1 + Ne^2} \]  

Where \( n \) = Corrected Sample Size, \( N \) = Population Size, \( e = \) Margin of Error (MoE), \( e = 0.05 \) or 5%. 561 Catfish Farmers gotten using the formula was administrated with questionnaire. However, a total of 538 farmers provided useful information for data analysis. The quantities of inputs used, socio-economic and production characteristics of the catfish farmers form the data used for the study.

Analytical Technics

Descriptive statistics such as means, frequency count, percentages and standard deviation and Tables were used to describe socio-economic characteristics and production systems of the catfish farmers were estimated with Stochastic Frontier Production Function.

Maximum Likelihood Estimates (MLE) of the Stochastic Frontier Production Function (SFPF) was used to estimate the technical efficiency (TE) of catfish production as used by Imade and Ahmady (2022).

The Cobb-Douglas Stochastic Production Frontier implicit form is specified as:

\[ Q_i = f(X_i; \beta) + \epsilon_i \]  

Where: \( Q_i = \) Output of the ith farm
\( X_i = \) Vector of inputs used by the ith farm
\( \beta = A \) vector of the parameters estimated
\( \epsilon_i = Composite error term \)
\( V_i = Random error outside farmer’s control \)
\( U_i = Technical inefficiency effects \)

The estimation using the log linear explicit form used is presented as:

\[ \ln Q_i = \beta_0 + \beta_1 \ln PS_i + \beta_2 \ln FC_i + \beta_3 \ln FU_i + \beta_4 \ln LU_i + \beta_5 \ln SD_i + \beta_6 \ln CL_i + (V_i - U_i) \]  

Where: The subscript \( i \) denotes the \( i^{th} \) farmer.
\( Q = Output of the Catfish farm per production cycle (kg) \)
\( PS = Pond Size used for Catfish production (m^3) \)
\( FC = Feed consumed by the Catfish (kg) \)
\( FU = Quantity of fertilizer used (kg) \)
\( LU = Quantity of lime used (kg) \)
\( SD = Stocking density (i.e number of Catfish stocked or Catfish seed in pond) \)
\( CL = Combined Family and Hired labour used (man-day) \)
\( \beta_0 = Constant or the intercept term \)
\( \beta_i (i = 1…7) \) are the elasticities of
production with respect to inputs used
\[ \ln = \text{Natural logarithm.} \]
\[ V_i = \text{Normally distributed random error term} \]
\[ U_i = \text{Inefficiency component with a half-normal distribution} \]

The factors affecting inefficiency of catfish farmers were estimated using the Inefficiency Model (Ahmadu & Erhabor, 2012; Imade & Ahmadu, 2022). The inefficiency model used for this estimation is expressed as:

\[ U = \gamma_0 + \gamma_1 Z_1 + \gamma_2 Z_2 + \gamma_3 Z_3 + \gamma_4 Z_4 + \gamma_5 Z_5 + \gamma_6 Z_6 + \mu \]

(5)

Where: \( U \) is the inefficiency index,
\[ \gamma_0 = \text{Intercept (constant)} \]
\[ Z_1 = \text{Age of the catfish farmers (years)} \]
\[ Z_2 = \text{Household size (i.e. number of persons residing in the farmers’ household)} \]
\[ Z_3 = \text{Educational Status (years)} \]
\[ Z_4 = \text{Catfish production experience (years)} \]
\[ Z_5 = \text{Number of ponds used by the catfish farmers} \]
\[ Z_6 = \text{Mortality of catfish of the catfish farmers} \]
\[ \mu = \text{Random (error) term} \]

Results and Discussion
Socio-economic and Production Characteristics of Catfish Farmers

The male (61.71%) dominance in the study area from the results in Table 1 could be linked to the arduous nature of catfish production activities which requires physical strength and men are known to be more physically endowed. This assertion is supported by Esu et al., (2009) reported that catfish production is dominated by males in Akwa Ibom State. The average age of the catfish farmers in study area was 48 years with standard deviation of 11.32. According to Kintu (2012), catfish farmers around this age category have the propensity for improved agricultural production. 86.62% of the catfish farmers in study area were married.

The majority of the catfish farmers that were married implied that there would be an added advantage of family labour as a result of higher household size (Asa et al., 2012). This means that the married catfish farmers might spend less on labour in their catfish production business.

Table 1 results also showed that the mean household size of the catfish farmers in study area was 5 persons as affirmed by Michael and Koyenikan (2020). This observed household size would serve as a good source of labour in catfish production which requires a great deal of human effort in the study area. The distributions of labour used by the farmers are as follows: family labour (17.73%), hired labour (22.01%) and both family and hired labour (60.26%). The finding of Ahmadu and Egbodion (2017) also confirm that both family and hired labour were used more in catfish production in Lagos Metropolis, Nigeria. For every 100 catfish farmers, about 62 of them had tertiary education in the study area. The finding implies that the catfish farmers in the study area had educational status that could enable them improve their business. This is because education is fundamental for improved catfish production (Ibeagwu, 2012). About 53% of catfish farmers operating on full time basis agree with the findings of Oyesola and Ademola (2011) that farming is a major occupation for self-reliance and income generation.

The results further revealed that the aggregate population of the catfish farmers using plastic/tarpaulin pond was higher (38.66%), concrete pond (33.83%) and earthen pond (27.51%) in Delta State having a mean pond size of 629.63 m². Only few of the farmers (7.81%) operated a pond size of 451-550 m² while a majority of them (92.19%) operated a pond size above 550 m². The dominance of medium scale size fish farms and above in the study area helped the farmers to enjoying the benefits of economics of
scale which is associated with large scale production (Akenbor & Ike, 2015). According to Akenbor and Ike (2015), small scale size fish farm fell below 500m² pond size. Delta State catfish farmers stocked more at juvenile stage (70.30%). This might be so because the farmers could well identify good culture stock even from the juvenile stage so as to reduce mortality of the catfish and as well aid the growth and maturity rate. 82.48% of local feed used by Delta State catfish farmers implies more access to local feed to cut down the cost of feed which often accounted for almost 60% of catfish production cost (Mustapha et al., 2014). This agrees with Ekanem et al., (2012) who compared the growth performance and food utilization of Clarias gariepinus feed on local, midst and import feed and concluded that locally formulated feeds are good alternative in catfish production.

Table 1 also reveals about 8 years for mean production experience of the catfish farmers in Delta State. According to the submission of Williams et al., (2012), the ability to manage catfish ponds efficiently depends on the years of experience, which they found was directly related to the total productivity of the farm. This implies that production experience is very important as it gives more insight into catfish production and productivity.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Freq (538)</th>
<th>% (100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>332</td>
<td>61.71</td>
</tr>
<tr>
<td>Female</td>
<td>206</td>
<td>38.29</td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 – 35</td>
<td>90</td>
<td>16.73</td>
</tr>
<tr>
<td>36 – 47</td>
<td>151</td>
<td>28.07</td>
</tr>
<tr>
<td>48 – 59</td>
<td>187</td>
<td>34.76</td>
</tr>
<tr>
<td>60 – 71</td>
<td>110</td>
<td>20.45</td>
</tr>
</tbody>
</table>
| Mean                       | 48.40      |oughout the cost of feed which often accounted for almost 60% of catfish production cost (Mustapha et al., 2014). This agrees with Ekanem et al., (2012) who compared the growth performance and food utilization of Clarias gariepinus feed on local, midst and import feed and concluded that locally formulated feeds are good alternative in catfish production.

Table 1: Socio-Economic and Production Characteristics of Catfish Farmers in Delta State.

<table>
<thead>
<tr>
<th>Stochastic Frontier Production Function (SFPF) on Catfish production systems in the Study Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 2: Maximum Likelihood Estimates (MLE) for Catfish Production by Production Systems</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables</th>
<th>Earthen Pond Coefficient</th>
<th>Concrete Pond Coefficient</th>
<th>Plastic/Tarpaulin Pond Coefficient</th>
<th>Total Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>6.743*** (0.107)</td>
<td>6.695*** (0.095)</td>
<td>13.210 (0.752)</td>
<td>6.750*** (0.049)</td>
</tr>
<tr>
<td>Pond Size</td>
<td>0.073***</td>
<td>0.115***</td>
<td>0.160**</td>
<td>0.041***</td>
</tr>
</tbody>
</table>
The results of the maximum likelihood estimates (MLE) for catfish production by production systems in Delta State are presented in Table 2. From the results; the gamma (γ) (0.981) indicates the variation (98.1%) of catfish output in the production frontier, the Log-likelihood function (1376.012) and Sigma squared (σ²) (0.311) showed good fitness of the model while the Wald-chi² (839880.07) showing the fitness of the explanatory variables in the model. The value of the prob>chi² (p<0.01) revealed that the log-likelihood, sigma squared, gamma and wald-chi² were significant at 1% indicating the significant presence of inefficiency parameters in the production function. The estimated results also showed that pond size, feed quantity, fertilizer quantity and stocking density had coefficients of 0.041, 0.008, 0.996 and 0.014 respectively that were positively signed and statistically significant at 1% level except fertilizer quantity that was significant at 5%. The coefficients 0.022 of labour used had negative correlation with the output and was significant at 1%. The positively signed inputs were consisting with a priori expectation, indicating that increased in their use increased the production level of the catfish, and hence increase their efficiency. The negative sign of labour used that decreased the efficiency level of the catfish production may be due to the scarcity of hired labour which made it expensive, hence its negative effect on production when more of man-power was employed by the farmers. All these inputs were the significant determinants of catfish production under production systems in Delta State.

Furthermore, the positive influences of the pond sizes under the various production systems of earthen pond, concrete pond and plastic/tarpaulin pond systems and the study area agrees with Akenbor and Ike (2015), who stated that adequate utilization of the pond size will increase productivity. The return to scale (RTS) is important in that it points to a resource user the region where he/she is operating for adjustment to be made. RTS recorded (Table 2) for catfish production under the production systems were earthen pond (0.086), concrete pond (0.089), plastic/tarpaulin pond (0.099) and the study area was 0.070 respectively, indicating decreasing returns to scale (DRTS). This implies that the farmers were operating in stage II of the production stages, the rational region of production where inputs utilization are between 0 - 1. The highest DRTS was recorded by the earthen pond systems (0.086) that confirm the results of the technical efficiency of the farmers where the earthen pond systems were the most efficient in Delta State. The question now is, what is the level of the technical efficiency of the farmers? The next focus answers this!

**Level of Technical Efficiency of Catfish Farmers**

Table 3: Technical Efficiency of Catfish Farmers by Production Systems in Delta State

<table>
<thead>
<tr>
<th>Class</th>
<th>Earthen Pond</th>
<th>Concrete Pond</th>
<th>Plastic/T. Pond</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freq.</td>
<td>%</td>
<td>Freq.</td>
<td>%</td>
</tr>
<tr>
<td>0.61 -</td>
<td>24</td>
<td>16.22</td>
<td>17</td>
<td>9.34</td>
</tr>
<tr>
<td>0.73</td>
<td>124</td>
<td>83.78</td>
<td>165</td>
<td>90.66</td>
</tr>
<tr>
<td>TOTAL</td>
<td>148</td>
<td>100</td>
<td>182</td>
<td>100</td>
</tr>
<tr>
<td>Mean</td>
<td>0.77</td>
<td>0.76</td>
<td>0.73</td>
<td>0.84</td>
</tr>
</tbody>
</table>

Source: Computed from Field Survey, 2021
Table 3 showed the technical efficiency (TE) of the catfish farmers by production systems and the result revealed the mean TE of 0.84 for Delta State farmers that showed efficiency gap of 16% operating below the frontier. The average TE’s of earthen pond, concrete pond and plastic/tarpaulin pond systems farmers in the study area were 0.77, 0.76 and 0.73 respectively, indicating that the farmers were 23%, 24% and 27% technical inefficient. Therefore, to improve the TE of the production systems’ farmers, their access to adequate inputs and improvement on their personal characteristics which are the determinants of inefficiency must be assured. Policy thrust is thus required in this direction.

Factors influencing Inefficiency of Catfish Farmers

Table 4: Inefficiency parameters of catfish farmers by production systems in Delta State

<table>
<thead>
<tr>
<th>Variables</th>
<th>Delta State</th>
<th>Plastic/T. Pond</th>
<th>Concrete Pond</th>
<th>Earthen Pond</th>
<th>Delta State</th>
<th>Plastic/T. Pond</th>
<th>Concrete Pond</th>
<th>Earthen Pond</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>Coefficient</td>
<td>Coefficient</td>
<td>Coefficient</td>
<td>Coefficient</td>
<td>Coefficient</td>
<td>Coefficient</td>
<td>Coefficient</td>
</tr>
<tr>
<td>Inefficiency Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>8.316</td>
<td>-7.332***</td>
<td>2.937***</td>
<td>-7.983***</td>
<td>8.316</td>
<td>-7.332***</td>
<td>2.937***</td>
<td>-7.983***</td>
</tr>
<tr>
<td>Age</td>
<td>2.886**</td>
<td>0.011**</td>
<td>0.090***</td>
<td>0.026***</td>
<td>2.886**</td>
<td>0.011**</td>
<td>0.090***</td>
<td>0.026***</td>
</tr>
<tr>
<td>Household Size</td>
<td>-0.943*</td>
<td>-0.014*</td>
<td>-0.023*</td>
<td>-0.138***</td>
<td>-0.943*</td>
<td>-0.014*</td>
<td>-0.023*</td>
<td>-0.138***</td>
</tr>
<tr>
<td>Educational Levels</td>
<td>-2.350**</td>
<td>-0.014*</td>
<td>-0.111***</td>
<td>-0.017**</td>
<td>-2.350**</td>
<td>-0.014*</td>
<td>-0.111***</td>
<td>-0.017**</td>
</tr>
<tr>
<td>Production Experience</td>
<td>-1.986***</td>
<td>-0.145**</td>
<td>-0.070*</td>
<td>-0.045***</td>
<td>-1.986***</td>
<td>-0.145**</td>
<td>-0.070*</td>
<td>-0.045***</td>
</tr>
<tr>
<td>Number of Ponds</td>
<td>-0.144*</td>
<td>-0.005**</td>
<td>-0.0003*</td>
<td>-0.150*</td>
<td>-0.144*</td>
<td>-0.005**</td>
<td>-0.0003*</td>
<td>-0.150*</td>
</tr>
<tr>
<td>Mortality of Catfish</td>
<td>0.002***</td>
<td>0.110**</td>
<td>0.015*</td>
<td>0.004***</td>
<td>0.002***</td>
<td>0.110**</td>
<td>0.015*</td>
<td>0.004***</td>
</tr>
</tbody>
</table>

Source: Computed from Field Survey, 2021

The results in Table 4 revealed the estimated technical inefficiency (TIE) parameters of catfish farmers by production systems in Delta State as age, household size, educational level, production experience, number of ponds and mortality of catfish and all were found to have significant effect on the farmers’ technical inefficiency. The age and mortality of catfish of the catfish farmers were positive and significantly related to their technical inefficiency (TIE) at 1%; while household size, educational level, production experience and number of ponds adopted were negative and significant determinants of the farmers’ inefficiency. The positive relationship indicates that increase in the variables in question increases inefficiency while the reverse is the case for negative relationship. Inefficiency of the farmers that increases with increase in age implies that older farmers were less efficient than the younger ones. This was expected because younger people are more vibrant, active and have the propensity for improved agricultural production than older people (Kintu, 2012). Increase in mortality of catfish that also increased the TIE of the farmers implies that the more the losses of catfish through death in pond, the less efficient the farmers. Improved effective management practices would reduce catfish mortality. The inefficiency of the farmers decreases with increase household size. This affirmed the report of Michael and Koyenikan (2020), who observed that household size serve as a source of labour in catfish production which requires a great deal of human effort. As educational level increased, it brought about decrease in TIE, which is in agreement with a priori expectation. This is because education enlightens and enables one to access useful information that enhances efficiency and increase productivity. Experience is the best teacher and practice makes perfect, as often said. This may be reason why production experience correlated negatively with the farmers’ inefficiency. The more years the farmers put in the practice of catfish production, the more they understand the enterprise, the more productive they become. This invariably would increase the farmers’ efficiency.

Conclusion

The application of Stochastic Frontier analysis on catfish production systems in the study area
concluded that the catfish farmers were operating about 16% below the production frontier which accounted for their technical efficiency gap in catfish production. Inefficiency in production increased with increase in the mortality of catfish and age of the farmers but decreased with increase in the household size, level of education, production experience and numbers of ponds used. To improve technical efficiency level, effort should be geared to minimized inefficient resources use and improved the overall catfish farmers’ productivity.

**Recommendations**

Based on the study, the following recommendations are therefore made:

1. To boost catfish production, young people who are more vibrant and active than old people should be encouraged to settle down and concentrate on catfish production to increase productivity.

2. More effective management measures should be put in place to reduce catfish mortality and improve the catfish production.

3. The government should provide adult education for the aged and uneducated fish farmers to minimize the challenge of inefficiency in the use of resources.

4. The catfish farmers should be encouraged to exploit the benefits of the earthen pond system to increase their productivity since earthen pond system is most efficient in Delta State.

5. Since the study area is dominated by male catfish farmers, more women should be encouraged to participate in catfish production enterprise (aquaculture) so as to ensure increased commercialization of catfish production.

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