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Economic Efficiency Estimate of Captured Fisheries from Plateau State, Nigeria: a Case on Pandam Lake fisheries innovation techniques

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Abstract:
This paper examines the productivity of captured fishery in Plateau state, with a view to examine the economics and sustainability of inland water fisheries innovation as renewable resource in the country. Daily fishing observations for 8 weeks and data collected through questionnaire from the 30 licensed fishers, using a purposive sampling technique was analysed by descriptive statistics, net farm income and stochastic frontier production and cost function models. The mean technical, allocative and economic efficiencies of the fishers were 0.91, 0.68 and 0.72 respectively. The fishing harvest rate indicates decreasing return to scale of 0.728, showing fishers were operating at stage II. Socioeconomics characteristics such as extension contact, age and educational status significantly explain technical efficiency and allocative efficiency. Transformation for effective and sustainable fisheries exploitation will need the involvement of educated fishers, extension education, and constraining of fishing gear at the fishery.

Keywords: fisheries, technical, efficiency, inefficiency, frontier, stochastic, renewable, innovation.

1 Introduction

The global captured fishery is in a crisis with a majority of the world's fisheries being fully exploited and about one third of them being either depleted or over-exploited (WB, 2002). FAO (2004) stated that, deterioration of global captured fisheries is raising significant concern, mainly because an estimated one billion people, mostly in low-income countries, depend on fish as their primary source of protein and the industry directly or indirectly employs some 200 million people worldwide (UNEP, 2006). This crisis has been wrought about by both market and policy failures which manifest themselves through among other things, improper management, inadequate property rights and regularly lack even rudimentary tools for management. The results of these are extinction of species, disturbances of delicate ecosystem, collapse of important fisheries, and destruction of natural environment, less dramatic, but of enormous importance, is the decrease in yield, income, and employment from fisheries.

Fisheries development plans in Nigeria have spanned for a period of 44 years however, the key objectives to make Nigeria self sufficient in fish production, conservation of the resource and other economic factors were considered targets of fisheries management remains unfulfilled((Azionu *et al.,* 2005) There is a growing consensus among ecologist, conservationist, biologist and fisheries managers that conventional season length and gear restriction management methods are bound to fail in the future, and that a new approach is therefore needed. (Bohnsack, 1993).

The state government in the last six years (2005) has adopted a regulatory mechanism at Pandam Wildlife Park lake fishery and the only of its kind in the Country. This is believed to conserved the fishery against stock collapse from desperate fishing efforts and overfishing; improve biological diversity, productivity and bring economic benefit (Bohnsack, 1998). It is directly being managed by government through the state tourism cooperation board for conservation, tourism and as a regulated commercial fishery. Our interest is on the impact of this innovation on the economics of participation on the future of captured fisheries.

2 Objective of the study.

The main objective of the study was to measure the economics of regulated fisheries innovation of Pandam Lake. Specific objective was to measure the net farm income (NFI), technical efficiency (TE), allocative efficiency (AE), and economic efficiency (EE)

3 Methodology

3.1 Study area

Pandam Lake is about 200 hectares located within the Pandam wildlife Park which lies within the Northern guinea Savannah in the middle belt plateau state of Nigeria. Plateau state lies between latitude 8°30′ and 10°30′N, longitude 7°30′ and 3°37′E with a land mass covering 53,585 square metres, the state has an estimated population of 3.6 million (NPC, 2006. 2012 estimate).

3.2 Data Collection

Primary data were collected using questionnaires on all licensed fishers, in addition to a daily fishing activities record of fishers carried out through a catch assessment survey (CAS) conducted between November 2010 and March 2011. The CAS was done to capture the lean months (April/May) and peak months (Nov/Jan) of fishing for period of four weeks each. The total observations of one thousand six hundred and eighty in eight weeks from thirty fishers (observations: 1680; 8wks; 30 samples).

3.3 *Method of Data Analysis*

3.3.1 Stochastic Frontier Production and Cost Function Models.

Stochastic frontier production and cost function models has the advantage of separation of impact of weather and luck from contribution of variation in both technical efficiency and allocative efficiency. A frontier model with output-oriented technical inefficiency is specified as follows:

$Y_i = E_i \beta + (\varepsilon_i = V_i - U_i)$ -- - - - - - - - - - - - - - - - (1)

Where Yi is output in kg of individual i (i= 1, 2,... N) E_i is the corresponding matrix of K inputs and β is a k x 1 vector of unknown parameter to be estimated. The disturbance term is made up of two independent components, εi = $V_i - U_i$ where $V_i \sim N(0, \sigma_v^2)$, and U_i is a one-side error term. The estimated frontier is stochastic since fishing is sensitive to random factors such as weather, resource availability and environmental influences (Kirkley et al., 1995). The first-best option is to consider a translog flexible functional form, because it represents a second-order approximation of any arbitrarily chosen function as well as being theoretically possible (Berndt and Christensen, 1973); it is specified as follows:

$\text{In } Y_j = \beta_o + \beta_1 \text{In}E_1 + \beta_2 \text{In}E_2 + \beta_3 \text{In}E_3 + \beta_{12}\text{In}E_1\text{In}E_2 + \beta_{13}\text{In}E_1\text{In}E_3 + \beta_{23}\text{In}E_2\text{In}E_3 + ½ (\beta_{11}\text{In}E_1 + \beta_{22}\text{In}E_2 + \beta_{33}\text{In}E_3)^2 + (V_i - \mu_i)$ - - - - - - - - - - - - - (2)

Where; subscript j refers to the jth fisher in the sample.

E_1 = is the length of fishing gears measured in meters.

E_2 = the time taken for passive gears to remain active in water (hours) per fishing trip as a proxy for hours fished (Kirkley et al, 1998).

E_3 = the number of fishing gears owned by the individual fisher that were in activity during survey period.

In = the natural logarithm (base e).

In Equation (2), the symmetry restriction is imposed a priori to be able to identify the coefficients (βij=βji). The corresponding cost frontier of Cobb-Douglas functional form which is the basis of estimating the allocative efficiencies of the fishers is specified as follows:

$C_i = g(P_i; \alpha) \exp(V_i + U_i)$; = 1, 2….n - - - - - - - - - - - - - - - (3)

a_1 = cost of gillnet used by fishers

a_2 = Cost of malia trap used by fishers

a_3 = Cost of hook line used by fishers

a_4 = Cost of gura trap used by fisher

a_5 = Cost of repairs/maintenance

a_6 = Cost of depreciation on equipment

Where C_i represents the total input cost of the i-th fisher; g is a suitable function such as the Cobb-Douglas function; P_i represents input prices employed by the i-th fisher and measured in naira; α is the parameter to be Estimated, V_is and U_is are random errors and assumed to be independent and identically distributed truncations (at zero) of the N (μ, σ^2) distribution. U_i provides information on the level of allocative efficiency of the i-th fisher. The allocative efficiency of individual fishers is defined in terms of the ratio of the predicted minimum cost (C_i*) to observed cost (C_i).That is: AEi= C_i^*/C_i = exp (U_i) Hence, allocative efficiency ranges between zero and one

3.3.2 Technical inefficiency model:
In the Battese and Coelli (1995) inefficiency effect model, the one-sided error term is specified as:
$U_i = \delta_0 + \sum_{j=1}^{4} \delta j\, Zj + \omega$ - - - - - - - - - - - - - - - - - (4)
Where Zs are socioeconomics variables used to explain efficiency differentials among fishers, δ's are unknown parameters to be estimated and ω_i is an iid random variable with zero mean and variance defined by the truncation of the normal distribution. The specific Z-variables the above model can be specified as follows:
$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \omega$ - - - - - - - - - - - - (5)
Where Ui is individual fishers' technical inefficiency measure in production and allocative efficiency in stochastic cost function and Z1, Z2, Z3 and Z4 represents age of fishers, family size, extension contact and level of formal education respectively. The technical inefficiency equation (5) can be estimated if the technical inefficiency and allocative inefficiency effects, Ui are stochastic and have particular distributional properties (Battese, et al, 1996). Under the null hypothesis $\gamma = 0$, the stochastic frontier model reduces to a traditional average response function, thus no technical inefficiency and allocative inefficiency effects.
3.3.3 Farm Business Analysis
The indicators used in this work were the Net farm Income (NFI) and Profitability Index. The total return was estimated by multiplying the total weight of catch by the prevailing market prices. The model used was represented by the equation;

$$NF1 = \sum_{i=1} P_i Y_i - \sum_{j=1} P_{xj} X_j - \sum_{k=1} F_k \quad - - - - - - - - - - - - (7)$$

Where;

NFI	=	Net farm Income (₦ per month of fishing)
Y_i	=	Fish output (kg/month)
P_i	=	Unit price of the fish (₦ / kg)
X_j	=	Quantity of variable input (where j=1, 2, 3 . . . m)
Px_j	=	Price/Unit of variable input (₦)
F_k	=	Cost of fixed inputs (Where k = 1, 2, 3...k fixed input)
∑	=	Summation (addition) sign.

The Net farm Income (NF1) is gross receipt less total cost. Profitability index (rate of return on an investment) was employed to explain the extent to which a Naira invested into regulated fishing will contribute to total value of output.

4.0 Results and discussion

4.1 *Descriptive statistic*

The descriptive statistics of variables for the production frontier estimations for the fishery are presented in Table 1 revealed that the average total value of fish caught by fishers (obtained by adding cash receipt from selling of fish and those consumed) was ₦60, 889.49 with a standard deviation of ₦24, 324.30. The large value of standard deviation implies that the fishers were operating at different levels of exploitation which is confirm by the minimum value of ₦11,376.00 and maximum value of ₦131, 328.09 for the fishery. Also, average total cost of investment for fishers was ₦56, 642 with standard deviation of ₦26, 546 and maximum figure of ₦120, 225. The highest cost item was the average cost of gillnet gear with ₦ 23,253. The mean "time in which passive gears remained active in water per fishing trip" was 1046.77 hours with a standard deviation of 1001.21 hours. This is an indication that fishing in the both systems are labour intensive exercise. The average number of fishing gears per fisher was 46.24, with a standard deviation of 38.24 gears.

Table 1: Descriptive statistics of variables used in the analysis

Variable	Notation	Mean	S ± D	MIN	MAX
Average Total Catch (kg)		3815.94	1621.62	758.40	8755.20
Total value of catch (₦)	Y	60889.49	24324.30	11376.00	131328.09
Length of fishing gears (M)	E1	1341.63	1328.57	45.72	5943.60
Time of passive gears in water	E2	1046.77	1001.21	48.00	4920.00
Number of gears owned/fisher	E3	46.24	38.24	14.00	210.00
Age of the sampled fishers	Z1	38.51	11.61	20.00	75.00
Family size of fishers	Z2	6.51	4.26	03.00	15.00
Extension contact	Z3	18.57	11.68	02.00	55.00
Formal educational status	Z4	8.05	6.27	00.00	13.00
Cost of gillnet used	c_1	23,253	13428	6300	60000
Cost of malia trap used	c_2	4,997	5349	1000	24000
Cost of hook line used	c_3	4,663	2992	1500	15000
Cost of gura trap used	c_4	15,970	13832	2000	50000
Cost of repairs/maintenance	c_5	717	365	200	1500
Cost of dep. on equipment	c_6	7,042	11541	1210	66825
Total cost of investment	c_t	56,642	26546	22340	120225

4.2 *Productivity analysis*

4.2.1 The Net Farm Income (NFI)

The Costs, returns and profitability analysis of fishers indicated in Tables 2, shows that labour represents about 29.90% of total cost, a figure less than the percentage reported in peasant agriculture, where the proportion of labour was found to make up to 80% of total cost (Sanaiya, 2001). The combine cost of fishing gears was about 61.13%. This may suggest that fishers do increase fishing effort during open season to achieved profit maximisation to make up for the closed season, thereby employing a more specialised gears and incurring more cost. The result confirms CBN (2004) findings on problems of artisanal fishing of inland fisheries in Nigeria, which they found that cost of gears forms over 60% of total cost of fishing.

The monthly estimated revenue was ₦ 52,194.46 and the profitability index (PI) of ₦ 6.0. This PI means that every naira invested in fishing business at the regulated site is expected to bring a five Naira return. This is a very important parameter for investment decision as fishers will wish to know the profit that they can possibly generate from their limited financial resource.

Table 2 Costs, return and profit analysis for Pandam Lake site

	Items	Amount/month	Open season Est.	percentage
A	**Returns**			
i.	Catch (Kg)	405.93		
ii.	Sales (₦)	60,889.49		
B	**Cost**			
i.	Labour (hr)	2600	18200	**29.9**
ii.	Gillnet (E_1)	2739.57	19176.67	31.50
iii.	Malia trap (E_2)	368.57	3980	6.64
iv.	Gura trap (E_3)	396.67	2776.67	4.56
v.	Hook line (E_4)	1602.86	11220	18.43
vi.	Repair/maint. (E_5)	67.14	470	0.77
vii.	Depreciation on Crafts (E_6)	720.27	5041.90	8.28
C	**Total cost**	**8,695.03**	60,865.21	100
D	**Net Farm Income**	**52,194.46**	365,361.22	
E	**Profitability Index**	**6.0**		

4.2.2 Stochastic frontier production and cost function

The maximum likelihood estimates of the stochastic frontier Production functions for fishers in the study area are presented in Table 3. The estimated coefficients of all the parameters of stochastic production function using translog specification is not necessarily meaningful in fisheries economics, however, the return to scale (RTS) shows that exploitation/ harvesting of fish was in stage where technical and economic efficiency is obtained, meaning that the estimated elasticity's of the explanatory variables of the model show that all the variables have decreasing function to the factors. The returns to scale (RTS) in Table 5 was 0.728, indicating a decreasing returns to scale and that fishing exploitation was in stage II of the production surface. This shows that efforts could be improved to expand the present scope of production/ harvesting to actualise the full potential of fishers that could result to the attainment of more output.

The estimates of the parameters of stochastic frontier cost model of the fishers in the area were also presented in Table 4. The result suggested that about 78% variation of total cost incurred by fishers were as a result the differences in the fishers' allocative efficiency. Furthermore, except for coefficient of cost of repairs/maintenance on fishing crafts/gears E5, which was negative and insignificant, the estimated coefficients of the parameters of cost function were all positive. This implies that the variables (E1= cost of gillnets, E2=cost of malia trap, E3=cost of gura trap, E4=cost of hook line, E6 = depreciation on fishing crafts) used in cost analysis have direct relationship with total cost of fishing used for output realised. In other words, cost of fishing increases by the value of each positive coefficient as the quantity of each variable is increased by one. The cost of hook line and depreciation on crafts were positive and significant at 5%, suggesting the items were major cost components of fishing in the study area.

Table 3: Technical Efficiency Analysis Using Translog Specification

	OLS			MLE		
Variable	**Coef**	**S.E**	**t-ratio**	**Coef**	**S.E**	**t-atio**
Intercept	5.37	2.54	2.10	5.56	1.05	5.27*
InE_1	0.33	0.38	0.87	0.29	0.17	2.72*
InE_2	0.45	0.73	0.611	0.47	0.39	2.21**
InE_3	0.29	0.90	-0.32	-0.15	0.63	-0.23
InE_1 InE_2	0.015	0.15	-0.98	-0.022	0.095	-0.23
InE_4 InE_3	0.073	0.18	0.38	-0.034	0.15	-0.22
InE_2 InE_3	0.088	0.10	0.87	0.057	0.087	0.65
$InE_1{}^2$	0.087	0.17	-0.49	-0.047	0.15	-0.31
$InE_2{}^{-2}$	0.071	0.20	0.34	0.10	0.18	0.55
$InE_3{}^{-2}$	0.15	0.19	-0.079	-0.12	0.16	-0.75
Constant	0			1.85	1.82	-1.01
Z^1	0			-0.0097	0.0027	-0.35
Z_2	0			0.083	0.065	1.27
Z_3	0			-0.092	0.05	-2.73*
Z_4	0			0.144	0.07	2.05**
δ^2	0.31			0.34	0.12	2.81*
γ	0.71			0.68	0.15	4.48*
Log likelihood				-34.55		
LR test (DF; 6, 095 = 12.59)				16.84		

*and ** significant at 1% and 5% respectively

Table 4: Stochastic cost function analysis using Cob-Douglass specification

Variable	OLS			MLE		
	Coef.	S.E	t-ratio	Coef.	S.E	T-ratio
Intercept	7.3	0.45	16.17	7.08	0.50	13.99*
InE_1	0.05	0.06	0.89	0.058	0.06	1.0
InE_2	0.013	0.10	0.12	0.400	0.0.70	0.57
InE_3	0.043	0.12	0.34	0.102	0.63	0.16
lnE_4	0.06	0.50	0.12	0.090	0.031	2.92**
lnE_5	-0.03	0.051	-0.59	-0.06	0.037	1.59
lnE_6	0.21	0.067	3.13	0.410	0.146	2.80*
Constant		0		0.77	0.46	1.66
Z^1		0		0.044	0.017	-2.57**
Z_2		0		0.018	0.049	-0.37
Z_3		0		0.040	0.0`7	2.24**
Z_4		0		0.013	0.013	1.01
δ^2		0.057		0.14	0.046	3.03*
γ		0.36		0.78	0.25	3.12*
log likelihood				-25.89		
LR test		df;6,095= 12.59		29.50		

*and ** significant at 1% and 5% respectively

4.2.3 Efficiency and inefficiency estimates

The distribution of fishers according to deciles ranges and frequency distributions of technical, allocative and economic efficiency are presented in Table 5 shows that there was no fisher operating below 50% technical efficiency level. Similarly, all the fishers were operating at 60% or more technical efficiency levels. The result further indicated that 76.67% of fishers were operating at 90% or more efficiency level. The mean technical efficiency score of fishers of regulated Pandam lake fishery was 92.50%. Generally, most fishers of regulated fishery were operating at higher technical efficiency. Allocative efficiency ranges between 40.21% -97.30% with a mean of 72.17% and economic efficiencies ranges from 40.11% - 96.42% with a mean of 68.12%. This result implies capacity of fishers to fished/harvest a predetermined quantity of output at a minimum cost is relatively high with TE contributing more to EE for the fishers sampled. The arithmetic means of the individual technical efficiency scores of 0.92 and allocative efficiency of 72.17% for regulated Pandam Lake fisheries can compare well with Lokina (2008) for Lake Victoria artisanal fisheries and Squires et al (2003) also found similar result, for the Malaysian gillnet fleets of artisan fishers. But these figures are comparatively higher than those found in Kuperan et al (2001) in Malaysian trawl

fishery. These comparatively high efficiency scores are consistent with Schultz's (1964) thesis of "Poor and efficient" smallholders and peasant farmers in developing country agriculture.
The stochastic frontier production function simultaneously estimated the technical inefficiency. The analysis indicated that the coefficients of Age of fishers and educational status were negative, with extension contact and educational status showing statistically significant at 5% level of significance. This suggests that increasing these two variables will decrease technical inefficiency i.e. increase technical efficiency. Family size was positive, indicating that this factor can lead to increase in technical inefficiency of farmers in the study area. The stochastic frontier cost function also simultaneously estimated the allacative inefficiency shows that The analysis indicated that the coefficients of Age of fishers and family size were negative, with Age of fisher being significant at 5%, this is suggesting that as the fishers become very old, their cost minimising efficiency decreases. Furthermore, educational status also shows statistically significant at 5% level of significance. This suggests that for a one year increase in formal education that a fisher made, there will be a 4% probability increase in his/her allocative efficiency.

Table 5 Deciles Range of frequency distribution of TE, AE and EE of fishers

	TE		**A.E**		**E.E**	
Range	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**
0.00-0.19	-	-	-	-	-	-
0.20-0.29	-	-	-	-	-	-
0.30-0.39	-	-		-	-	-
0.40-0.49	-	-	2	6.67	2	6.67
0-50-0.59	-	-	6	20	2	6.67
0.06-0.69	2	8	5	16.67	4	13.33
0.70-0.79	2	10	4	13.33	7	23.33
0.80-0.89	3	16	6	20	4	13.33
0.90-0.99	23	20	7	23.33	11	36.67
TOTAL	30	100	30	100	30	100
Min	6.74		40.21		40.11	
Max	98.32		97.30		96.42	
Mean	**91.52**		**72.17**		**68.12**	
St.D	18.11		11.18		8.91	
Return to scale			SPF		SCF	
Variable			**Elasticity**	**Variable**	**Elasticity**	
LnE1			0.29	LnE1	0.058	
LnE2			0.47	LnE2	0.400	
LnE3			-0.15	LnE3	0.102	
LnE1E2			-0.022	LnE4	0.090	
LnE1E3			-0.034	LnE5	-0.06	
LnE2E3			0.0570	LnE6	0.410	
LnE1			-0.047			
LnE2			0.10			
LnE3			-0.12			
RTS			0.728		1.00	

5.0 Conclusion and Policy Implications

The profitability index shows for every one naira invested, a return of five naira is made means that the business is worthwhile for low income earnings. This level of profit can be sustained if the high technical efficiency level at the Pandam Lake is kept in cheek by fishery managers at the lake to reduce technical efficiency by constraining number of gears per fisher, which at the moment averages fifty seven with a 91.50% mean technical efficiency. Constraining gears at Pandam Lake the only way of keeping overexploitation.

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General Model		Model I		Model II	
		C	se	C	se
constant		5.8	1.91	7.54	1.0*
LnE1		-0.25	0.28	0.01	-0.17
LnE2		0.26	0.52	0.07	0.34
LnE3		0.17	0.63	-0.04	0.57
LnE1lnE2		0.27	0.08	0.04	0.06
LnE1lnE3		0.02	0.09	0.02	0.08
LnE2lnE3		0.03	0.05	0.02	0.04
$LnE1^2$		-0.04	0.40	-0.04	-0.03
$LnE2^2$		-0.06	0.05	-0.07	-0.05
$LnE3^2$		-0.05	0.09	-0.05	-0.09
	Inefficiency model				
Constant	Z_0		0	-0.35	-0.96
Age	Z^1		0	-0.01	0.02
Family size	Z_2		0	0.05	0.04
Ext. con	Z_3		0	-0.07	0.03*
Education	Z_4		0	0.09	0.4*
Sigma			0.24	0.29	0.09**
Gamma			0.67	0.72	0.15**
Log likelihood			-47.24	-32.73	
LR test	(df, χ^2 =6,095 =12.59)			21.01	