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ECONOMIC EFFICIENCY OF ARTISANAL FISHING HOUSEHOLDS UNDER OIL POLLUTION ENVIRONMENT IN THE NIGER DELTA REGION OF NIGERIA

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Abstract

Fish supplies more than 87% of the animal protein in Nigeria, and more than 90% of coastal communities depend solely on fishing and fisheries related activities for their survival. Available information however, shows that Nigeria's inland water bodies are producing less than 13% of their estimated fishery potential. And domestic demand for fish has never been met by dependence on output from available aquatic sources. Nigeria therefore imports over US$ 200 million worth of frozen fish per annum. The capacity of artisanal fisheries to play its role of bridging this food gap, providing employment and generating income, particularly for the coastal communities in Nigeria, will largely depend on the adoption of appropriate management strategies that will ensure efficiency and sustainability given their debilitating oil pollution environment. This study employed a Cobb- Douglas stochastic frontier cost function to measure the level of economic efficiency and its determinants among these households. A multi-stage random sampling technique was used to select 160 respondents from whom input-output data, prices and socioeconomic characteristics were obtained. The results of the analysis showed that individual levels of economic efficiency ranged from 0.10 – 0.96 with a mean of 0.68. While age, household size and number of fishing trips made in a week decreased, access to credit, membership of co-operative society, and oil spill increased, significantly, the respondents' level of economic inefficiency. These observations particularly suggest that the farmers were yet to harness the potentials of farm credit and membership of cooperative societies in their farm business, perhaps as a result of poverty. We recommend training workshops and seminars to remedy this. There is also the need for policies that could compel oil companies to minimize oil spill within the farmers' fishing environment. The adverse effects of oil spill on the environment and the economic politics of forcing oil companies to deal with it are global problems that the international community could assist poorer nations find ways out of it.

Keywords: Economic efficiency, oil pollution, artisanal fishing, Niger Delta region, Nigeria

Introduction

Agriculture is the major economic activity, accounting for about 90% all such activities, in the Niger Delta region of Nigeria (Federal Office of Statistics, 1995). In this regards, fisheries resources represent the foci of livelihood activities in the region. Fish supplies more than 87% of the animal protein in Nigeria, and more than 90% of coastal communities depend solely on fishing and fisheries related activities for their survival (Davies, 2005). Artisanal fisheries is however, fast depleting (Kapadia 2002) in Nigeria. Available statistics show that Nigeria's inland water bodies are producing less than 13% of their estimated fishery potential (Sule ,Ogunwale and Atala 2002). And it is obvious that domestic demand for fish in Nigeria has never been met by dependence on output from available aquatic sources. The annual economic report by Central Bank of Nigeria shows that, Nigeria imports over US$ 200 million worth of frozen fish per annum to offset the gap in the domestic demand (CBN, 2006).

One of the major factors responsible for the declining supply of fish, from capture fisheries is oil spills. Oil exploitation in Nigeria has, no doubt, contributed enormously to the country's economic growth, but it has also left profound adverse impact on the natural environment. When oil spills occur, they cover the surface of the water. This reduces oxygen exchange thereby causing death of fishes because the oil coats the gills of the fishes preventing them from inhaling oxygen. In the same vein, oil spills endanger fish hatcheries in coastal waters, and contaminate commercially valuable fish. Also, oil slicks prevent sunlight from reaching deeper levels of water where coral life thrives, thus limiting food production by plants (photosynthesis). Hence, it brings a set-back to households whose main source of survival is fishing and consequently a decrease in their income earning capacity, exacerbating hunger and poverty among them. This has also increased the spread of different types of diseases among the fishers and their household such as conjunctivitis, cholera, dysentery etc. Inoni and Oyaide (2007) noted that oil spillage is one of the more pervading dynamic forces modifying the farm production relationship through its effect on the structure and income of producing households; it alters the structure of the agricultural production process by affecting the physical and value productivities of farm inputs. Aghalino (1998) observed that the impacts of oil exploitation on the oil- producing communities are three fold: first, it leads to environmental pollution, second, it destroys the ecosystem and the ways of life of the households; and third, it impoverishes the oil producing communities. And oil spill incidents have occurred in various parts and at different times along the Nigerian coastal waters. Between 1976 and 2005, 7,619 incidents resulted in the spilling of approximately 2,748,307.9 barrels of oil into the environment (ISNAR, 2006).

In addition, there is the issue of labour migration. As intensive oil exploitation activities take place, the issue of having enough labour for fishing becomes a problem in the area as many rural dwellers now prefer working as temporary staff in oil related contracting firms around the villages instead of fishing. This has led to labour shortages for many fishing operations and has resultantly caused fish shortage.

However, as fishing activities remain low largely because of the foregoing, production costs remain unacceptably high (Maduagwu 2000), perhaps because of production inefficiencies. The capacity of artisanal fisheries to play its triple role of food supplier, employment provider and income earner for the coastal communities in the Niger Delta will therefore depend on the adoption of appropriate management strategies that will ensure their efficiency and sustainability in the face of intensive oil exploitation activities. Ajibefun and Aderinola (2003) reported that efficiency of production is central to raising production and productivity of the African agriculture. This paper examines the economic efficiency of artisanal fishing households under oil pollution environment in the Niger Delta area of Nigeria. Several studies have reported efficiency estimates, especially among small holders farmers (Ajibefun and Aderinola, 2003; Ogundari and Ojo, 2009; Ike and Inoni, 2006) but little or no empirical studies exist on the economic efficiency of artisanal fishing households in the oil producing communities. The paper is guided by the null hypothesis that artisanal fishing households in the Niger Delta region of Nigeria are economically efficient.

Methodology

The study area is Niger Delta Region of Nigeria. The region spreads across nine States in Nigeria: Abia, AkwaIbom, Bayelsa, CrossRivers, Delta, Edo, Imo, Ondo and Rivers. It covers an area of about 70,000km^2 and has a population of 31,277,901 (Federal Republic of Nigeria Official Gazette, 2007). The Niger Delta Region is a highly petroliferous basin that situates at the mouth of River Niger bordering the Atlantic Ocean. It lies between latitudes $4^0 31^1$ and $5^0 30^1$ North and longitude $7^0 35^1$ and $8^0 51^1$ East (Uwatt, 2000).

Two States namely Delta and Bayelsa States were purposively selected for the study because they are home to several oil producing communities and also are leading sources of on-shore and offshore oil production activities. In addition, the two states have had cases of incessant oil spillage. Other reasons for choosing the two states are that they are largely riverine and are rich in fish stocks that support artisanal fishing activities. Two Local Government Areas were also purposively selected from each of the two states, based on predominance of fishing and oil exploitation activities; giving a total of four Local Government Areas. The Local Government Areas were Burutu and Ughelli north in Delta State, Ekeremor, and Southern Ijaw in Bayelsa State. Five communities each, that have suffered oil spillages between 2000 and 2010, were selected from the four Local Government Areas, giving 20 Communities for the study. From a list of artisanal fishing households, provided, for each community, by the state agricultural development project, eight households were randomly selected, giving 80 per state and 160 households for the study.

Data for the study were collected using a well-structured questionnaire. The questionnaire was administered to the selected households with the help of trained enumerators. The survey was conducted between September, 2011 and March, 2012.

Estimation Procedure:

The stochastic frontier production model was used for the analysis. It represents an improvement over the traditional average production function and over the deterministic functions, which use mathematical programming to construct production frontiers. The notion of a deterministic frontiers shared by all firms ignores the possibility that a firm's performance may be affected by factors entirely outside its control such as bad weather and input supply breakdowns as well as by factors under its control (i.e. technical inefficiency). To lump up the effects of exogenous shocks, both favourable and unfavourable, together with the effects of measurement errors and inefficiency into a single one-sided error term, and to label the mixture inefficiency is a problem with the deterministic frontiers.

According to Forsund, Lovell and Schmidt (1980) this conclusion is reinforced if one considers also the statistical noise inherent with every empirical interpretation such as measurement errors in the dependent variables and incomplete specification of the equation. Both of these arguments hold just as well for production functions as for any other kind of equation, and it may not be good not to distinguish this noise from inefficiency, or to assume that noise is one-sided. These arguments lie behind the stochastic frontier (also called composed error) model developed independently by Aigner, lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977). The essential idea behind the stochastic frontier model is that error term is composed of two parts. A symmetric component which permits random variation of the frontier across firms, and the other component which captures the effect of measurement errors, other statistical noise and random shocks outside the firm's control. A one-sided component only captures the effects of inefficiency relative to the stochastic frontier. Thevariant of the stochastic frontier production model that was used in this study is based on the one proposed by Battese and Coelli (1995) in which the stochastic frontier specification incorporates models for the technical inefficiency effects and simultaneously estimate all the parameters involved in the production and cost function models.

This is specified as follows:

$$Y_i = f(X_i\beta) + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where Y_i measure the quantity of output; X_i is a vector of the input quantities; β is a vector of parameters to be estimated; $f(Xi\beta)$ is a frontier production function; and ε_i is a composite error term (Aigner et al., 1977). Following Aigner et al (1977) the composite error term is given as;

$$\varepsilon_i = v_i - \mu_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where v_i is a random error, assumed to be independently and identically distributed as $v \sim N(0, \sigma^2 v)$. It represents random variability in production that cannot be influenced by the producing households. $\mu$is a non-negative random variable associated with technical inefficiency in production that is identically and independently distributed as $\mu_i \sim N(0, \sigma\mu^2)$. The frontier production function $f(X_i\, B)$ measures the maximum potential output for a given input vector, X_i. Both v_i and $\mu_i$cause actual production to deviate from the frontier.

Using a Cobb-Douglas functional specification to model artisanal fish production technology, the frontier production function in equation (1) is estimated using maximum likelihood estimation procedures which provides estimators for β and variance parameters, $\sigma^2 = \sigma^2 v + \sigma^2\mu$ and $\gamma = \sigma^2\mu / \sigma^2$. To empirically measure efficiency, deviations from the frontier are separated into a random (v) and an inefficiency (μ) component. Following Jondrow et al (1982) and given the distribution and independence assumptions on v_i and μ_i in addition to the fitted values of ε_i the conditional mean of μ can be estimated as:

$$E\left({}^{\mu_i}\!/\!{}_{\varepsilon_i}\right) = \alpha\left[\frac{f*\left({}^{\lambda\varepsilon_i}\!/\!{}_{\sigma}\right)}{1 - F*\left({}^{\lambda\varepsilon_i}\!/\!{}_{\sigma}\right)} - \frac{\lambda\varepsilon_i}{\sigma}\right]\ldots\ldots\ldots\ldots(3)$$

where $\sigma_*^2 = {}^{\sigma^2\mu\sigma_v^2}\!/\!{}_{\sigma^2}$ $f*$ is the standard normal density function and F* is the distribution function, both functions being evaluated at ${}^{\lambda\varepsilon}\!/\!{}_{\sigma}$. From this calculation, estimates of v and μ may be determined.

According to Bravo-Ureta*et al*. (1997), the ith artisanal household efficiency is measured using adjusted output. This output is derived by subtracting the random error v_i from both sides of equation (1).

Thus:

$$Y_i* = f(X_i\ ; B) - \mu_i = Y_i - v_i \ldots\ldots\ldots\ldots(4)$$

whereY_i^* is the adjusted output of the ith artisanal household; and μ_i is obtained from equation (3). Adjusted output Y_i^* is then used to derive the ith artisanal household technically efficient input vector X_{it} by simultaneously solving equation

(4) and the observed input ratios $X_1 / X_i = K_i(\forall_i > 1)$, where K_i is equal to the observed ratio of the two inputs in the production of Y_i^*. Given the assumption of Cobb-Douglas technology, the frontier production function is self-dual (Sharma, Leung &Zaleski, 1999). The dual cost frontier can be derived analytically from the production function in equation (1) thus:

$$C_i = h(P_i, Y_i^*, \phi) \text{..........}(5)$$

Where C_i is the minimum cost of the *i*th artisanal household associated with output Y_i^*, P_i is a vector of input prices for the *i*th artisanal household and ϕ is a vector of parameters to be estimated. The economically efficient input vector for *i*th artisanal household, X_{ie}, is derived by applying Shephard's (1970) procedure and substituting the artisanal household's input price and adjusted output levels into the derived system of input demand equations given by

$$dc_i / \partial P_k = X_{ie}(P, Y^*; \phi) \text{..........}(6)$$

Where ϕ is a vector of estimated parameters. The observed and economically efficient costs of production of the *i*thartisanal household are equal to $\sum X_i P_i$ and $\sum X_i e P_i$, respectively. These cost measures are used to compute the economic (EE) efficiency index for *i*th artisanal household as follows;

$$EE_i = \frac{\sum X_{ie} P_i}{\sum X_i P_i} \qquad \text{..................}(7)$$

The Cobb-Douglas cost frontier function, which is the basis of estimating the allocative efficiencies of the artisanal household, was employed to estimate the farm level overall economic efficiency. It is specified explicitly as:
$LnTC = W_0 + W_1LnPx_1 + W_2LnPx_2 + W_3LnPx_3 + W_4LnPx_4 + W_5Lnx_5$ ---------(1)

Where Ln denotes logarithm to base e
TC = Total production cost (₦) pa
Wo = regression constant
$W_1 – W_5$ = vector of unknown parameters to be estimated
X_1-X_5 = Vector of input variables in the model
P = vector of input prices
P_{X1} = wage rate
P_{X2} = cost of fuel and lubricant/pa
P_{X3} = cost of fishing baits/pa
P_{X4} = depreciation of capital inputs/pa
x_5 = output of fish (kg)/pa

The corresponding inefficiency effects model, which was simultaneously realized with the stochastic frontier model through maximum likelihood estimation (MLE) (Coelli, 1996) is stated explicitly as:

Economic inefficiency Effects Model:
This is given by:

$U_i = \delta o + \delta_1Z_1 + \delta_2Z_2 + \delta_3Z_3 + \delta_4Z_4 + \delta_5Z_5 + \delta_6Z_6 + \delta_7Z_7 + \delta_8Z_8 + \delta_9Z_9 + \delta_{10}Z_{10} + \delta_{11}Z_{11} + \delta_{12}Z_{12} + \varepsilon_i$ ……………..……….(2)
Where:
δis are the parameter estimates.
Z_1= age of household head (years)
Z_2 = household size
Z_3 = fishing distance (km)

Z_4 = level of formal education of household head (years)
Z_5 = access to credit (access =1, otherwise = 0)
Z_6 = gender (male=1, otherwise=0)
Z_7 = membership of co-operative society (membership = 1, otherwise = 0)
Z_8= fishing experience of household head (years)
Z_9= extension contact (number of visits in a year)
Z_{10} = number of fishing trips per week
Z_{11} = type of fishing craft (motorized canoe/boat=1, non-motorized canoe/boat = 0)
Z_{12} = oil spill (oil spill = 1, no oil spill = 0)

Results and Discussion

Estimation of Economic Efficiency:

The frequency distribution of economic efficiency estimates is presented in table 1. The table indicates that the artisanal household efficiency ranged from 0.10 to 0.96; the mean economic efficiency was 0.68. This indicates that the average fishing household in the study area would enjoy a cost saving of about 29.17 (1-0.68/0.96) percent if he or she attains the level of the most efficient household. The most economically inefficient respondent will have an efficiency gain of 89.6 (1-0.10/0.96) percent in fish production if he or she is to attain the efficiency level of the most economically efficient.

Estimation of Cost Function:

The Maximum Likelihood (ML) estimates of the stochastic frontier and cost function are presented in Table 2. For the cost function, the sigma ($\sigma^2 = 0.92$) and the gamma (γ=0.97) are quite high and significant at 5% and 1% level of probability respectively. The high and significant value of σ^2 indicates the goodness of fit and correctness of the specified assumption of composite error terms. The gamma shows that 97% of the variability in the output of artisanal households that are unexplained by the function is due to economic inefficiency.

The coefficients of wage rate, price of baits and output (adjusted for statistical noise), all had direct relationships with the total cost of production as expected and were highly significant at 1% level of probability. This implies that any increase in any of these variables would lead to an increase in total cost of production. The coefficients of price of fuel and lubricants and depreciation of capital inputs were also positively signed but not significant.

Wage rate was positively signed probably because labour had become costly perhaps because of the earlier stated general preference for working as temporary staff in oil firms by members of oil producing communities. A unit increase in output would lead to a 1.7% increase in cost. This is in line with a priori expectations that households incur higher costs as they produce more (Amaefula, 2007).

Sources of Economic Inefficiency:

Table 2 also shows the results of the factors influencing economic inefficiency of the artisanal households. The estimated negative coefficient for age of household head means that older heads of households tended to have smaller economic inefficiencies than younger ones, ceteris paribus. A one percent increase in age of household head will reduce economic inefficiency by 9.9522%. This goes against similar results by Idiong (2005), who noted that age of household head was directly related with economic inefficiency through misallocation of resources and conservatism. However, it may be that older heads of households are able to take healthier production decisions than younger ones because of their wealth of experience in artisanal fishing (Enete et al. 2002).

Household size was negatively signed and significant at 5% level of probability. This implies that larger households were more economically efficient than smaller ones. This disagrees with the findings of Sesabo and Tol (2005) who reported that households with larger sizes tended to be less efficient than those with smaller sizes. It is possible that large households have readily available labour for fishing than those with small sizes. Our earlier explanation regarding wage rate and labour migration refers.

The coefficients of access to credit and membership of cooperative societies were positively signed and significant at 5% level of probability. This implies that households who had access to credit and belong to cooperative societies were economically less efficient than their counterparts who had no access to credit and do not belong to any form of social organization. This could be because those who had access to credit may have diverted the credit to other uses than artisanal fishing. Loan diversion, perhaps to school fees, is generally a common phenomenon among farm households in Africa, essentially because of poverty. Similar result was reported by Okoye et al (2007) among cocoyam farmers in Anambra State, Nigeria. In addition, membership of social organization does not always translate to enhanced fortunes especially with respect to individual members' productive activities because the extent of benefits from such organizations most often depend on the level of contribution by members.

The coefficient of number of fishing trips was negatively signed and highly significant at 1% level of probability. This suggests that the higher the number of fishing trips made, the lower the level of economic inefficiency of the households. This is in agreement with a priori expectations probably because, as the frequency of trips increase, better knowledge of the fishing area also increase which could lead to a more cost effective utilization of inputs.

The coefficients of fishing distance, gender, fishing experience and type of fishing craft used were negatively, while education and extension contact were positively, signed but none was statistically significant. The coefficient of oil spill was however, positively signed and highly significant at 1% level of probability. This implies that any increase in oil spill will lead to a corresponding increase in economic inefficiency of the households. The result is not unexpected because of the adverse effects of oil exploitation on the fishing activities of the households as earlier discussed.

Test of Hypothesis:
The null hypothesis specified implies that inefficiency effects are absent and the variables included in the inefficiency effect model, have no effect on the level of economic efficiency. The chi-square test score of 95.43 was found to be greater than the critical value of 12.08 (table 3). This null hypothesis is therefore rejected, showing that the joint effect of these variables on economic efficiency is statistically significant. A corollary of the null hypothesis, which is that the explanatory variables in the economic inefficiency model are not stochastic, was also rejected. The chi-square test score of 55.70 was found to be greater than the critical value of 9.06. Therefore, the artisanal fishing households were not economically efficient, there were inefficiency effects. Thus, it can be concluded that the explanatory variables in the model do contribute significantly to the explanation of economic inefficiency of the respondents.

Conclusion

The study investigated the economic efficiency of artisanal fishing households in the Niger Delta region of Nigeria under oil spill environment. The study indicated that the respondents were not generally economically efficient, perhaps principally because of oil pollution. Individual levels of economic efficiencies range between 0.10 - 0.96 with a mean of 0.68, which reveal substantial economic inefficiencies hence considerable potential for enhanced profitability by reducing cost through improved efficiency. By operating at full economic efficiency levels, on average, the households would be able to reduce their cost by 29.17%. The variables age, household size and number of fishing trips made per week, all decreased the artisanal households' economic inefficiency and invariably increased their efficiencies, while access to credit, membership of co-operative society, and oil spill increased their economic inefficiencies. These observations particularly suggest that the farmers are yet to harness the potentials of farm credit and membership of cooperative societies in their farm business. This could be corrected through training and workshops for the farmers. There is also the need for policies that could compel oil companies to minimize oil spill in the farmers' fishing environment.

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Table 1: Frequency distribution of economic efficiency indices.

Economic Efficiency Index	Frequency	Percentage
≤0.50	28	17.5
0.51-0.60	06	3.75
0.61-0.70	17	10.63
0.71-0.80	25	15.63
0.81-0.90	62	38.75
0.91-1.00	22	13.75
Total	160	100
Maximum Economic Efficiency	0.96	
Minimum Economic Efficiency	0.10	
Mean Economic Efficiency	0.68	

Source: Field survey data, 2011

Table 2: Estimated stochastic frontier cost function for artisanal households in the Niger Delta region, Nigeria

Production Factors	Parameter	Coefficient	Standard Error	t-value
Constant Term	w_o	0.9246	0.4270	2.1650**
Wage rate	w_1	0.3154	0.0628	5.0236***
Price of fuel and Lubricants	w_2	0.0126	0.0607	0.2076
Price of Baits	w_3	0.4586	0.0646	7.0943***
Depreciation on capital inputs	w_4	0.0883	0.0575	1.5371
Output (Y*)	w_5	1.7023	0.2909	5.8507***
Inefficiency Factors				
Constant	z_0	4.0140	1.2507	3.2093***
Age	z_1	-0.0222	0.0022	-9.9522***
Household Size	z_2	-0.0166	0.0063	-2.6454**
Fishing Distance	z_3	-0.0364	0.0261	-1.3925
Education	z_4	0.2305	0.1855	1.2425
Access to Credit	z_5	0.5835	0.2838	2.0557**
Gender	z_6	-0.0461	0.3799	-0.1212
Membership of Cooperative Societies	z_7	1.2389	0.4968	2.4937**
Fishing Experience	z_8	-0.0241	0.0264	0.9099
Extension contact	z_9	0.3084	0.2277	1.3537
Number of Trips	z_{10}	-1.3979	0.4470	3.1227***
Type of fishing Craft	z_{11}	-2.9472	1.9906	-1.4805
Oil spill	z_{12}	0.8295	0.1363	6.0868***
Diagnostic statistics				
Log – likelihood function	-54.22423			
Total Variance (Sigma squared)	(σ)	0.9212	0.3466	2.6578**
Variance Ratio (Gamma)	(γ)	0.9675	0.0146	66.1242***
LR Test	90.6453			

*, ** and *** Significant at 10%, 5% and 1% respectively
Source: Field survey data, 2011

Table 3: Generalized likelihood ratio test of hypothesis for the parameters of the stochastic frontier production for artisanal fishing households

Null hypothesis	X^2 statistics	Critical value	Decision
(1) Ho :$\gamma = \delta_1 = --- = \delta_{12} = 0$ Artisanal households were economically efficient (noinefficient effects)	95.43	12.08	Reject Ho
(2) Ho :$\gamma = 0$ (the explanatory variables in inefficiency model are simultaneously equal to zero)	55.70	9.06	Reject Ho

Critical value is at 5% level. The critical values are in Kodde and Palm (1986)