Measurement of Technical Efficiency of Farmed Catfish Production in Southwest, Nigeria: A Stochastic Frontier Production Function Approach

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Abstract

Catfishes are the most popularly raised and consumed fish species in Nigeria. Given changes in the dynamics of the aquaculture sector, this paper estimated technical efficiency and factors contributing to it using data collected from 108 farmers stocking catfish in earthen ponds in the study area. Catfish aquaculture was found to be capital intensive. The most expensive item of total variable cost (TVC) was fish feeds which accounted for 61.4% and 67.8% of TVC in Ondo and Ogun States, respectively. There were no significant differences in cost items between the two States. Empirical analysis showed wide variations in predicted TEs across farms ranging from 48.4% to 77.2% in Ondo State and 45.4% to 82.1% in Ogun State with means of 64.0% and 67.0%, respectively. The results also indicate that coefficients of the quantity of feeds, total number of ponds, labour and number of times pond water is changed were positive and highly significant in catfish production. The inefficiency model revealed that age and farming experience coefficients (significant) and education level coefficient (not significant) were negative indicating that older and more experienced farmers tended to be less inefficient. The test of various null hypotheses showed that the inefficiency effects were related to the age, management pattern, years of experience and education level of farmers. The study identified the opportunities that exist for improving TE in the study area. Results of the analysis having implications for the aquaculture industry and for policy-makers were discussed.

INTRODUCTION

Aquaculture involves raising fish under controlled environment where their feeding, growth, reproduction and health can be closely monitored [1]. It has now become an important source of food fish for the low-income class globally and especially in Africa where the problem of inadequate consumption of high-value proteins is well documented [2-6]. Expansion in production from aquaculture globally has been recognized as a possible panacea to dwindling catches from the over-tasked wild fisheries sector [4, 7, 8].

Nigeria's total fish production from all sources is at present put at 0.55 million metric tons (mt) annually while the current fish demand is about 1.5 million mt per annum leaving a deficit of about 1million mt which will cost about $1.6 billion annually to import [9].Nigeria has extensive areas of both mangrove and freshwater grounds suitable for raising fish. It has been estimated that if only 30-35% of the available mangrove areas suitable for aquaculture is fully harnessed, there is the potential to produce 2.5 million mt of fish annually which will both satisfy domestic demand and make Nigeria a fish exporting nation [10-12]. Farm-raised fish now accounts for a considerable and rising proportion of total fish consumed in Nigeria and other developing countries [13-14]. In Nigeria for example, the proportion of domestic fish production emanating from aquaculture has moved from about 0.5% in the 1980s to 2.5% in the 1990s and to 6.0% by year 2004 [10,14].This growth source is, though not exclusively a result of expansion in aquaculture production, the larger proportion can be attributed to it. The recent expansion in aquaculture production is not unconnected with dwindling catches from the wild fisheries sector which, until recently, accounts for more than 80% of total fish landings in Nigeria [15]. The reported dwindling catches has been attributed to a combination of factors which include water pollution from oil spillages, constant upward reviews of the prices of fishing gears and other inputs and depletion of the natural fish stock from over-fishing owing to use of irresponsible fishing methods [4,12,17-18]. An example of the last problem is the harvesting of fingerlings from the wild to stock fish ponds by farmers who either cannot afford the prohibitive cost of fingerlings/juveniles from commercial hatcheries or are unable to access it owing to distance. Also, fisher-folks especially in trawl fishing harvest large quantities of by-catch which are sold along with target species [4, 13, 16, 19].

Catfishes of the family Clariidae are the most popular farm-raised and consumed fish species in Nigeria as they account for up to 90% of total cultivated fish species on commercial farms and 62% of consumption of fresh fish nationally [6,16,20-23].This follows from the situation in Africa in which catfish, tilapia and carp are the most commonly raised freshwater fish species [6,16].The reasons adduced for the popularity of Clariid fishes in aquaculture in Nigeria as stated by previous researchers include cheapness of juvenile fish-stock (N19.50 per unit in 2009), ease of hatching seed-stock on own farm by resource-constrained farmers, hardiness, adaptation to a wide variety of natural food organisms and manufactured feeds, easy culturing, efficiency of food conversion, high fecundity and high demand owing to moderate average price [4,6,16,23]. On the demand side, however, the preference for clarias is based on its near bonelessness (except for the middle bone which can be easily removed) making it easy for adult and children to consume with minimal caution and supervision, its moderate price compared with other freshwater fish species (Table 1), acceptable organoleptic properties and ease of availability. Catfish is therefore commonly served in household and hotel meals, pepper soup joints and meals for social occasions in which attendees express preference for fish over meat [4, 21].

Table I: Average Prices for Selected Farm-raised Fresh Fish in Nigeria (2006)

Fish Common name	Scientific name	Farm Gate Price (N/Kg)	Retail Price (N/Kg)
Catfish*	*Clarias spp. and Heterobranchus spp.*	428.65	516.50
Trunk fish	*Gymnanhus niloticus*	760.65	916.54
African Bony Tongue	*Heterotis niloticus*	680.94	820.49
Alestes	*Alestes baramose*	656.81	729.93
Tilapia	*Tilapia spp.*	215.94	311.74

Source: Mafimisebi and Okunmadewa, 2006b

*The price shown for clarias is the average for four species, *Clarias gariepinus*, *Clarias lazera*, *Heterobranchus spp.* and Heteroclarias.

Farmed catfish production thus has the potential to become a lasting solution to the seemingly hydra-headed problem of animal protein malnutrition in Nigeria. This is because its production is capable of increasing rapidly to bridge or eliminate the demand-supply gap for fish in general and freshwater fish in particular [4, 6, 23]. The differences in farmer and farm-specific characteristics across production areas may have some implications for efficiency levels. For catfish production to attain sustainable growth rate, there is a need for improvement in technical efficiency (TE) and productivity in the sub-sector. TE is an indication of the ability of a productive unit to produce maximum output from an array of productive factors at a specified level of technology. However, in spite of the stated importance of farm-raised catfish in meals served in various places, the paucity of data on the sub-sector has meant limited analysis culminating in very little knowledge on the extant level of TE.

A multiplicity of past and present studies in TE in the agricultural sector in Nigeria used measures resulting from computation of simple ratios such as labour efficiency and feed efficiency. Even though, some information is contained in these simple measures, they generally are capable of yielding very limited policy predictions having analyzed for inputs in isolation. In the last twenty years, however, there has been a number of studies using the Stochastic Frontier Production Function (SFPF) approach in Nigeria [23-29]. Given changes in the dynamics of the Nigerian aquaculture sector in which catfish production is now preponderant [16], this study estimates the TE of catfish production and isolates the factors impinging on its efficiency levels in the study locale.

THEORETICAL FRAMEWORK OF ANALYSIS

Productive efficiency approximates attainment of production goals without waste. On the premise of this basic idea of “zero tolerance for wastage”, a number of theories of efficiency has been built by economists. However, a string of commonality in all efficiency measures is that of the quantity of goods and services produced per unit of input. Based on this fundamental idea, a farm is said to be technically inefficient if the output produced from a given bundle of inputs falls short of the expected amount. In other words, enterprise inefficiency involves a disproportionate and excessive consumption of all inputs in a production process [25].Two basic approaches exist for measuring TE; the classical and frontier approaches.

The Classical Approach

This method, which is based on the ratio of output to a given input, is essentially a partial productivity measure because output is compared with only one input at a time. The commonest ratios under this approach are output per man-hour (labour productivity), output per unit of capital (capital productivity) and crop yield per unit of land (land productivity).

The Frontier Approach

Arising from the shortcomings of the classical approach, economists have developed advanced econometric, statistical and linear programming methods capable of analyzing TE-related issues. A product of this effort is the emergence of the SFPF model which has stimulated and is still stimulating great intellectual and academic interest and debates among researchers and policy makers [25, 30]. The fundamental idea of the family of measures in this method is the concept of a frontier. By implication, efficient firms are those operating on the production frontier (PF) with an efficiency index of 100%.Thus, the degree of inefficiency of a firm is captured by the amount by which the firm lies below its PF. Farrel [31] came up with the seminal work on the frontier approach. The initial form of his model has been modified and improved upon several times by other economists.

Developments in SFPF Analyses and TE

The theoretical definition of a PF is based on computing the maximum amount of output derivable from a given bundle of inputs under specified technology. This is tantamount to estimating average production function. A fundamental assumption of this definition is that technical inefficiency (TI) is not present in the PF. As a result of pioneering and independent works by Aigner, *et al*., [32], Battese and Corra [33] and Meeusen and Van den Broeck [34], a deeper attention was accorded the possibility of estimating frontier production functions with the overriding aim of bridging the gap between theory and empirical work. These applications have been reviewed by Battese [30], Bravo-Ureta and Pinheiro [35], Coelli [36] and Ajibefun [37].The recent past has witnessed various model propositions for studying TI in SFPFs. Using the Zellner-Revanker type of model as the starting point, Kumbhakar *et al*. [38] specified a SFPF in which the TI effects were assumed to be a function of other observable endogenous (explanatory) variables. The model by Kumbhakar *et al*. [38] also captured allocative and scale efficiencies. Battese and Coelli [39] also propounded a SFPF model capable of analyzing panel data in which TI effects were specified in terms of various endogenous variables which sometimes included time variable. Coelli [40] included an extension to the FRONTIER program to estimate the SFPF model which he jointly developed with Battese [41]. A non-neutral SFPF came on the scene as an outcome of the efforts by Huang and Liu [42].This form of the SFPF specified TI effects in terms of various firm-specific variables and interaction among these variables and the input variables. Reifschneider and Stevenson [43] fashioned out a SFPF in which TI effects were dependent on other stipulated variables.

A number of studies have identified the sources of TI and have also, by further model manipulations, subsequently come up with a prediction of TEs in some firms. This model is now classified as the two-stage analytical approach. The study by Pitt and Lee [44] of the origin of TEs in the weaving industry in Indonesia was one of the earliest applications of the two-stage SFPF. Maximum likelihood was the method employed in their estimation of SFPF while their predicted TEs were regressed on specified variables to isolate those having significant impacts on the firm's TE. However, the theoretical consistency of the two-stage approach came under serious criticisms from studies by Khumbhakar *et al*., [38], Reifschneider and Stevenson, [43], Huang and Liu,[42], Battese and Coelli [45] and Battese *et al*.[46] which proposed application of SF models capable of analyzing the TI effects and simultaneously estimating the stipulated parameters.

The SF Model

Consider a farm using n inputs (x_1, x_2,….x_n) to produce a single output y. Efficient transformation of inputs into output is characterized and captured by the production function f(x), which shows the maximum output obtainable from various input vectors. A fundamental assumption of the SFPF is that of presence of TI of production which may be represented by

$$Qi= f(x_i,b) \exp(Vi-Ui) \qquad i = 1,2,\ldots.N \qquad (1)$$

Where Qi is the output of the i-th farm; x_i is a vector of inputs; b is a vector of parameters to be estimated; f(x) is a suitable functional form, such as the Cobb-Douglas or translog, where V is a symmetric random error that is assumed capable of capturing measurement error and other factors beyond the farmer's control. Ui accounts for TI in the production process and 'exp' is the short for exponential function. In the SFPF model, the possible production, Y_i, has a limit imposed on it i.e. is bounded above by the stochastic quantity, f(x_i; b) exp(Vi) which explains the origin of the term "stochastic frontier." Vi, the random errors are assumed to be independently and identically distributed as $N(0,s^2\ v)$ random variables independent of the Uis, which are in turn assumed to be non-negative truncations of $N(0,s^2v)$ distribution (i.e half-normal distribution) or have exponential distribution. The Maximum Likelihood method can be used to estimate the parameters after making the assumptions regarding the distributions of Vi and Ui which are assumed to be half-normal and normal, respectively.

The primary limitations of the SFPF arise from the need to specify the distributional form of the two error terms. Thus, evidence abounds that the two approaches to the estimation of unknown parameters in SFPF (the stochastic frontier approach and data envelopment analysis, DEA) have inherent problems. The DEA method uses linear programming in analyzing efficiency. While the SF approach is parametric, the DEA approach is non-parametric. Any of these two methods could have been used in the ensuring analysis but preference was for the SF approach because it is more capable of capturing the possible effects of outliers arising from measurement error or other factors that can influence the shape and positioning of the frontier, thus affecting the measures of TE [25].

Obtaining indices of TE in a productive venture is worthwhile for three reasons. First, it is a success indicator and performance measure through which production units are evaluated. Second, the only way by which one can explore hypotheses concerning sources of inefficiency and their differentials is by measuring inefficiency and disaggregating its effects from the effects of the production environment. Thirdly, being able to quantify efficiency provides the decision maker with a control mechanism with which to maintain and improve on the performance of the production unit. At the individual farm level, TE is defined as the ratio of the observable output to the corresponding frontier output, given the available technology.

$TE=Y_i/Y_i$*--------------------(1)
$=f(xi; b) \exp(Vi-Ui)/f(xi; b) \exp(Vi)$------------------(2)
$=\exp(-Ui)$

If a farm operates exactly on the PF, it is regarded as being technically efficient and the extent to which a farm operates away from the PF to the left hand side is usually seen as its measure of TI.

MATERIALS AND METHODS

Study Area and Sampling Technique

The study was carried out in Southwest, Nigeria. Multi-stage sampling method was used in selection of respondents that provided the data analyzed. Two out of the six states in Southwest, Nigeria; Ondo and Ogun, were selected purposively for having the highest number of fish farmers and aquaculture production figures. Four Local Government Areas (LGAs) at the rate of two per state were also purposively selected based on geographical location and number of registered commercial fish farmers. Thus, one rural and one urban LGA were selected per state. These four LGAs were Ijebu-Ode and Ijebu Waterside (Ogun State) and Akure South and Ilaje (Ondo State). From a list of registered commercial fish farmers got from the Agricultural Development Programme offices of the two states, a compilation of the physical or farm addresses of contact farmers in each LGA was made and this helped with tracing them and other farmers. In the third stage, purposive sampling was used to select farmers exclusively or predominantly raising catfish in earthen fish ponds as earthen fish pond is still the dominant structure for aquaculture in Nigeria [6]. When a farmer using earthen pond was cited, the first question was for s/he to say, using the ten-finger method, the proportion of the fish reared at the time of the survey that was clarias. If the farmer indicated that the proportion was at least 70%, s/he was subsequently interviewed otherwise the search for another farmer meeting the set criteria, continued. After concluding interview with a farmer, s/he was requested to take the survey team to another catfish farmer or describe the location of his/her farm. Thus, the sampling was also snow-ball in nature. In all, 54 farmers (27 per LGA), who stocked their earthen fish ponds with 70% catfish in each of Ondo and Ogun States were interviewed.

Data and Data Collection

A well-structured and pre-tested questionnaire was used to collect cross-sectional data on operational characteristics and management of the farms, farmer-specific factors such as sex, education level and catfish farming experience of the major farm decision-maker. Data were also collected on production inputs consumed and outputs from the most recent previous crop of catfish. Copies of the survey questionnaire were administered on farmers with little or no formal education by trained enumerators. However, literate farmers were able to complete them with or without guide by enumerators. Farm records, where kept, were inspected so that useful information could be extracted. The data gathered were used to predict individual technical efficiency (TE) through SFPF model.

Model Specification

The SFPF for catfish farmers in the study area is assumed to be defined by:

$\ln Q_i=b_0 + b_1 \ln(size) + b_2 \ln(feed) + b_3 \ln(labour) + b_4 \ln(\text{water change freq.}) + b_5 \ln(fert.) + b_6 \ln(\text{de-weeding freq.}) + b_7 \ln(\text{seed-stock source}) + b_8 \ln(\text{other costs}) + Vi-Ui$----3

The TI is in turn assumed to be explained by

$m_i=d_0 + d_1(age) + d_2(\text{management pattern}) + d_3(education) + d_4(experience)$----4

where ln denotes natural logarithm which is logarithm to base e. The subscript i is in reference to the i-th farmer while size represents the number of ponds devoted to clarias production. Feed represents the quantity of feeds fed to fish in kilogrammes while labour is the total labour, measured in hours, put into farm activities. Water freq. represents the frequency of change of pond water in a production cycle while fert is the quantity of fertilizers such as lime and other chemicals used in pond soil and water conditioning in kilogramme. Age denotes the age of the major decision maker on the farm while education represents the number of years of formal schooling by the farm decision maker. Experience represents the number of years which the decision maker of the fish farm has put into catfish farming while management pattern indicates whether the farmer runs the venture as a full- or part-time one. V and U are as earlier defined.

The SFPF indicated by equation 3 is a linearized form of Cobb-Douglas PF. The Cobb-Douglas form was assumed for fish farms because it is the convention in many empirical studies in developing countries' agriculture or aquaculture. It is also more commonly used for its simplicity. For example, the parameters can be interpreted as direct elasticities [25, 47]. Equations 3 and 4 were estimated in a single step following the practice by Battese *et al.*[46]. Using Frontier 4.1 program, the MLEs of the model parameters were obtained. The MLE method was preferred because as posited by Ajibefun and Daramola [25], the estimates are asymptotically efficient; they are consistent and are also asymptotically normally distributed.

RESULTS AND DISCUSSION

Operational and Farm Characteristics

Pond Size and Number: There was no standard pond dimension in the study area as earthen ponds varied in size from one farm to another. The same was observed for pond number. The number of pond units for raising clarias in all the farms surveyed varied between one and six. In Ondo State, fish ponds used for rearing clarias varied in dimension from 882.7m^2 to 2560.5m^2 with the average being 1689.2m^2. For Ogun State, pond dimension varied from 856.7m^2 to 2702.4m^2 while the average stood at 1920.5m^2.The number of ponds devoted to raising clarias varied from one to six in Ondo State and from one to five in Ogun State. The average number of fish pond units devoted to clarias production was 6 in Ondo State and 5 in Ogun State. The total number of pond units devoted to raising clarias by the 54 farmers interviewed in each case was 328 in Ondo State and 286 in Ogun State. While the value for Ondo State constituted 80.7% of the total number of ponds operated by farmers interviewed, the value for Ogun State was 74.1%.

Gender of Farmers: A predominant proportion (75%) of the 108 fish farms surveyed was owned by males while the balance of 25% was owned by females. State level distribution also followed this general pattern as there were 42 (77.8%) and 39 (72.2%) male farmers in Ogun and Ondo States, respectively. The balance of 12 (22.2%) and 15 (27.8%) in Ogun and Ondo State respectively, was accounted for by females. This finding is reasonable considering the fact that fish farming has been shown to be capital intensive [4, 6, 48] and most people investing in it usually have to borrow credit/loans from institutional and other sources [4]. Since females usually have less access to credit and loans from formal lending institutions compared with males in Africa [49-50], it is understandable why the proportion of females in the fish farming venture is very small.

Fish Species Cultured: Even though, the farmers dealt with in this study were those predominantly or exclusively rearing catfish, it was considered worthwhile to know the other fish species cultivated. From the response by farmers, other fish species reared were Tilapia, Heterotis, Gymnarchus and Alestes. In Ondo State where Catfish accounted for 77% of total fish stocked, Tilapia, Heterotis, Gymnarchus and Alestes accounted for 11.7%, 7.3%, 2.6% and 1.4%, respectively. In Ogun State where Catfish as a proportion of total fish stocked was 73%, Tilapia, Heterotis, Gymnarchus and Alestes accounted for 12.6%, 9.4%, 3.2% and 1.8%, respectively. The results corroborate findings from past studies that the above named fish species are the most commonly raised freshwater fish species in Southwest, Nigeria [4].

Reasons for Preference for Catfish by Farmers: Farmers were asked why they preferred rearing clarias to other fish species. The reasons given for preference for clarias included availability and cheapness of juvenile fish-stock (78%), ease of hatching seed-stock on own farm (70%), high survival rate of stocked seeds (88%), easy culturing (69%), fast growth (92%), high reproductive rates (86%) and high demand owing to moderate average price (96%). From these results, it can be inferred that the factors driving farmers to cultivate a particular fish species are of economic nature both in terms of being able to minimize production cost and being able to dispose of products in a timely fashion and at acceptable profit level. Thus catfish farmers doggedly pursue the profit goal [6, 51] as it is in the production of any other commodity.

Source of Fingerlings and Culture Period for Catfish: From the responses by farmers, culture period for catfish varied between 6 and 10 months depending on the extent of supplemental feeding, source of fingerlings and specie of catfish. Farmers who procured fingerlings from established commercial private or public hatcheries and who fed fishes twice per day harvested their fish in 6 months from the date of stocking in ponds once buyers indicate interest.

However, if fingerlings were got from the wild and feeding is irregular, attainment of marketable weight could take up to ten months in an earthen pond. Most of the farmers interviewed (64%) owned private hatcheries on their farms and depend on own source for fingerlings. About 25% sourced their fingerlings from other farms specializing in hatchery operations while about 11% still depend on harvesting fingerlings from the wild to stock their ponds. It was noted that those depending on wild fingerlings were mostly farmers in rural, riverine locations where access to fingerlings from other sources is made difficult by poor roads or weed-infested waterways which result in high transport cost**.**

Cost Items: From the information provided in Table 2, catfish aquaculture was found to be capital intensive. The single most expensive item of total variable cost (TVC) was fish feeds which accounted for 61.4% and 67.8% of TVC in Ondo and Ogun States, respectively. Labour was the most important item of total fixed cost (TFC) taking 58.2% and 55.7% of TFC in Ondo and Ogun States, respectively. This finding is similar to that by previous researchers who studied mono- or multi-specie fish farms in Nigeria [4, 17, 23,48].

Table II: Fixed and Variable Cost for One Hectare Catfish Farm (2005-2009)

Fixed Items	**Ogun State**		**Ondo State**		**P- Value**
	Mean Value (₦)	**%**	**Mean Value (₦)**	**%**	
Land	45,274.99	2.39	44,698.85	2.35	0.140
Pond Construction	167,815.17	8.86	171,145.68	9.00	0.234
Farm Structures	56,637.20	2.99	55,220.53	2.91	0.157
Vehicles/Boats/Canoes	184,086.83	9.72	203,096.39	10.69	0.163
Nets	45,709.67	2.41	66,091.49	3,48	0.144
Boreholes &Water Pumps	206,887.57	10.92	222,651.17	11.71	0.138
Generators/Deep Freezers/Weighing Scale	27,697.13	1.46	26,408.58	1.39	0.242
Wheel barrows and Basins	17,395.49	0.92	19,662.24	1.03	0.284
Local Hatchery	40,345.73	2.13	32,384.11	1.70	0.176
Labour (Permanent)	1,102,527.60	58.20	1,059,218.60	55.73	0.265
Sub- total	**1,894,377.38**	**100.00**	**1,900,577.84**	**100.00**	
Variable Items					
Seed-stock	460,660.59	7.16	443,064.13	6.78	0.233
Fish Feeds	4,145,414.48	64.40	4,399,446.10	67.30	0.177
Fertilizers & Chemicals	157,881.50	2.45	148,141.03	2.27	0.155
Transportation & Fuelling	829,108.36	12.88	850,634.74	13.01	0.281
Repairs and maintenance	330,965.45	5.14	200,617.71	3.07	0.082
Casual Labour	512,948.62	7.97	495,163.31	7.57	0.195
	6,436,979.00	**100.00**	**6,537,067.02**	**100.00**	

Source: Computed from survey data

Model Analysis

The results of the SF model and their inefficiency component for the farms in the two states were similar. The result for the pooled data for both states was then used in explaining this section. Some of the signs of the coefficients of SF model followed *a priori* expectation. The results indicated that coefficients of the quantity of feeds, total number of ponds, labour input and number of times pond water was changed during a production cycle were positive and highly significant in catfish production as shown in Table III . The coefficients of number of ponds and feeds carried positive signs and were significant at the 1% level of significance (los) indicating that there is a direct relationship between these variables and quantity of catfish produced.

Table III: Maximum Likelihood Estimate of the Stochastic Production Function

Variable	**Parameter**	**Standard Error**
No. of Ponds	0.657**	0.069
Feeds	0.529**	0.083
Labour	0.384*	0.160
Freq. of Water Change	0.204*	0.093
Fertilizers	0.144	0.097
De-weeding	0.056	0.022
Seed-stock source	0.174	0.145
Other costs	0.125	0.101
Constants	5.479	0.304
X	0.648	0.587
δ	1.759	0.412
g	0.781	0.280
Log likelihood function	-66.287	
δU^2	0.041	
Δv	0.066	

Source: Computed from data analysis

The estimated coefficients for labour and frequency of water change were 0.204 and 0.144 and were significant at 5% los. The coefficients of fertilizers, de-weeding frequency, fingerling source and other costs were relatively small and not significant. The inefficiency model revealed that age and farming experience coefficients were significant at 1% los while that of management pattern was significant at 5% los. The inefficiency model coefficient for education was not significant. The negative sign borne by the age coefficient indicated that older farmers tend to be less inefficient probably as a result of being able to make informed decisions in managing fish farms. The coefficient of management pattern had a negative sign which means that managing the farm as a full-time business rather than part-time one tends to reduce TI. This may be as a result of the efficient supervision which results in timeliness of farm operations critical for fish growth and development. Also, a full-time farm operator is likely to be present on the farm every time since the proceeds from the farm are the major income source. His/her being present every time may prevent smarts practices such as poaching, loafing and stealing of fish by workers. Experience also carried negative sign which is interpreted to mean that the more the years of experience of the farm decision maker, the less is the extent of TI. The estimate of the variance parameter (0.759) approached unity with the implications that the inefficiency effects are highly significant and therefore relevant in analyzing the volume of farm-produced catfish in the study area. The S^2 has a value of 1.759 and this is an indication of the variance resulting from measurement error. The log-likelihood function has an estimate of -66.287.This is the value that maximizes the joint densities of the estimated model. Since this value is greater than the tabulated value of 42.846, it means the postulated variable collectively have significant influence on quantity of catfish produced. The coefficients of all the variables are all inelastic since they are all less than unity. The sum of the elasticities were however greater than unity indicating that catfish production is characterized by increasing returns to scale in the study area. The results of the null hypotheses tested on the inefficiency frontier using the log-likelihood testing procedure involved computing

Alpha= $2[LLF(H_0) - LLF(Ha)]$

Where $LLF(H_0)$ and LLF(Ha) are the values of the log-likelihood function under the null and the alternative hypotheses, respectively. According to Ajibefun and Daramola [25], the alpha statistic is characterized by asymptotic chi-square distribution, with degrees of freedom equal to the number of imposed restrictions under the null hypothesis. The results are presented in Table IV.

Table IV: Test of Hypotheses on Estimates of Inefficiency Model Parameters

Null Hypothesis	**Log(likelihood)**	**$X_{2\ 0.95}$ value**	**Test Statistic***
Ho: $g=d_0=1/4=d_3=0$	-69.917	16.216	29.897*
Ho:$g=0$	-65.371	10.072	20.935*
Ho:$d_1=d_2=d_3=d_4=0$	-61.351	10.072	12.895*

***The asterik sign on the test statistic indicates that it exceeds the 95th percentile of the corresponding rtc^2 distribution and then, the null hypothesis is rejected.

The first null hypothesis specifying that inefficiency effects were absent from the model was strongly rejected. Also, the null hypothesis which states that the inefficiency effects were not stochastic was rejected (see the g parameter which was 0.781). The third null hypothesis that the inefficiency effects are not a linear function of age of farm decision maker, management pattern, years of experience and education level, was also rejected at the 5% los. This implies that the inefficiency effects in the SF had a relationship with age, management pattern, education level and years of experience of farmers.

Predicted Technical Efficiency on Farms

Empirical analysis further showed there were wide variations in predicted TEs across farms. This ranged from 48.4% to 77.2% in Ondo State and 45.4% to 82.1% in Ogun State with means of 64.0% and 67.0%, respectively (Table V). The predicted technical efficiencies of all the farms surveyed were less than one meaning that they all operated below the SF. Ondo State farms recorded a minimum TE of 48.4% while the maximum was 77.2%. The average stood at 64.0%.

Table V: Distribution of Catfish Farms by Efficiency Levels

Efficiency Class	**Class Mark(X)**	**Ondo State**			**Ogun State**		
		Frequency	**Deviation**	**FD**	**Frequency**	**Deviation**	**FD**
0.01-9.99	5.00	0	-50	0	0	-50	0
10.00-19.99	15.00	0	-40	0	0	-40	0
20.00-29.99	25.00	0	-30	0	0	-30	0
30.00-39.99	35.00	0	-20	0	0	-20	0
40.00-49.99	45.00	5	-10	-50	4	-10	-40
50.00-59.99	55.00	5	0	0	2	0	0
60.00-69.99	65.00	36	+10	360	33	+10	330
70.00-79.99	75.00	8	+20	160	10	+20	200
80.00-89.99	85.00	0	+30	0	05	+30	150
90.00-99.99	95.00	0	+40	0	0	+40	0
		∑f=54		**∑fd=470**	**∑f=54**		**∑fd=640**

The corresponding value for Ogun State was 45.4%, 82.1% and 67.0%, respectively. The interpretation of these values is that there is a scope to increase productive efficiency in catfish aquaculture in Ondo and Ogun States by 28.8% and 36.7%, respectively, if all the farms adopt the production method of the most efficient farms. The mean TE of 64.0% and 67.0% in Ondo and Ogun States, respectively, is considered low relative to the most technically efficient farms in both locations. This shows that there is inefficiency in the allocation of resources on catfish farms. The results are however comparable with previous findings on studies of TE using the SFPF model in the Nigerian agricultural or aquaculture sectors [23, 25, 27, 29, 52].

Several factors could account for the wide variations noted between the worst and the best farms in both locations. First, location of fish farms differed; some were upland while some were close to flowing rivers which enabled the fish farmers to advantage of a natural environment which can enhance growth and development of cultured fish. Second, soil types in earthen ponds also differed with different implications for pond edge stability, water pollution and growth of natural organisms which can be used by fish as food. Three, trees were planted round some ponds, some were located in forested areas while some were without any type of shade. There may be implications for pond water temperature, quality and fish performance. Four, there were also differences in feeds and feeding technology. Some farms depended exclusively on commercial feeds, others used feeds compounded on own farm while some used a mixture of household wastes, dead organisms and commercial feeds. Some farmers fed their fish once while other did so twice in a day. Some farmers weighed samples of fish every week before arriving at the quantity of feeds to serve in order to prevent excessive leftovers while some did not weigh samples of fish and depended on experience to determine the quantity of feed to serve. The feed served can therefore be simply inadequate or excessive with varying implications. The factors stated above could not enter the SFPF model used to explain variations in efficiency levels to prevent it from becoming unwieldy.

SUMMARY AND CONCLUSION

Data collected from 108 catfish farmers in Ondo and Ogun State were used to estimate the TE of production and isolate factors which influenced efficiency levels in catfish farming. The SFPF approach using the

MLE procedure was utilized in estimating the model and predicting individual TEs. Empirical analysis showed that there were wide variations in predicted TEs across farms ranging from 48.4% to 77.2% in Ondo State and 45.4% to 82.1% in Ogun State with means of 64.0% and 67.0%, respectively. The results also indicate that coefficients of the quantity of feeds, total number of ponds, labour and number of times pond water is changed are positive and highly significant in catfish production. The inefficiency model revealed that age, management pattern and farming experience coefficients were significant while the education level coefficient was not significant. The age coefficient was negative indicating that older farmers tend to be less inefficient probably as a result of being able to make informed decisions in managing fish farms. The test of various null hypotheses showed that the inefficiency effects were related to the age, management pattern, years of experience and education level of farmers.

The policy implication of the findings is that there exists ample opportunities for improving the extant level of TE in the study area given the wide variations among and between farms. Since management pattern and experience bore a relationship with the level of TE, government policy should be directed at addressing ways to encourage fish farmers to take to the venture on full-time basis. Experience is often said to be the best teacher and what can compensate for this for very young, inexperienced farmers is increased extension contact directed at building their capacity especially in technical issues critical for improved production. Inputs need to be within easy reach of farmers and credit is very critical in accessing inputs. It is therefore not out of place if an aquaculture credit window is put in place to assist fish farmers. The level of profitability already established to be high in aquaculture may connote that default will be low in this credit scheme [4, 6, 48]. From the discussion of the possible factors that can lead to variations in TE, it is certain that further theoretical and applied work are required to include more farm- and farmer-specific variables in the modeling of TE so as to obtain better results and come up with a more generalized SF model and the TI effects in the Nigerian catfish aquaculture sub-sector.

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