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## **TECHNICAL EFFICIENCY OF SMALL SCALE FARMERS: AN APPLICATION OF THE STOCHASTIC FRONTIER PRODUCTION FUNCTION TO FISH FARMERS IN IBADAN METROPOLIS, OYO STATE, NIGERIA.**

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### **Abstract**

*This study assessed the technical efficiency of fish farmers in Ibadan metropolis of Oyo State, Nigeria using the stochastic frontier production function analysis. Primary data were collected from 82 fish farmers in Ibadan metropolis. The mean efficiency value was 0.906 with majority (65.9 percent) of the fish farmers being over 90 percent efficient and about 34.1 percent having technical efficiency ranging from 50 to 90 percent. The distribution of results also showed that the fish farmers were more efficient in the use of some inputs. Changing the input combinations was observed to increase farm level efficiency. The farmers in the study area therefore need to use available input intensively and rationally so as to produce better output and be more technically efficient.*

**Keywords:** *Small scale, Fish farmers, Stochastic frontier, Technical efficiency*

### **1. Introduction**

Nigerian agriculture is dominated by small scale farmers who produce the bulk of food requirements in the country. Despite their unique and pivotal position, the small holder farmers belong to the poorest segment of the population and therefore, cannot invest much on their farms. The vicious cycle of poverty among these farmers has led to the unimpressive performance of the agricultural sector. While several efforts have been undertaken to raise their production and productivity so as to achieve food security, such efforts have had negative implications for the environment. As the population density increases, the food requirements of the populace increase, pushing many farmers into new lands and some others into marginal lands. One of the enormous challenges in the drive to increase food to feed the growing population is on how to raise productivity and efficiency in the agricultural sector. More so that Nigeria's rapid population growth has outstripped the nation's capacity to grow food. From 1980 to 2005, Nigeria's population grew by 3.1% a year, while agricultural production lagged far behind - growing at just 2.5% a year (Ojo *et al* 2006). This has aroused the consciousness of the operators in the agricultural sector of the economy to stimulate increased food production.

Nigerian governments, had at various times, adopted different agricultural development programmes aimed at raising the production, efficiency and productivity of these farmers. The programmes

included the Agricultural Development Project, National Agricultural Insurance Scheme, National Directorate of Employment, River Basin Development Authority, Green Revolution, National Agricultural Land Development Programme, the Agricultural Credit Guarantee Scheme, and National Accelerated Food Production Programme etc. Given these various agricultural programmes and policies implemented over the years to raise farmers' efficiency and productivity, the Nigerian farmers are still not able to meet the food needs of the populace. This then makes it imperative to quantitatively measure the current level of and determinants of technical efficiency and policy options available for raising the present level of efficiency, given the fact that efficiency of production is directly related to the overall productivity of the agricultural sector vis-à-vis the fishery sub-sector.

Nigeria being a coastal country has about 1,280 kilometer square marine areas and about 124,878 kilometer square of inland waterways. But in spite of this potential, domestic fish production is grossly inadequate to meet even growing domestic demand. It is noteworthy to state that, the socio-economic welfare of a particular nation is dependent on the level of productivity of the agricultural and industrial sectors of that economy. Therefore, if this level of productivity is hampered or not maximized, the economy will suffer as in the case of the Nigerian agricultural sector, which has been suffering from poor productivity due largely to inadequate supply of the right quality of inputs. It is in this wise that, it is expedient for us to examine the level of technical efficiency of input use of the agricultural sector vis-à-vis, the fishery sub-sector. Also from the vast literature on technical efficiency (Abdulkadir *et al* 1999; Ajibefun *et al* 1996, Amaza, and Olayemi 2002, Ajibefun and Daramola, 2003, Omonona, *et al* 2006, Awoniyi and Omonona, 2006; Omonona and Sopitan, 2006 etc), those that have been carried out on technical efficiency of fish farming have been very few and limited in scope.

The measurement of farm efficiency is an important area of research both in the developed and developing world (Olayide *et al* 1979, Engle *et al* 1993, Battesse and Coelli 1995, Amaza and Olayemi 2002, Kareem *et al*, 2006) affirmed that at least 73% of all rural Africans are small-scale farmers. But despite that such a high percentage of the population are involved in farming, most of the food requirements are still not being met from local production, suggesting that policy interventions should always be linked to efficiency. There is a need therefore, to study the input and output technical efficiencies of small-scale fish farmers, because this will serve as a source of guide for investment decisions of farmers and the basis for policy recommendations to the government.

The issue of inputs used and outputs made, pose a lot of problems to small-scale fishery producers. Consequently, information on the various inputs at the optimum formulation that contribute significantly to maximization of output would be of much benefit to intending fish farmers.

## 2. Methodology

## **2.1 Study area and data**

The study was conducted in Ibadan the capital of Oyo State, which is the third largest city in Nigeria by population (after Lagos and Kano), and the largest in geographical area. It is located in south-western Nigeria, 78 miles (125.5km) inland from Lagos and is a prominent transit point between the coastal region and the areas to the north. Its population is 2,550,593 according to 2006 census results, including 11 local government areas. The population of Ibadan municipal, including five LGAs, is 1,338,659 according to 2006 national census figures, covering an area of 128 kilometer square.

Primary data were collected from a population of small scale fish farmers in the city for this research work. Different fish farmers from different local government areas in Ibadan metropolis were randomly sampled as respondents. A list of all the fish farmers operating in the metropolis was obtained, from where a sample of 89 small scale fish farmers was selected. However, only 82 respondents' questionnaires were good enough for analysis. Both descriptive and stochastic production frontier models were used in this paper. The descriptive statistics used include measures of central tendency and dispersion in addition to graphical and tabular analyses

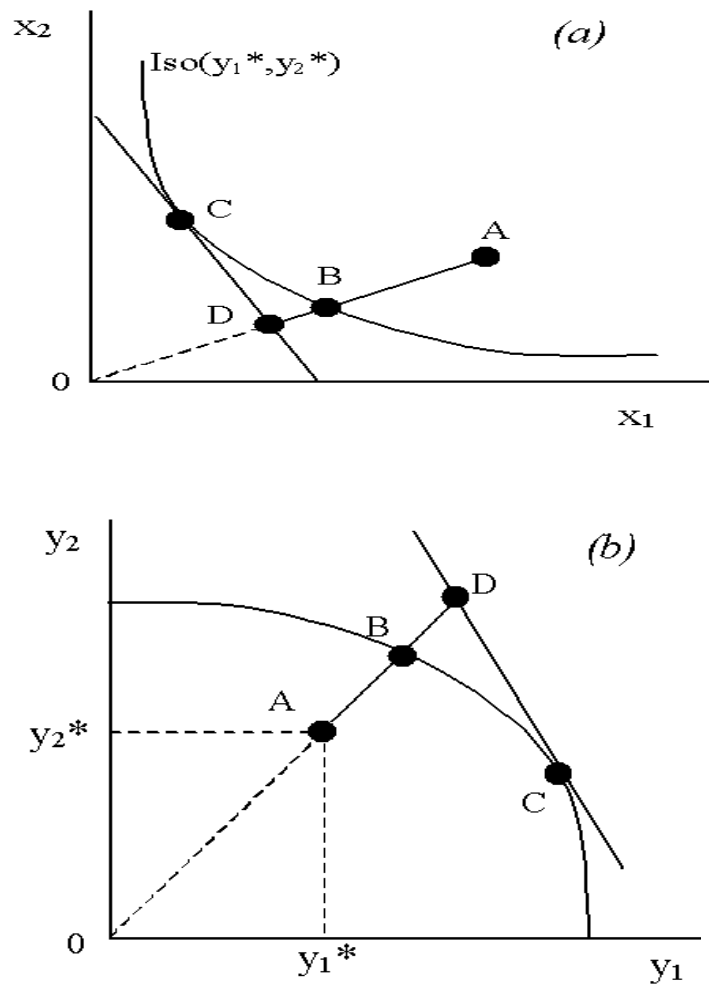
## **2.2 Theoretical and analytical techniques**

The concept of technical efficiency model can be illustrated graphically using a simple example of a two input ( $x_1, x_2$ )-two output ( $y_1, y_2$ ) production process (Figure 1). Efficiency can be considered in terms of the optimal combination of inputs to achieve a given level of output (an input-orientation), or the optimal output that could be produced given a set of inputs (an output-orientation).

In Figure 1(a), the firm is producing a given level of output ( $y_1^*, y_2^*$ ) using an input combination defined by point A. The same level of output could have been produced by radially contracting the use of both inputs back to point B, which lies on the isoquant associated with the minimum level of inputs required to produce ( $y_1^*, y_2^*$ ) (i.e. Iso ( $y_1^*, y_2^*$ )). The input-oriented level of technical efficiency ( $TE_i(y, x)$ ) is defined by  $OB/OA$ . However, the least-cost combination of inputs that produces ( $y_1^*, y_2^*$ ) is given by point C (i.e. the point where the marginal rate of technical substitution is equal to the input price ratio  $w_2/w_1$ ) (Kumbhaker and Lovell, 2000).

The production possibility frontier for a given set of inputs is illustrated in Figure 1(b) (i.e. an output-orientation). If the inputs employed by the firm were used efficiently, the output of the firm, producing at point A, can be expanded radially to point B. Hence, the output oriented measure of technical efficiency ( $TE_o(y, x)$ ); can be given by  $OA/OB$ . This is only equivalent to the input-oriented measure of

technical efficiency under conditions of constant returns to scale. While point B is technically efficient, in the sense that it lies on the production possibility frontier, higher revenue could be achieved by producing at point C (the point where the marginal rate of transformation is equal to the price ratio  $p_2/p_1$ ). In this case, more of  $y_1$  should be produced and less of  $y_2$  in order to maximize revenue. To achieve the same level of revenue as at point C while maintaining the same input and output combination, output of the firm would need to be expanded to point D. (Kumbhaker and Lovell 2000).



**Figure 1: Input (a) and output (b) oriented efficiency measures**

Following Richmond, 1974, Seyoum *et. al.* 1998, Mohammad and Erandi, 2003), this study used the Cobb-Douglas functional form

approach in analyzing the technical efficiency of fish farmers in Ibadan metropolis. The functional form is specified as follows:

$$Y_i = A \prod_{i=1}^N X_i^{\beta_i} e^{-U_i+V} \quad (11)$$

Where A and  $\beta_i$  are unobservable parameters indicating the efficiency parameter and the output elasticity coefficients respectively.

The estimating equation becomes:

$$\ln Y_i = \ln A + \sum_{i=1}^n \ln X_i + e_i \quad (12)$$

Where  $e_i = V_i - U_i$  and  $\ln e = 1$

Hence,

$$\ln Y_i = \ln A + \sum_{i=1}^n \beta_i \ln X_i + (V_i - U_i) \quad (13)$$

Or,

$$\ln Y_i = \ln A + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \dots + \beta_4 \ln X_4 + (V_i - U_i) \quad (14)$$

The MLE which, however, has been found to be asymmetrically more efficient than the corrected OLS estimators (Coelli, 1995) was used in this paper. Therefore, Maximum Likelihood Estimator (MLE) provided estimation for  $\gamma$ ,  $\lambda$  and  $\sigma$ .

Where:

$$\lambda = \frac{\sigma U}{\sigma V} \quad (15)$$

$$\sigma = \sigma^2 u + \sigma^2 v \quad (16)$$

$$\gamma = \frac{\lambda^2}{1 + \lambda^2} \quad (17)$$

Where

$Y_i'$  is the output, which represents the quantity of harvest measured in kilogram

$X_1$  is the pond size as a proxy for farm size,

$X_2$  is the total quantity of labour use (in mandays)

$X_3$  represents total feed used per application (in Kilogramme)

$X_4$  represents the stocking rate (pieces)

The a-priori expectation of the independent variables is that, yield should increase with increased pond size as a proxy for farm size, optimum labour use, increased quantity of feed with increased stocking rate respectively or vice-versa ceteris paribus.

The determinants of technical inefficiency are hypothesized as follows:

$$M_i = d_0 + d_1 Z_1 + d_2 Z_2 + d_3 Z_3 + d_4 Z_4 + d_5 Z_5 + d_6 Z_6 \quad (18)$$

Where

$M_i$  is the inefficiency value for the  $i$ -th fish farmer

$Z_1$  is the type of feeding regime used ( $D = 1$  for traditional methods, and 0 otherwise)

$Z_2$  is the tertiary education of farmers ( $D = 1$  if tertiary education was attained, 0 otherwise)

$Z_3$  is the secondary education of farmers ( $D = 1$  if secondary education was attained, 0 otherwise)

$Z_4$  is the years of experience of farmers

$Z_5$  is the pond type ( $D = 1$  for improved and 0 otherwise)

$Z_6$  is membership of cooperatives ( $D = 1$  if yes and 0 if no)

It is anticipated that the level of inefficiency in fish production should rise with the use of traditional feeding regime but should reduce with tertiary and secondary education, experience, use of improved pond types and membership of cooperatives.

The maximum likelihood estimate of the parameters of the model was obtained using the FRONTIER 4.1 program. The maximum likelihood estimation procedure was used because it is asymptotically normally distributed. (Coelli, 1996).

The error terms in equation (1) are  $V_i$  and  $U_i$ . The first component of error term,  $V_i$ , is a two-sided conventional random error term that is independent of  $U_i$  and assumed to be normally distributed with constant variance and mean of zero (i.e.  $N \sim (0, \sigma^2_v)$ ). This component is supposed to capture statistical noise (i.e., measurement error) and random exogenous shocks such as bad weather and diseases that disrupt production. The second component,  $U_i$ , is also a random variable but, unlike  $V_i$ , it is only a one-sided variable taking non-negative values. This term captures technical inefficiency of an urban crop farm in producing output.

### 3. Results and discussion

### 3.1. Summary of variables

A summary of the values of the variables which were used in the regression analysis of the determinants of production of fish is presented in Table 1.

Table 1  
**Summary Statistics of the Variables for Fish Farmers**

Output / Input Variables	Minimum	Maximum	Mean	Standard Deviation
Total production (Y)	800	19620	2943.841	3542.514
Pond Size (ha) $X_1$	0.001	0.2	0.008	0.024
Total Labour used (Man-days) $X_2$	36.75	324	84.277	55.742
Quantity of Feed (Kg/ha) $X_3$	30	180	46.451	26.017
Stocking Rate (Kg/ha) $X_4$	1000	20000	3170.732	3601.217

The average output of fish per production cycle was 2,943.84 kilogrammes that is produced from a hectare of land with ponds of an average size of 0.008 hectares and an average of 84.28 mandays of labour.

### 3.2. Determinants of output of fish

Table 2 shows the estimated coefficients of the production function and their corresponding levels of statistical significance. Three out of the four variables (all except total labour used) were significant determinants of fish production. The maximum likelihood estimation (MLE) of the frontier function revealed that the  $\sum^2$  of 89060.094 and  $\gamma$  of .999 were significant at 1 percent level respectively. The significant value of the  $\sum^2$  shows the presence of inefficiency effects in fish production in the area. The analysis of the inefficiency model shows that the signs of the estimated coefficients in the inefficiency model have important implications on the TE of the fish farmers.

Table 2  
**Maximum Likelihood Estimate of the Frontier Function Coefficients**



	Estimated Parameters	Standard-Error	T-statistics
$\beta_0$	-90.1752	0.9984	-90.3171***
$\beta_1$	-560.0554	0.9998	-560.0563***
$\beta_2$	0.0878	0.1762	0.4984
$\beta_3$	2.7574	0.0896	30.7655***
$\beta_4$	0.9862	0.0031	314.4336***
$\Sigma^2$	89060.0940	0.9999	89060.0960***
$\Gamma$	0.9999	7436.7200	1254018.0000***
Log-likelihood function = -528.0371			

\*\*\*Significant at 1 percent

The variables that were significant include pond size, total quantity of feed used and the stocking rate all at 1 percent level of significance. The positive coefficient of stocking rate and total quantity of feed used with respect to fish production implies that the higher the stocking rate and consequently the quantity of feed used, the higher the total level of fish production at an optimal labour supply. The total labour used positively influence the total output of fish but the labour used must be kept at optimal level after which farmers will be operating at sub-optimal level. Also, there was a negative relationship between the level of output of the fish farmers and the pond size. This is quite unexpected but given that, farmers may have large pond size but they need more capital to increase their stock commensurate with the carrying capacity of the pond.

### 3.3. *Production elasticities*

Production elasticities indicate the percentage change in output relative to a percentage change in inputs, if other things are held constant. From the nature of the Cobb-Douglas production function fitted, the regression coefficients which is also known to be the estimated parameters of each variable in Table 2 is the elasticity of production of the variables.

The estimated elasticities of the explanatory variables show that the total quantity of labour, total quantity of feed and the stocking rate were positive decreasing functions to the factors, indicating that the variable allocation were in the stage of economic relevance of the production function. The elasticity of pond size used is -560.055, meaning that the output of small fish farmers will decrease by 560 percent for every percent increase in pond size. This result, though not expected with respect to the

magnitude is true. Because of the limited managerial ability of these small farmers, an increase in pond size without commensurate increase in the managerial ability of operators will lead to a lot of inefficiency and wastes. Also the elasticity of quantity of labour used is 0.0878 and that of total quantity of feed used is 2.757 meaning that a 100 percent increase in these inputs will raise output of small fish farmers by 8.78 and 275.7 percent respectively. On the other hand, a 100 percent increase in stocking rate will bring about 98.6 percent increases in the output of fish.

### 3.4. *Technical efficiency in fish production*

Table 3 show the frequency distribution of the technical efficiency estimates of the fish farmers. The predicted farm specific technical efficiencies (TE) ranged between 0.51 and 0.998, with a mean of 0.906. Thus, in the short run, there is a scope for increasing fish production by about 9.4 percent, on the average, by adopting the technology and techniques used by the best-practiced fish farms. One of such measures is addressing the issue of negative elasticity of pond size used.

The deciles range of the frequency distribution of the efficiencies show that about 65.9 percent of the farmers had TE exceeding 0.901 about 34.1 percent had TE ranging between 0.501 and 0.900.

*Table 3*  
**Frequency Distribution of Technical Efficiency  
Estimates of Fish Farmers**

Efficiency Level	Frequency	Percent
0.51-0.60	2	2.4
0.61-0.70	1	1.2
0.71-0.80	2	2.4
0.81-0.90	23	28.0
>0.91	54	65.9

*Mean Efficiency = 0.906*

### 3.5. *Determinants of technical inefficiency in fish production*

From Table 4, the coefficients of feeding regime was positive, indicating that this factor led to increase in technical inefficiency or decrease in TE of fish production in the study area. This result may be due to the fact that the more the farmers feed the fish per day with low quality feed, the less their output efficiency. Also, the coefficients of educational level, years of experience, pond type and cooperative membership were negative, indicating that these factors led to decrease in technical

inefficiency or increase in technical efficiency. This agrees with the *a priori* expectation that TE should increase with increase in years of schooling and experience since education and experience are expected to be positively correlated with adoption of improved technology and techniques of production (Abdulkadir *et al*, 1999 and and Ajibefun *et al*, 1996 and 2004, Omonona, et al 2006, Omonona and Sopitan 2006).

Similarly, in the results shown, tertiary education was significant at 1 percent level, secondary education and cooperative membership were significant at 5 percent levels of significance.

Table 4  
**Estimates of the Technical Inefficiency of Fish Farmers**

Variables	Coefficient	Standard Error	T-Statistics
Constant	-0.342	0.999	-0.342
Feeding regime	0.555	0.991	0.560
Tertiary Education	-0.389	0.095	-4.094***
Secondary Education	-0.198	0.085	-2.329**
Experience	-0.107	0.977	-0.110
Pond type	-0.117	0.999	-0.177
Cooperative membership	-0.452	0.200	-2.260**

\*\*\*Significant at 1 percent \*\*Significant at 5 percent

#### 4. Conclusion

The maximum likelihood estimates of the frontier production showed clearly that pond size, quantity of feed and stocking rate are the most important inputs in fish production. The stochastic frontier function estimated for the 82 respondents showed that the mean technical efficiency value was 0.906. Majority of the fish farmers of about 65.9 percent are over 90 percent efficient and about 34.1 percent had TE ranging from 50 percent to 90 percent, based on the use of input.

The level of inefficiency was found to be negatively related to coefficients of educational level, years of experience and pond type. This indicated that these factors led to decrease in technical inefficiency or increase in technical efficiency.

This result showed that inputs in fish production need to be efficiently used by all farmers so as to produce more output than ever before. Alternatively, some inputs like size of pond and labour used could be reduced at the same level of feed and stocking rate for the farmers to operate at optimal level and be efficient. The elasticities of production for the inputs used are -560.0554, 0.0878, 2.7574 and 0.9862 for pond size, total

quantity of labour, total quantity of feed and stocking rate respectively. Those with low values of below 1, point to relative inelastic response. The farmers could intensify more on the use of feed for more output and be technically efficient.

Stakeholders in fish production such as research institution, extension agents and fish producers association should intensify effort in the area of sensitizing farmer with respect to the right level of input combinations that can improve efficiency level of fish production in Nigeria. This is so, since findings have shown that the ration combinations if not strictly adhered to as empirically demonstrated in the study will lead to decrease in efficiency in fish production. In addition, as shown that education is an important determinant of efficiency, fish farmers' education should be taken with all seriousness in order to be able to derive maximum benefits from improved technologies. This is because, the appreciation and use of improved technologies of production and marketing increases with the level of education and awareness.

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