FARM-LEVEL EFFICIENCY AND RESOURCE-USE: APPLICATION OF STOCHASTIC FRONTIER ANALYSIS TO AQUACULTURE FARMS IN SOUTHWEST NIGERIA

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ABSTRACT

This paper comparatively examined resource-use and technical (TE) efficiencies of aquaculture farms in the Southwest Nigeria. A total of 160 farms were randomly selected from four states across the region. Econometric applications of the stochastic frontier models provide measure of the farm's technical efficiency. The results of regressions specified for the farms in each states, show that, elasticites for inputs, such as: size of the pond, feeds, labour, numbers of fingerling stocked, and costs of materials were positive and significant. This suggests that, the production functions monotonically increased with input from the study. The returns to scale estimates show that, an average farm in the states like, Ogun and Ondo exhibit increasing returns to scale, while similar numbers of farms in Osun and Ekiti states exhibit decreasing returns to scale. The results of marginal value product (MVP) show that, none of the farms across the states optimally used their variable inputs ($MVP_x = MFC_x$). Most farms were found to have underused ($MVP_x > MFC_x$) feeds and numbers of fingerlings stocked, as against overused ($MVP_x < MFC_x$) of labour across the states. The estimated TE shows that, about 11%, 18%, 22% and 44% of outputs of the farms in Ogun, Ondo, Ekiti and Osun states are forgone due to inefficiency respectively. The implications of these findings, therefore, suggest that improvement in the technical efficiency of the farms, as well as, optimal input utilization, will contribute significantly to aquaculture expansion program in the county.

Key words: Aquaculture, resource-use, income, technical and allocative efficiencies

INTRODUCTION

In Nigeria, fish provides the cheapest source of animal protein especially in the rural and urban communities. Presently, the domestic fish supply in the country stands at about 400,000 tons per annum. 80% of the supply comes from the artisanal fisheries (capture fisheries). Unfortunately, the domestic fish supply is far below the demand because of the progressive increase in the country's population (Ojo *et al.* 2006). This, therefore, necessitated the importation of frozen fish to offset the gap in the domestic demand.

The annual trade statistic from the Central Bank of Nigeria, shows that Nigeria expended over US$200 million annually on the importation of frozen fish to argument the under production in the country (CBN, 2006). Continue importation of frozen fish among others, had been identified as one of the significant sources of drain in the country's foreign reserves.

With decrease in artisanal fish supply from ocean fisheries as a result of over-fishing and pollution, raises a lot of concerns among the policy makers, about possibility of capture fisheries bridging the gap between supply and demand in the country. Aquaculture in light of this development had been suggested over the years, as a more environmentally friendly source of fish protein in the country.

Aquaculture is a predominantly an extensive land-based system, practiced at subsistence levels in the country (Fagbenro, 2002). Its current yield is put at 14,388 tons per annum which offer considerable potential for commercial aquaculture (Fagbenro and Adebayo, 2005). Recent published annual agricultural production statistics by the Central Bank of Nigeria, shows that, the contribution of aquaculture to the total fisheries production in Nigeria increases from about 11% in 2003 to 21% in 2005 (CBN, 2006). This is an indication that aquaculture activity in the country is taking a giant step for repositioning. Continue expansion of aquaculture production across the country, however, is expected to play a significant role in ensuring sustainable fish production among other benefits in the country in the future.

Therefore, examining, resource-use and technical efficiencies of aquaculture farms in the country will provide the decision makers, a control mechanism with which to examine the performance of aquaculture farms in the county. This study intends to provide such examination comparatively across aquaculture farms in the Southwest Nigeria.

METHODOLOGY

Study area and the Data:

The study was carried out in four states across Southwest Nigeria. The states are: Ekiti, Osun, Ondo and Ogun. The whole Southwest Nigeria have a total population of about 28 million people equivalent to about 20 percent of the Nigeria population (NPC, 2007). Tropical climate characterized the region with moderate temperature all year round, heavy rainfall during the rainy season (April to October), and dry wind during the dry season (November to March).
A multistage sampling technique was employed for the study. Two local government areas (LGAs) in each of the states with highest prevalence of aquaculture farms were first selected. Successful identification of the LGAs was made possible by the fishery unit of the state`s agricultural development program (ADP). The ADPs have the list of the aquaculture farms in their respective states. Second stage involved random selection of 20 farms from each LGA. A total of 40 farms were selected in each state. In all, 160 farms were interviewed with aid of a well structured questionnaire administered through trained enumerators in 2006. Information collected include: mature fish harvested (kg) and their price per kg in naira within the period under consideration. Also collected is information on quantity and prices of input used in naira. This include: pond size (m^2), feeds (kg), labour (hours), numbers of fingerlings stocks, and costs of materials (include cost of lime and fertilizer)

Analytical technique

We employed stochastic frontier models proposed by Aigner *et al.* (1977) and Meeusen and Van de Broeck (1977) for the study. The specification of the models incorporates in the deterministic function, error terms that account for the statistical noise, as well as, a non-negative random component, to generate a measure of technical inefficiency.

Indexing the farms by *i*, the specification can be express as:

$$y_i = f\left(x_{ij};\beta_j\right)\exp\left(\nu_i - \upsilon_i\right) \qquad 1$$

Where, y_i is output of i-th aquaculture farm; x_{ij}-a vector of j-th inputs of i-th aquaculture farm; β_j-a vector of parameters to be estimated. The error term ν_i is i.i.d~ $N\left(0,\sigma_V^2\right)$. We assume ν_i captures random variation in fish production, due to factors beyond the control of the farmers. Such factors include variation in weather, among others. The second error term υ_i, captures technical inefficiency in fish production. This is assume to be farm-specific non-negative random variables, i.i.d.~$\mathbf{N}(\mu,\sigma_u^2)$. A higher value for υ_i implies an increase in technical inefficiency. If υ_i is zero the farm is technically efficient.

Consequently, technical efficiency (TE) is defined as the ratio of the mean output for i-*th* aquaculture farm, given the values of the inputs x_i and its technical inefficiency effect υ_i, to the corresponding mean output if there were no technical inefficiency in the production (Battese and Coelli, 1988).
The definition can be express mathematically when y_i and x_{is} are in logarithm form as:

$$TE_i = \frac{E\left(Y_i \mid \mathbf{u}_i, X_i\right)}{E\left(Y_i \mid \mathbf{u}_i = 0, X_i\right)} = \frac{\mathbf{f}\left(X_j;\ \beta_j\right)\exp\left(\nu_i - \upsilon_i\right)}{\mathbf{f}\left(X_j;\beta_j\right)\exp\left(\nu_i\right)} = \exp\left(-\upsilon_i\right) \qquad 2$$

All estimates of equation 1 and 2 are obtained through maximum likelihood procedures in the computer program FRONTIER 4.1c (Coelli, 1996).

Measure of input-specific allocative efficiency

This study follows a neoclassical production theory approach. Using farm specific production function with the highest associated iso-profit line, we obtained a measure of input-specific allocative efficiency for the aquaculture farms. The highest iso-profit, however, is determined when marginal value product (MVP_x) of the inputs equate marginal factor costs (MFC_x). In other words, MVP_x is obtain, when slope of production function (marginal product -MP_x) equate the ratio of the prices of the factor inputs and the output$\left(MFC_x / P_y\right)$ [1] (Kalirajan and Obwona, 1994).

Mathematically:

$$MP_x = \frac{MFC_x}{P_y} \qquad 3$$

$$MP_x.P_y = \mathbf{MFC}_x \qquad 4$$

[1] This assumption in economic theory holds in principle for functional forms other than Cobb-Douglas and Tans-log functional forms. While in case of Cobb- Douglas or Trans-Log, the slopes serve as a direct measure of elasticites.

Where:

$$MP_x.P_y = MVP_x$$

$$MVP_{\mathbf{x}} = \mathbf{MFC}_x \qquad 5$$

For this study, we expressed the derivation of the individual farm specific allocative efficiency for the inputs slightly different from the expression 3 to 5. This is because of our choice of Cobb-Douglas functional form[2] to represent the frontier model (equation 1).

However, we derived the individual farm input specific allocative efficiency using the following expression because of the reasons outlined in the foot note 1 as

$$\beta_j\left[Y_i / X_{ij}\right] = \frac{MFC_x}{P_y}\ ^{3} \qquad 6$$

$$\beta_j\left[Y_i / X_{ij}\right].P_y = MFC \qquad 7$$

Here, β_j is the estimated input elasticities (coefficient of the chosen Cobb-Douglas functional form); Y_i / X_{ij} is average product of j-th input; MFC_x is price of the factor input *j*; P_y is price of output; $\beta_{ji}\left[Y_i / X_{ij}\right]$ equivalent to the marginal product $\left(MP_x\right)$ of the input.

The expression in equation 7 is the measure of the input –specific allocative efficiency employed for the study. This was calculated for each variable input per aquaculture farm.

Input specific allocative efficiency described above, shows how farmers responds to price signals for output and inputs in order to allocate their resources (input-mix) in an optimal manner. This might involve using less of one input or using more of another input in order to increase their production over time.

For an optimal input utilization, marginal value product (MVP) of input x_j is expected to equate marginal factor cost (MFC) of the input for an optimum production level to be achieved (i.e. $MVP_x = MFC_x$). However, when MVP of an input x_j is greater than its MFC (i.e. $MVP_x > MFC_x$) under utilization of the input x_j under consideration is implies. While over utilization of the input is observed when its MVP is less than the MFC (i.e. $MVP_x < MFC_x$). The implications of the last two scenarios signal non optimum production level. Such characterizations implied continue application of under-utilized inputs as well as decrease application of over utilized inputs in order to ensure optimum production level.

Model specification

For this study, Cobb-Douglas functional form is specified for the study for the reason stated in foot note 2. The frontier functional form is therefore defined as

$$\ln y_i = \beta_0 \prod_{j=1}^{J} \beta_j \ln x_{\mathbf{j}} + \nu_i - \upsilon_i \qquad 8$$

Where, *ln* represents the natural logarithm; the subscript i-th sample farmer; y_i represents the harvested fish (kg) for farmer *i* ; x_j represents pond size, feeds, labour, numbers of fingerlings-stocked and costs of materials; β_j represents the input coefficients while $\mathbf{v_i}$, and $\mathbf{u_i}$ as earlier defined.

[2] Cobb-Douglas functional form was chosen because it's widely used in farm efficiency for developing agriculture.

[3] Here, MP = β_j .AP, where AP = Y/X.

EMPIRICAL RESULTS AND DISCUSSIONS

***Summary Statistics*:**
The summary statistics of variables included in the regressions show that, an average farm in Ogun, Ondo, Ekiti, and Osun states cropped about 23,000kg, 19,000kg, 15,000kg, and 13,000kg respectively of fish per annum. For the inputs, analysis show that an average farm in Ogun state, obtained about 341 m^2 of pond size; 4,400 kg of feeds; 1,300 hours of labour; 34,800 numbers of fingerlings stoked, and ₦ 48,000 costs of materials. Likewise, an average farm in Ondo state obtained about 260m^2 of pond size; 3,100kg of feeds, 910 hours of labour; 26,000 fingerlings stocked, and ₦ 32,000 costs of materials. Also, for an average farm in Ekiti state we observed 210m^2 of pond size; 2,510kg of feeds; 968 hours of labour; 14,560 fingerlings stocked, and ₦ 33,000 costs of materials. While an average farm in Osun state obtained 194 m^2 of pond size; 2,240kg of feeds, 893 hours of labour, 14,100 fingerlings stocked, and ₦ 28,485.56 costs of materials.

Resource-use efficiency of the inputs
Presented in Table 1 are the results of the point estimates of input elasticities of the farms across the states. All the estimated coefficients had positive sign and significantly different from zero. The implication of this is that, the production functions monotonically increased with input level for the farms across the states. The returns to scale (RTS) computed as the summation of the input elasticities, shows that, a joint increased in the inputs by 1% increase the output by 0.88%, 1.33%, 1.15% and 0.92% for farms in Ekiti, Ogun, Ondo, and Osun respectively. These imply that; farms in Ogun and Ondo states exhibit increasing returns to scale, while farms in Ekiti and Osun exhibit decreasing returns to scale.
The result of the input specific allocative efficiency shows that none of the farms across the states appear to have efficiently allocated any of the variable inputs considered $\left(MVP_x = MFC_x\right)$.
The results revealed that 90%, 85%, 60%, and 70% of the farms in Ogun, Ondo, Ekiti, and Osun states appear to have under-used feeds respectively. While 70%, 78%, 65%, and 68% of the farms in Ogun, Ondo, Ekiti, and Osun states appear to have under-used number of fingerlings stocked respectively. 93%, 70%, 88% and 55% of the farms in Ogun, Ondo, Ekiti, and Osun states appear to have over-used labour.
The economic implication of the results is that, increase the use of feeds, as well as, numbers of fingerlings stocked for farms across the states will increase the farms output level. Contrary, decrease the use of labour, will increase the farms output level across the states.
However, one possible reason for the observed allocative inefficiency across the farms can be attributed to financial constraints of the farms. This observation was pointed to us by the farmers as one of the most frequent identify problem from the study areas.
The observation is similar to the findings of Liefert (2005). Liefert in his study of allocative efficiency of material inputs in Russian agriculture stressed the significant influence of credit constraint on optimal input utilization in Russian agriculture. He concluded that, improving access of the farmers to credit will improve allocation of resources among the farmers.

Another reason can be attributed to the availability of the inputs. The most affected of all the inputs considered for the analysis is number of fingerlings stocked. Except Ogun and Ondo states, where there were numbers of hatcheries, other states have few and partially functioning hatcheries so to speak. Most hatcheries in Ogun state are privately own. Contrary, most hatcheries in Ondo state are government own. Farms in Osun states relied on hatchery supply from their neighboring states like Oyo and Ogun states while farms in Ekiti relied on hatchery in Ondo and Oyo states. With hatcheries in Ogun and Ondo states supplying farms in their states and farms in the neighboring states, demand seems to outstrip the supply. A measure must be put in place to address this. This observation was confirmed by the farmers, who identified fingerlings supply as another significant factor threatening their expansion across the region.

Technical efficiency Analysis

The summary statistics of the point estimates of the technical efficiency scores for the farms is presented in the lower part of Table 2. The results show that an average farm in Ogun, Ondo, Ekiti and Osun obtained an average technical efficiency of 0.892, 0.816, 0.784 and 0.565 respectively.

In terms of resource-use efficiency, the results of the technical efficiency, shows that, an average farm in Ogun, Ondo, Ekiti and Osun states could scale up their present level of output by approximately 11%, 18%, 22% and 44% respectively to reach the frontier level of most efficient farm across individual states. Comparatively, it implies that, less than 20% current output of the farms in Ogun and Ondo states is forgone due to inefficiency as against more than 20% in Ekiti and Osun states.

Table 1: **Estimates of the stochastic frontier production function**

Variables	Parameters	Frontier ML estimates			
		Ogun	**Ondo**	**Ekiti**	**Osun**
Constant	β_0	2.614*(3.95)	5.039*(2.49)	4.115*(3.74)	1.851**(1.98)
ℓn Pond Size	β_1	0.149**(2.17)	0.267**(1.98)	0.223*(2.79)	0.311*(3.64)
ℓn Feeds	β_2	0.368**(1.97)	0.295**(2.26)	0.187**(2.02)	0.209**(2.12)
ℓn Labour	β_3	0.123*(2.54)	0.169*(6.31)	0.149**(1.99)	0.003*(3.82)
ℓn fingerlings stocks	β_4	0.305*(1.96)	0.297*(2.75)	0.283**(2.36)	0.146**(2.38)
ℓn costs of capital	β_5	0.387*(5.93)	0.124**(1.97)	0.142*(3.28)	0.252**(2.04)
Variance Parameters					
Sigma square	σ^2	0.445*(3.46)	0.319*(8.35)	0.523*(3.96)	0.464*(3.09)
Gamma	γ	0.821*(5.85)	0.803*(3.07)	0.941*(6.24)	0.894**(2.36)
Log likelihood	LL	-47.954	-68.251	-60.298	-55.892
Returns-to-scale(RTS)		**1.332**(2.49)**	**1.153*(5.07)**	**0.882*(2.86)**	**0.921*(3.17)**
Technical Efficiency					
Minimum		0.581	0.295	0.246	0.127
Maximum		0.982	0.927	0.811	0.763
Average		0.892	0.816	0.784	0.565
Standard Deviation		0.013	0.028	0.017	0.035

*Figures in parentheses are t-ratio; * and ** estimates are significant at least 1% and 5% level of significance respectively*

Table 2: Allocative efficiencies of variable inputs

Ogun state						
Decisions	**Feeds**		**Labour**		**Fingerlings**	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**
$MVP_x > MFC_x$	36	90	3	7	28	70
$MVP_x < MFC_x$	4	10	37	93	12	30
	Ondo state					
$MVP_x > MFC_x$	34	85	12	30	31	78
$MVP_x < MFC_x$	6	15	28	70	9	22
	Ekiti state					
$MVP_x > MFC_x$	24	60	5	12	26	65
$MVP_x < MFC_x$	16	40	35	88	14	35
	Osun state					
$MVP_x > MFC_x$	28	70	18	45	27	68
$MVP_x < MFC_x$	12	30	22	55	13	32

CONCLUSIONS AND POLICY IMPLICATIONS

The findings show that, assessment of farm-level technical and input specific-allocative efficiencies, provide the needed performance indicator of aquaculture farms in the country. Whilst the results have implication on sustainable fish production in Nigeria, effort must be made, to address inefficiency inherent in aquaculture production in the country, as highlighted from the study. Therefore, any measure aim at improving economic efficiency of the culture fish production in Nigeria should address allocative inefficiency as well as improve current level of technical efficiency of the farms.

Therefore, we suggested that, policy options for improving the economic efficiency of the farms should follow closely the combination of the following approaches: Expansion of the present fingerlings production capacity across the states. A possible way to implement this suggestion is to embrace public-private partnership that will lead to the establishment of more hatcheries across the states. Government should provide enabling environment to encourage individuals/ entrepreneurs to invest in fingerlings production across the states. This approach had been working well in other parts of the country. Another option is to extend the provision of credit facility to the fish farmers as currently extended to the food crops farmers across the states. A credit delivery system without bureaucratic bottleneck will improve allocative, as well as, technical efficiency of the farms.

Finally, the role of effective extension activities in fish production, preservation, and processing cannot be rule out if expansions of fish production, as well as, its sustainability are crucial in fulfillment of the millennium development goal (MDG) of food security in the country.

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