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Technical efficiency and economic returns in artisanal fishery in the Niger-Delta, Nigeria

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Abstract
Stochastic Production Function approach and cost benefit analysis were used in this study to examine technical efficiency and economic return of artisanal fishery in the Niger Delta, Nigeria. Primary data were collected from 120 artisanal fishermen selected from 3 major fishing local government areas in Delta State. Empirical results showed that artisanal fish production is profitable as shown by gross margin, net returns and enterprise economic efficiency which were N90, 496.03, N49, 377.18 and 0.20 respectively. The results of stochastic production function showed that labour, capital inputs and cost of baits were significant determinants of fish output, while education, fishing experience, age of fishermen, fishing distance and household size significantly reduced inefficiency. The average technical efficiency was found to be 64% indicating that efficiency can be improved by as much as 36%, while production function exhibit increasing return to scale. Policies for capacity building of the fishermen and better access to production technology are recommended.

Keywords: Technical efficiency, Profitability, Artisanal fishery, Nigeria.

1. Introduction

The demand for fish in Nigeria is increasing astronomically, while domestic supply appears to be declining. Available statistics show that Nigeria imports about US$8 billion worth of frozen fish annually to offset the gap in the domestic demand. Fish provides a cheap source of high quality protein for human consumption and it can be consumed in a variety of forms, including smoked, dried, fried or steamed. Its protein contains the essential amino acids such as methionine, lysine, tryptophan which are absent in proteins of plant origin. Currently, the per capita fish consumption in Nigeria is estimated to be between 25-30 kg annually [1, 2].

The domestic fish supply come from two main sources; aquaculture and capture fisheries. While the former is largely undeveloped, accounting for less than 5 percent of fish production, capture fishery and importation account for the rest. However, the larger portion of the country's fish requirement is met through importation as the domestic production has not met 30 percent of the required fish demand in the last 20 years [3]. Capture fishery involves harvesting naturally existing fishes from the wild, either by smallholder fishermen (artisanal fishermen) or industrial trawlers. Artisanal fishery has been regarded as one of the most important activities which form the basis of livelihood for fishermen living along the coasts in Nigeria. The coastal artisanal fishermen operate with traditional dug-out canoes or pirogue ranging from 8-12 meters in length while the gears used include cast nets, hand-lines, basket traps, long-lines set gillnets and beach, and purse seines. Their operations range between 20 meters depth contour and a maximum depth of 40 meters with fishing activities taking place in coastal and brackish waters as well as all inland fishery sources [4].

A major setback to the development of artisanal fishery is crowding of efforts in coastal inshore waters as a result of lack of resources for longer distance exploration. The intensity of fishing in the inshore waters has increased drastically, leading to over fishing. This, coupled with the use of low technology fishing equipment, oil spillages and gas flaring, pose a big threat to domestic fish supply, economic returns in artisanal fishery and the livelihood of the inhabitants of the coastal areas. The policy makers being aware of this discouraging trend have, at various times put in place policies to improve the situation. These include various tailor-made extension programs, fish exploitation reforms, while fishermen themselves are encouraged to form viable cooperative societies. These programs are aimed at educating fishermen on fishing regulation compliance on one hand, and raising their productivity and efficiency through increased catch, value addition and improved marketing skills on the other hand. Several studies have examined resource use efficiency of culture fishery in Nigeria [5, 6] however, production efficiency of capture fishery has not received adequate attention. Therefore, this study is designed to examine technical efficiency of artisanal fishery in order to enhance its productivity for increased domestic fish supply and profitability of the enterprise.

2. Material and methods

2.1 Analytical framework

A production function describes the technical relationship that transforms inputs (resources) into outputs (commodities) at a given level of technology [7]. Farrel [8] explained that the efficiency of a production firm consists of technical, allocative and economic components; technical efficiency is the ability to produce a given level of output with a minimum quantity of inputs under certain technology; allocative efficiency refers to the ability to choose optimum input levels for given factor prices, while economic or total efficiency is the product of both technical and allocative efficiencies. Earlier studies on firm's production efficiency have focused on the use of deterministic and mathematical programming techniques for estimating production functions.

However, Aigner *et al*, [9] and Meeusen and Van den Broeck [10] independently proposed the Stochastic Frontier Production Function (SFPF) model which measures efficiency of a firm with reference to the production frontier representing maximum output that is technologically feasible for a given set of inputs and a benchmark of optimum production. In the SFPF, the error term is assumed to have two components *V* and *U*. The *V* covers random effects (random errors) which are outside the control of the decision unit while the *U* measures the technical inefficiency effects, which are behavioral factors that come under the control of the decision unit. They are controllable errors if effective management measures are put in place. The stochastic frontier approach is generally preferred in agricultural research due to its appropriateness to address the inherent variability of agricultural production process as a result of the interplay of weather, soil, pests, diseases and environmental factors as well as measurement errors which may result from not keeping accurate records especially in smallholder agriculture, such as the one being practiced in Nigeria.

The stochastic frontier production function model is specified as:

$$Y_i = f(x_i, \beta) + V_i - U_i \qquad \text{.........}(1)$$

Where, Y_i is quantity of fish catch (output) by fisherman i (in Kg), X_i denotes the inputs utilized, β is the vector of production function parameters, V_i is the stochastic error component, which is independently and identically distributed (iid) with zero mean and variance (σ^2v), while U_i is a non-negative, one-sided error term obtained by truncation (at zero) of the normal distribution. As indicated above, *Ui* captures the technical inefficiency relative to the frontier production function and it is assumed to be independently distributed with mean μi and variance (σ^2u) [11]. The variances of the random errors (σ^2_v) and that of the technical inefficiency effects (σ^2_u) and overall model variance (σ^2) are related thus: $\sigma^2 = \sigma^2_u + \sigma^2_v$, and the ratio, σ^2_u/σ^2 is called gamma. Gamma measures the total variation of output from the frontier, which can be attributed to technical inefficiency [12].

The technical efficiency (TE) of an individual firm is defined in terms of the observed output *(Y_i)* to the corresponding frontier output *(Ymax)*. The *Ymax* is maximum output achievable from inputs mix at the existing level of technology, assuming that 100 percent efficiency is obtainable. According to Coeli et al, [13], technical efficiency can be expressed as

$$TE = \frac{Yi}{Ymax} = \frac{exp(Xi\beta + vi - ui)}{exp(Xi\beta + vi)} = exp(-ui) \qquad (2)$$

Technical efficiency takes a value between zero and one.

2.2 The study area and data collection

The study was carried out in Delta State, Nigeria. Delta State lies between latitude 5^0 00/ and $6^0$30/N and longitudes $5^0$00/ and $6^0$45/E. It has a land area of 17,011km^2 and a population of 4,0981,391 [14]. The State is characterized by two climatic seasons; dry season between November and March and rainy season between April and October. The area is endowed with mangrove swamps, rivers, creeks and flood plains which offer enormous opportunities for fishing. A cross-sectional data obtained from artisanal fishermen from three local government areas (LGAs) in the State (Bomadi, Burutu and Patani) were employed for the study. The three LGAs were purposively selected because of the prevailing climatic and hydrographic conditions that favour a blossoming fishery economy. A random selection of 40 fishermen from each LGA making a total sample size of 120 fishermen was carried out while data were collected with the aid of well-structured and pretested questionnaire between February and May 2013. Information was gathered on socio-economic, fishing and marketing activities of the fishermen

2.3 Data analysis

Descriptive statistics (mean, standard deviation), gross margin and the stochastic frontier production function approach were employed to analyze the socio-economic characteristics, profitability and technical efficiency of artisanal fishery. Following Battese and Coelli [15], the production function of the artisanal fishermen is expressed in Cobb-Douglas functional form as follows:

$$\text{In}Y_i = \beta_0 + \beta_1 \text{In}X_{1i} + \beta_2 \text{In}X_{2i} + \beta_3 \text{In}X_{3i} + \beta_4 \text{In}X_{4i} + V_i - U_i \quad \text{.......}(3)$$

Where,

Y = fishing output of the ith fisherman

X_1 = labour used (based on number of fishing trips/week)

X_2 = depreciation of capital inputs such as boats, gears and accessories

X_3 = cost of fuel and lubricant per fishing trip (N)

X_4 = quantity of baits used (N)

While the inefficiency model (Ui) is defined by

$$Ui = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} \quad \text{...}(4)$$

Where,
Z_1, Z_2, Z_3, Z_4, Z_5, Z_6 represent years of formal education, household size, fishing experience, fishing season, fishing distance and age of respondents respectively. These socio-economic variables are included in the model to capture their possible influence on technical inefficiencies of the fishermen. Theβ's and δ's are scalar parameters to be estimated.

2.4 Economic return and profitability analysis
Budgetary analysis is used to examine cost and returns, and determine the profitability of artisanal fishery. Budgetary analysis is given by:

$$GM = TR - TVC \qquad \ldots\ldots\ldots\ldots (5)$$

and

$$\pi = GM - TVC \qquad \ldots\ldots\ldots\ldots (6)$$

Where,
π = profit (N)
TR = Total revenue (N)
TVC = Total variable cost (N)
GM = Gross margin (N)
TFC = Total fixed cost (N)
π /TC = Efficiency level

Olukosi and Erhabor [16] stated that gross margin is a good approximation for net-farm income, since small-scale farmers usually have negligible fixed costs.

3. Results and Discussion
The summary statistics of the key variables involved in fishing operation are presented in table 1 below. The mean output of fish-catch (output) by the fishermen is 1,482.60 kg with a standard deviation of 1, 023.38 kg. The average age of the sample fishermen is 44years, while labour is 5.12 fishing trips/week on average, with standard deviation of 3.02, showing that artisanal fishery is labour intensive. The average cost of capital inputs is N3, 024.20 with standard deviation of N1, 460.30, this shows that fishing requires a lot of capital inputs. Baits has an average cost of N 2,996.48 with standard deviation of N 1,820.58. The average years of experience in fishing and education of the fishermen are 17 and 11 years respectively, while the average household size is 6 persons. Summary of the descriptive statistics are presented in table 1

Table 1: Summary statistics of production function variable

Variables	Mean	Standard deviation
Output of fish caught (kg)	1,482.60	1,023.38
Labour (fishing trips/week)	5.12	3.02
Capital inputs (N)	3,024.20	1,460.30
Quantity of baits used (N)	2,996.48	1,820.58
Age of fisherman	44.34	24.55
Fishing experience	16.57	11.23
Educational level	10.83	4.62
Household size	6.25	3.38

Source: field survey data, 2013.

3.1 Estimates of stochastic frontier production function
The maximum likelihood (ML) estimates of the Cobb-Douglas stochastic frontier production parameters for artisanal fish production are presented in Table 2. The coefficients of labour, capital inputs and quantity of baits have positive signs and they are statistically significant, showing direct relationships with output. This implies that a 1% increase in labour, capital inputs and quantity of baits will increase the quantity of catch (fish output) by 0.300%, 0.260% and 0.418% respectively. The estimated variance ($\sigma^2 = 0.52$) is statistically significant at 5% indicating goodness of fit and the correctness of the specified distribution assumptions of the composite error term. Gamma (γ) is estimated to be 0.778 and it is statistically significant at 1% indicating that 78% of the total variation in fish output is due to technical inefficiency.
The inefficiency model shows that education, fishing experience and fishing distance have negative and significant effect on technical inefficiency. While household size and age of respondents have positive effect.

A negative coefficient means that the variable reduces inefficiency, while positive coefficient on the other hand implies that the variable increases inefficiency. As such, the negative coefficient of education implies that fishermen with higher level of education are likely to be less inefficient because they have higher tendency to pay attention to effective management of their fishing activities. Similarly, the negative coefficient of fishing experience means that increase in fishing experience leads to decrease in technical inefficiency. This is in accordance with the *a priori* expectations and consistent with the findings of Onyenweaku and Effiong [17] and Onyenweaku and Nwaru [18]. The positive coefficient of age of fishermen indicates that fishermen who are older are relatively less efficient in artisanal fishing and vice versa. This may be attributed to the rigour and drudgery of fishing which may be quite tasking for ageing people. This finding is in agreement with Amaefula [19] and Ogundari and Ojo [20] who in their studies of small scale farmers in Nigeria found age to be positively related to inefficiency.

Table 2: Estimates of stochastic frontier production function

Variables	Parameters	Coefficients	S.E
Constant	β_0	2.623**	1.156
Labour	β_1	0.300***	0.063
Capital inputs	β_2	0.260*	0.149
Fuel and lubricants	β_3	0.141	0.132
Baits	β_4	0.418**	0.193
Inefficiency model			
Constant	δ_0	1.194***	0.037
Education	δ_1	-0.129***	0.017
Household size	δ_2	0.373***	0.127
Fishing experience	δ_3	-0.225**	0.102
Fishing season	δ_4	0.005	0.492
Fishing distance	δ_5	-0.614***	0.212
Age of fisherman	δ_6	0.259**	0.107
Variance parameters			
Log likelihood ratio		36.835	
Sigma squared	σ^2	0.516**	0.235
Gamma	γ	0.778***	0.021

*, ***, and *** = 10%, 5% and 1% level of significancere spectively

The coefficient of fishing distance is also negatively signed and significant at 1% probability level. This implies that fishermen who travel longer distance for exploitations tend to be more efficient than their counterparts who operate within short distances. The summation of the output elasticities to inputs used in the production process is 1.119 (table 3).

Table 3: Elasticity of fish production and return to scale

Variable	Output Elasticities
Labour	0.300
Capital inputs	0.260
Quantity of baits used	0.418
Fuel and lubricants	0.141
Return to scale (RTS)	1.119

Source: field survey data, 2013.

As shown in table 3, the RTS value of 1.119 shows that the fishermen in the study area are in stage 1 of the production function, i.e. increasing returns to scale. At this stage, every addition to production inputs would lead to more than 100 increase in output. This is an indication that production inputs are not being efficiently utilized.

3.2 Technical efficiency analysis
The summary of the predicted technical efficiency scores are presented in table 4. The indices show that fishermen have varied efficiencies ranging from 0.976 (98%) to 0.275 (28%). The mean technical efficiency is 0.643 (64%), implying that on the average, fishermen in the study area are able to obtain a little over 64% of the potential output that could be realized by a fully efficient fisherman from a given mix of inputs at the present technology level. Although, this indicates that the fishermen are generally relatively efficient, there is still room for improvement as efficiency can be improved by as much as 36%

Table 4: Technical efficiency distribution of fishermen

Technical efficiency level	Frequency	Percentage
0.21 - 0.30	8	6.67
0.31 – 0.40	12	10.00
0.41 – 0.50	16	13.33
0.51 – 0.60	12	10.00
0.61 – 0.70	6	5.00
0.71 – 0.80	38	31.67
0.81 – 0.90	24	20.00
0.91 – 1.00	4	3.33
Total	120	100.0
Minimum (TE)		0.275
Maximum (TE)		0.976
Mean (TE)		0.643

Source: field survey data, 2013

3.3 Profitability analysis
The profitability analysis of artisanal fishery in the study area is presented in table 5. Gross margin of fishing is estimated to be N90, 496.03, while the net return is N49, 377.18. This shows that artisanal fishery is highly profitable in the study area as total revenue is more than double the total cost incurred by the fishermen. As such, greater efforts in fishing operations will enhance the income of the fishermen, all things being equal. The enterprise economic efficiency is 0.20. This means that for every N1 invested into artisanal fishing enterprise, 20 kobo is realized as profit.

Table 5: Costs and returns in non-motorized canoe fishing

Parameter	Amount (N)
Total revenue	134,535.73
Labour	28,533.05
Repairs & maintenance	9101.14
Miscellaneous expenses	6,405.51
Total variable cost	44,039.70
Gross margin	90,496.03
Fishing craft	18,371.17
Fishing gears	16,781.61
Accessories	5,966.07
Total fixed cost	41,118.85
Profit	49,377.18
Efficiency level (π /TC)	0.20

Source: field survey data, 2013.

4. Conclusion
In Nigeria, the role of fishing in national development, both from poverty alleviation point of view and food security perspectives poses some interesting concerns. Presently, fish production by artisanal fisher folks dominates fish production in Nigeria. The present study employs the stochastic frontier production function and gross margin analysis to investigate smallholder artisanal fishery in Delta State, Nigeria. Empirical results show that capital inputs, labour and baits are major contributing factors to technical efficiency. Estimates of the inefficiency model show that education, fishing experience and fishing distance have negative and significant effects on technical inefficiency while age and household size have positive effect. Without doubt, artisanal fishery is profitable in the study area, however profitability level as well as technical efficiency can be substantially improved if fish farmers have better access to production inputs, improved technologies and trainings.

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