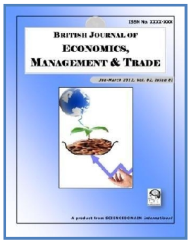

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Analysis of Production Relationships in the Capture Fishery of the Middle Cross River Basin: A Stochastic Frontier Approach

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Authors' contributions

This work was carried out in collaboration between both authors. Author IEE did the research design, data collection and writing of first draft. Author SOA did data analysis and correcting of first draft. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: Aims of the study were to carry out an empirical analysis of fish production in the capture fishery subsector. Estimates were to be made of the maximum likelihood production and inefficiency frontier functions. Also analysis of the determinants of technical efficiency was done in both rainy and dry seasons.
Study Design: Primary data were collected from fishermen through the use of questionnaires and measurement of fish catch.
Place and Duration of Study: This study was carried out in the Middle Cross River Basin, Nigeria between April 2010 and March 2011
Methodology: Multistage purposive and random sampling procedures were adopted for data collection.
Results: Findings show that labour and credit were the most important variables in fish production in the capture fishery subsector. Determinants of technical efficiency were age, fishing experience, educational level contact with extension and canoe length. The mean technical efficiency is 86% while the range is 48-99%.
Conclusions: Recommendations were made on timely and appropriately sized credit for fishermen according to seasonal needs. The use of appropriate mesh size of nets should be a policy issue that is monitored and enforced.

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Keywords: Middle cross river basin; maximum likelihood; production function; capture fishery; inefficiency frontier.

1. INTRODUCTION

The recurring issue of annual food importation particularly fish into Nigeria has continued to be a serious food security challenge. This is why it has also been constantly a major bane of the country's development agenda and in fact part of the transformation agenda for the current administration. Recently, there are attempt to tackle this huge fish imports by encouraging substantially domestic production through the West African Agriculture Productivity Programme (WAAPP). This it wants to achieve by using research institutes and universities to disseminate existing improved practices in fish production. It is estimated that the cost of fish importation into the country is N1billion and this is to take care of 50% demand-supply gap.

The Federal Department of Fisheries estimated that about 85% of the inhabitants of the coastal belts of the country were gainfully employed by the fisheries subsector [1]. In the Cross River State Basin, about 40% of the inhabitants of the Cross River estuary are involved in fishing while the percentage is relatively lower in the freshwater sector where crop farming has overtaken fishing in employment generation. Enhancement and sustained fish production system is capable of reducing significantly the unemployment situation in the country through its various value adding processes in the fish production and marketing chain. Fish can be used as a source of human food, livestock feed, source of income, foreign exchange earner. Fishing/fish is also important in sports, culture and aesthetics. It is important in human health as research has found that some fish species have the capacity to reduce heart diseases in heart attack risk. Low levels of certain types of Omega-3 fats in the blood are indications of possible fatal heart attack. It has always been known for some time that eating only some fishes protects the heart and reduces the risk of possible heart attack [2].

For human nutritional purpose therefore fish is next to meat as a source of animal protein [2]. The edible portion of the fish contains, on the average, about 20% protein [3]. At the household level, fish is used for soup, stew, porridge, Jollof and fried rice and for other food preparations. Also fish is used in confectionaries in fish pies and pizza production and contributes about 50% of available animal protein in Africa [4]. In Cross River State 80% of the available animal protein comes from fish products [3]. The middle Cross River basin accounts for a very large population of its supply. Critical issues that should be tackled if sustainable production is to be assured are the production, efficiency levels and profit margins of fish producers in different fish subsectors.

The current study sets out to fulfill the following three issues:

1. Analyze the determinants of fishermen efficiency of production in the Middle Cross River State Basin,
2. Determine the frequency distribution of technical efficiency among fishermen in the Middle Cross River State Basin,
3. Analysis of the frequency distributions based on seasonal production.

1.1 Theoretical Framework

Estimation of production frontier of production firms (fishermen) falls under two techniques, the parametric and non parametric method [5]. The parametric approach (stochastic frontier) incorporates a measure of random error which is prevalent in the fishing subsector where luck and weather are factors that affect daily catch [6]. The other method, the non parametric approach also known as linear programming techniques of Data Enveloping Analysis (DEA) does not take into account, the random error.

Stochastic production frontier estimation involves two general models; these are the error component model and the technical efficiency effects model [7-9].

Estimation of the parameters of the stochastic frontier and inefficiency models simultaneously in one stage has been done by [10-14]. This study estimated the stochastic frontier by adopting the approaches of [9,15,16].

A double log (Cobb Douglas) specification was adopted for the fish firms (respondents). It is implicitly specified as

$$lnY_i = \beta_0 + \sum_K \beta_k lnX_{ki} + V_i - U_i$$

Where:

Y_i = Fish output of the i^{th} firm in Kg.
X_{ki} = Factors determining the production frontier (labour, credit use, rental price, mesh size.)
V_i = Random variables reflecting noise and other stochastic shocks.
U_i = Non-negative random variables which measure technical inefficiency.

The random variable V_i is specified as independent, normally distributed with zero mean, constant variance σ^2_v and independent of the X_{ki}

$$V_i \sim iid\ N(O, \sigma^2_v)$$

The non-negative random variable U_i is assumed to be distributed independently of V_i and the X_{ki}. The model was estimated by maximum likelihood once a density function for U_i as specified below is obtained. The log likelihood function was:

$$Ln\ Y = \frac{N}{2}\ Ln\left(\frac{2}{\pi}\right) - N\ ln\sigma + \sum_{i=1}^{N} ln\ \ l\text{-}F\left[\frac{(-\varepsilon i\lambda)}{\sigma}\right] - \frac{1}{2}\sigma^2 \sum_{i=1}^{N} \varepsilon_i^2$$

Estimation of U_i provides a measure of the technical efficiency of the fishermen. A model of technical efficiency was also specified and it depended on firm specific variables. The effect of a set of variables on the production frontier was separated from the effect of a set of variables on the placement of a particular observation inside the frontier [15]. The easiest way to doing the truncated normal specification is to specify one of the parameters of the distribution as a linear function of several variables [7].

$$U_{it} \sim iid\ N(U_{it}, \sigma^2 u)$$
$$U_{it} = \partial_0 + \sum_j \partial_j 1n_j Z_{jit}$$

The Z variables are those variables that affected technical efficiency of producers (age, educational level, canoe length etc.) The Z variables affected the technical efficiency e^{-u} in a log linear way and so the ∂ j was interpreted as the negative of the elasticity of technical efficiency with respect to Zi. The technical efficiency model was tested using the likelihood ratio test. The test statistics was estimated as

$$\lambda = -2[L(H_0)–L(H_i)].$$

Where:

$L(H_0)$ = Value of log likelihood function of the average function
$L(H_1)$ = Value of the log likelihood function of the frontier function

The null hypothesis that $\partial_1 = \partial_2 \ \partial_3 = O$ was rejected if estimated likelihood ratio is greater than the critical value of X^2 (4) distribution. The critical values are in [17].

Testing of hypothesis on comparing technical efficiencies between the dry and rainy seasons was carried out using the Z- test.

$$Z_{cal} = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\frac{S_1^{1}}{n_1} + \frac{S_2^{2}}{n_2}}}$$

Where:

$\overline{X_1}$ = the mean Technical efficiency indices of fishermen in the dry season.
$\overline{X_2}$ = the mean Technical efficiency indices of fishermen in the rainy season.
S_1^2 = Standard deviation of technical efficiency in the dry season
S_2^2 = Standard deviation of technical efficiency in the rainy season.
n_1 = Number of sampled fishermen in the dry season.
n_2 = Number of sampled fishermen in the rainy season.

It should be noted that samples were assumed to be independent during the dry and rainy seasons.

2. METHODOLOGY

2.1 Study Area

The study area is the Cross River State Basin which covers an area of 45, 000 Km 2 made up of 40,000 Km 2 in Nigeria [3]. Hydrologically, the basin is dominated by the cross river which overflows its banks seasonally. This overflow makes the river rich in fish food and fish population. The Cross River can be separated into the upper, middle and lower segments. Cross River is the main river in south and south eastern Nigeria and it originates from Cameroon Republic. The middle Cross River covers the following Local Government Areas (LGA) – Obubra, Yakurr, Abi, Biase and Akamkpa in Cross River State, Nigeria.

2.2 Sampling Procedure

The five LGAs in the middle Cross River Basin were used for the study. A two stage multi-sampling procedure was used to first select the fishing settlements and next the fishermen respondents for the study. Purposive sampling was used to sample the fishing villages in the LGAs. Two fishing villages/settlement were picked from each LGA except Akamkpa. The sampled villages were Ohaha, Appiapum (in Obubra), Ekori, Assiga (in Yakurr), Igbo Imabana, Ediba (in Abi), Ikot Okporo and Agwagune (in Biase), Umon Island (in Akamkpa).

The sampling frame was drawn up with the assistance of community leaders in the communities. Simple random sampling procedure was thereafter used to sample 50 fishermen from the 9 villages/fishing settlements.

2.3 Data Collection and Analysis

Data were collected for a period of one year spanning from April 2010 to March 2011. Wet weight of fish caught by each respondent was weighed using a weighing scale while structured questionnaires were used to collect production data from the respondents. The Stochastic Frontier production package by [18] was used to estimate the maximum likelihood production and inefficiency frontier functions for all the respondents.

2.4 Model Specification

Empirical model specification for the determinants of technical efficiency is as follows;

$$\text{Ln } Q = \beta_0 + \sum \beta j \ \ln Xij + Vt - Ut$$

Where:

Q = Daily wet weight of fish caught by each respondents in kg.
Xi = Labour used by the respondents (in man-days)
X2 = Rental price of fixed assets used by the respondents (₦)
X3 = Credit used by each respondents (₦)
X4 = Mesh size of nets used by each respondent (mm)

Following [7] the mean of the firm specified technical inefficiency (Ui) was defined as

$$U = \partial_0 + \sum \partial Zij$$

Where:

Z1 = Age of fishermen (years)
Z2 = Fishing experience (Years)
Z3 = Educational background (Years)
Z4 = Contact with Extension Agents (number of times per fishing season)
Z5 = Length of canoe (cm)

3. RESULTS AND DISCUSSION

The maximum likelihood estimates of the parameters of the Cobb Douglas Stochastic frontier model is presented in Table 1. Significant variables in the all year round aggregate fish catch were labour, rental price and credit. They were all significant at the 1% level of significance. Labour and credit had the expected apriori signs. An increase in the use of labour, rental price and credit would increase fish catch.

The coefficients of the variables were also the elasticity's of production. The coefficient of labour, rental price and credit indicate that a 10% increase in these variables could increase fish catch by 3.5%, 1.1% and 1.7% respectively. Labour had the highest coefficient of 0.35 signifying its importance in the production process. Most fishermen in the middle Cross River did not bother about employing labour and carried out fishing alone. Some fishing gears require extra labour for effective use. Sum of all the coefficient of the parameters is 0.809 and is an indication that the fishermen are operating in the region of diminishing returns.

The estimated log likelihood ratio is 38.60 and is significantly different from zero. It is a measure of the goodness of fit of the variables in the production function and also shows the correctness of the specified distribution assumption of the error term. The critical value of 9.49 for the null hypothesis of no inefficiency effects are obtained from [17]. Gamma had a value of 0.72 and was significant at 1%. This value shows that about 72% of the variation in fish catch is caused by technical inefficiency. All deviations from the frontier are entirely due to technical inefficiency [19].

Table 1 also shows that the aggregate data were disaggregated into dry season and rainy season production activities. The maximum likelihood estimate of the Cobb Douglas stochastic model shows that in the two seasons, credit was the only variable that was not significant in the dry season. Other variables labour, rental price and mesh size were significant in both seasons. However, the level of significance differs in both seasons. For instance, labor was significant at 10% in the dry season but 1% in the rainy seasons while mesh size was significant at 1% in the dry season, but 5% in the rainy season. The implication is that the level of the use of these resources should be altered in the two seasons. Credit had a negative sign in the dry season but had a positive sign in the rainy season. This implies that an increase in the use of credit in the rainy season would contribute to increased fish catch. In the dry season credit could be reduced while fish catch will probably be maintained or increased. This is the main fishing period because water levels are low and catch increases. Labour was the most important variable in the rainy season while mesh size was the most important in the dry season. Increase in the amount of labour in the rainy season will, ceteris paribus, lead to more fish catch. Gamma is significant in both seasons. Gamma was 0.86 and 0.80 in the dry and rainy seasons respectively. It shows that 86% and 80% of the variation in fish catches in the dry and rainy seasons respectively are caused by technical inefficiency.

Table 1. Maximum likelihood estimates of stochastic production Frontier function for fish production in the Middle Cross River Basin

Variable	Dry season			Rainy season			Aggregate		
	Coefficient	SE	t	Coefficient	SE	t	Coefficient	SE	
Intercept	4.5535	0.9953	4.5749***	4.8941	0.9952	4.9176***	7.1324	0.8448	8.4428***
Labour (X1)	0.1369	0.0813	1.6884*	0.8866	0.3910	2.2674**	0.3561	0.0831	4.2852***
Rental price (x2)	0.1607	0.0616	2.6105**	0.2381	0.01616	3.8645***	0.1062	0.0128	8.2765***
Credit (x3)	0.0021	0.0755	0.0281	0.4483	0.1439	3.1148***	0.1748	0.0488	3.5778***
Mesh size (x5)	0.4089	0.1256	3.2560***	0.2035	0.0987	2.0615**	-0.1719	0.1175	0.1464
DIAGNOSTIC STATISTICS									
Sigma-squared	0.7109	0.3093	2.2984**	0.6507	0.0913	7.1305***	0.0312	0.01172	2.6642***
Gamma	0.8619	0.0995	8.6634***	0.8007	0.0999	8.0099***	0.7204	0.1248	5.7733***
Log like-hood function	20.7861			17.0849			32.1058		
LR test	17.6164			15.8629			38.6007		

*Key: 1. *** Significant at 1%, ** Significant at 5%, *Significant at 10%*
Source: Estimated from field data, 2011/2012

The sum of the coefficient of the variables show that there is diminishing return to scale in the dry season (0.7086) while there is increasing returns to scale in the rainy season (1.7765). This is in line with what is observable in the study area where fishing activities are more predominant in the dry season when more migrant fishermen flood the beaches for fishing. During this period less/same effort will lead to increased fish catch. Some fish species migrate for spurning during this period and are caught by the fishermen. The LR test statistic of 17.61 and 15.86 for the dry and rainy seasons respectively were significant. The models correctly fit the data.

The estimated technical efficiency distribution of sampled respondents is presented in Table 2. It shows that the fishermen in the Middle Cross River have a mean technical efficiency of 86%, [20] had 84% for large growers of tilapia, [21] had 69-89%. Only 62% (31) of the firms have above the mean technical efficiency. About 38% of the fishermen are below the mean technical efficiency level. They had technical efficiency of less than 0.80. These firms need to improve on the use of current technology. Technical efficiency ranges from 48% to 99%. Technical efficiency in the context of fishery is generally considered to be an indicator of the capacity of the Skipper (Head fisherman) [15].

For seasonal estimated distribution of technical efficiency, Table 2 shows that technical efficiency is better in the dry season (81.5%) than in the rainy season (78.2%). In the middle of the rainy season, the volume of water in the river rises and overflows its banks in many locations. At this period, some migratory fishermen abandon fishing or move to other locations. The pattern of technical efficiency also differs in the two seasons. In the dry season 54% (27 fishermen) had technical efficiency of above the mean while in the rainy season it is less than 34% (17 fishermen). Freshwater fishing is better organized in the dry season than in the rainy season. Migration of fishes from the marine/estuarine to the freshwater system for spurning is noticeable in the dry season and fishermen land the fishes in great numbers.

Table 3 shows the maximum likelihood estimates of the parameters of the determinants of the technical efficiency of the respondents. Firm specific determinants such as age, fishing experience, educational level, contact with extension and length of canoe were investigated and estimated. Fishing experience and educational level were significant at 1% while age and length of canoe were significant at 5%. The contact with extension was not significant in the rainy season and in the aggregate data. Contact with extension agents (EAS) was highly significant in the dry season at 1% level of significance. Educational level and length of canoe all had negative signs. The negative sign implies their inverse effects on technical inefficiency. In terms of efficiency, this means that fishermen with higher level of education, older age and longer canoes have higher technical efficiency. Positive association between educational level and technical efficiency is consistent with the studies of [22-24]. Usually more educated fishermen are better managers due to their ability to obtain timely information on technological advances and market conditions [20]. Larger and longer canoes have more capacity to carry fishing inputs (labour, nets, hooks etc) and should increase technical efficiency. Educational level had the highest coefficient due to its importance to technical efficiency.

Table 2. Frequency distribution of technical efficiency among freshwater fishermen in the Cross River Basin

Range of technical efficiency	Dry season		Rainy season		Aggregate	
	No. of fishermen	%	No. of fishermen	%	No. of fishermen	%
0.41-0.50	0	0	0	0	1	2
0.51-0.60	4	8	6	12	2	4
0.61-0.70	4	8	9	18	5	10
0.71-0.80	15	30	18	36	11	22
0.81-0.90	13	26	13	26	15	30
0.91-1.00	14	28	4	8	16	32
Total	50	100	50	100	50	100
Mean	0.8148		0.7817		0.8622	
Std deviation	0.1165		0.1125		0.1207	
Minimum	0.3593		0.3593		0.4790	
Maximum	0.9562		0.9411		0.9857	

Source: Estimated from fieldwork, 2010/2011

Table 3. Maximum likelihood estimates of determinants of technical efficiency in fish production in the Middle Cross River Basin

Variable		Dry season			Rainy season			Aggregate		
		Coefficient	SE	t	Coefficient	SE	t	Coefficient	SE	t
Intercept		-45.5779	0.9933	45.8829***	0.0043	0.9887	0.0043	1.1632	0.7615	1.5275
Age	Z_1	0.4959	0.0886	5.5990***	0.0245	0.8078	0.0303	-0.3511	0.1359	2.5824**
Fishing experience	Z_2	0.5140	0.1126	4.5665***	0.0909	0.8755	0.1039	0.4062	0.1388	2.9267***
Educational level	Z_3	-0.2963	0.9618	0.3081	0.3383	0.0909	3.7191***	-0.5942	0.0962	6.1786***
Contact with EAS	Z_4	-0.1457	0.0498	2.9251***	-0.0868	0.9937	0.0873	0.0559	0.1116	0.5015
Length of canoe	Z_5	-0.2410	0.0991	2.4307***	-0.1649	0.0987	1.6701*	-0.6239	0.2700	2.3106**

*Key: 1. *** Significant at 1%, ** Significant at 5%, *Significant at 10%*

2. Diagnostic statistics are the same as those in Table 1

Source: Estimated from field data, 2010/11

Table 3 also shows the maximum likelihood estimates of the parameters of the determinants of technical efficiency in the rainy and dry seasons. Age, fishing experience, contact with extension were significant in the dry season at 5%. The only determinant that was not significant in the dry season was educational level. The reason is because of increase in population of fishermen due to arrival of migrant fishermen. In the rainy season, only educational level and length of canoe were significant at 1% and 10% respectively. The only consistent determinant that was significant in both seasons was length of canoe. The negative sign on length of canoe was also consistent in both seasons. The implication of the negative sign is that canoe size should be increased so that technical efficiency will increase. The level of significance of the coefficient differs in the two seasons implying that the length (size) of canoe used in the two seasons could be changed for increased efficiency. Those hiring canoes should go for longer (larger) canoes in the rainy season or during periods of heavy catch. Educational levels, contact with extension had negative signs in both seasons. This is still consistent with the fact that increased educational level and contact with extension would increase technical efficiency especially in the dry season where contact with extension agents is significant.

4. CONCLUSION AND RECOMMENDATION

1. The stochastic frontier result showed that credit was a significant variable. Credit should be made available to the fishermen through their organizations on time and in the right amount. Credit for the dry season should be separated from that needed in the rainy season.
2. The result of the technical efficiency model calls for special extension services for the fishermen. Education and contact with extension agents were significantly associated with technical efficiency. Extension should be so coordinated that it should reach all the settlements in both dry and rainy seasons.
3. Policy on mesh size should be monitored and enforced. Enforcement of mesh size especially in the dry season will lead to avoiding overfishing.
4. Fishermen hiring canoes for fishing should use smaller canoes in the dry season and larger ones in the rainy season. Length of canoe was significant in both seasons.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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