COMPARATIVE TECHNICAL EFFICIENCY OF POND FISH PRODUCTION UNDER TWO MANAGEMENT SYSTEMS IN ABEOKUTA METROPOLIS, OGUN STATE, NIGERIA

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Abstract

This study compared the technical efficiency of fish production under two management systems in Abeokuta metropolis, Ogun state, Nigeria. Primary data for this study were collected from forty-five fish farmers using earthen pond and thirty fish farmers using concrete pond through simple random sampling technique and complete enumeration techniques respectively. The Stochastic Frontier production function was employed for the determination of the technical efficiency of the fish farmers. Results revealed an average age of 44years and 46years for operators of concrete and earthen pond technologies respectively. They were mostly males and educated. There was a fairly high but almost equal technical efficiency scores in fish production for concrete (0.6429) and earthen pond (0.6432. Significant variables affecting fish production in concrete pond were stock size ($\alpha_{0.01}$) and feed ($\alpha_{0.05}$), while the factors affecting inefficiency was gender. For earthen pond technology the factors were pond size ($\alpha_{0.05}$), stock size ($\alpha_{0.01}$) and feed intake ($\alpha_{0.01}$), while the factors affecting inefficiency were age ($\alpha_{0.05}$), education level ($\alpha_{0.05}$) and household size ($\alpha_{0.10}$). Elasticity values for resources used for both technologies indicate that they were allocated and used in the stage II of the production process and that fish production in earthen pond technologies had higher feed conversion efficiency. The study recommended among others that, appropriate government agencies and community-based organisations, should encourage young and educated people to go into fish production as a precursor towards increasing technical efficiency of fish production.

Keywords: Comparative analysis, Technical Efficiency, fish production technologies

Introduction

Given the stagnation in capture fisheries production, aquaculture has been the sole source of supply growth in the fisheries sector of the world during the 1990s (Delgado, *et. al.*, 2003). This is occasioned by incidence of overexploitation associated with capture fisheries. Pond fish production is fast becoming a livelihood option in Nigeria especially the south-western part of the country, partly for income generation and to reduce fish importation in the country. Homestead fish production is a grassroots approach whereby fish is cultured at backyard of homes, provided there is adequate water supply to raise fish (Otubusin, 1988). The production of pond fish provides important economic and nutritional benefits to many regions of the developing world (FAO, 2010). The enterprise operates mainly under two management systems, production in earthen ponds and concrete ponds. In earthen pond construction, a piece of land usually with high water table (e.g. *Fadama* or other flat plains) is excavated to the desired specification of embankments, incorporating services of dykes/monks, outlets and inlets as well as water quality management. This technology helps to raise fish in near natural environment for optimum performance. Concrete pond on the other hand features the construction of concrete embankments with inside either excavated to 1metre deep or levelled. Whether excavated or not, the pond bottom is concreted to prevent water seepage. This technology could be very expensive when large ponds are considered. Both technologies have been widely patronized by investors depending on the perceived comparative economic advantage with both yielding high return to investment (Otubusin, 1988). As at 1999, the total fish production under aquaculture was 152,796 tonnes (Federal Department of Fisheries, 2009) while the daily per capita production of fish in Nigeria is 26.502g per day translating to 3.98 billion tonnes per year. This figure according to Otubusin (2011) is a far cry from what is needed for 2011 even if the 1999 estimate is tripled. This suggests that aquaculture fish production needs to be better positioned to meet the imminent challenge of increased productivity by increasing the efficiency of available resources to maximise output of fish.

The task of this paper therefore is to establish the technical efficiency of fish production under the two management systems with a view to describing the input requirement, output pattern and profitability, using Abeokuta metropolis in Ogun State as the study area.

Concept of Technical Efficiency:

Farrel (1981; cited in Kalirajan and Shand, 1989) defined technical efficiency as the measure of a firm's success in producing maximum output from a given set of inputs. Measure of technical efficiency for each firm describes how close the individual firms are to the highest production frontier. The technical efficiency is the ratio of the observed output (Yi) to the corresponding frontier output (Yi*) given the available technology. That is, Technical Efficiency (TE) =Yi/Yi* where Yi is the observed output and Yi* is the frontier output. This definition of technical efficiency implies that differences in technical efficiency between firms exist. When firms operate below the frontier output, they are said to be technically inefficient. For such firms, an improvement in technical efficiency is possible and may be achieved in three ways according to Olayide and Heady, (1982). These are improved production techniques, improvement in the production technology and a combination of the two. Technical inefficiency arises when actual or observed output from a given mix is less than the maximum possible.

Specification of the Stochastic Frontier Production Model:

The stochastic frontier production function model for estimating farm level technical efficiency is specified as:

$Y\,i = f\,(Xi;\,\beta) + \varepsilon_i \quad i= 1,2,\ldots\ldots..n$ …………(1)

Here Yi is output, Xi denotes the actual input vector, β is vector of production function and ε is the error term that is composed of two elements, that is:

$$\varepsilon = V_i - U_i \qquad \text{………… (2)}$$

Where Vi is the symmetric disturbances assumed to be identically, independently and normally distributed as $N(0,\sigma^2_v)$ given the stochastic structure of the frontier. The second component Ui is a one-sided error term that is independent of V_i and is normally distributed as $(0,\sigma^2_u)$, allowing the actual production to fall below the frontier but without attributing all short falls in output from the frontier as inefficiency.

$$\sigma^2 = \sigma^2_u + \sigma^2_v \qquad \text{…………(3)}$$

Furthermore, $\gamma = \frac{\sigma_u^2}{\sigma^2}$ …………(4)

The variance ratio parameter γ (Gamma) according to Battesse and Corra (1977) $\gamma = (0 \leq \gamma \leq 1)$. The variance ratio parameter γ has two important characteristics:

i. when σ^2_v tends to zero, then u is the predominant error in equation (1) and γ tends to 1, implying that the output of the sampled farmers differs from the maximum output mainly because of difference in technical efficiency.

ii. when σ^2_u tends to zero, then the symmetric error v is the predominant error in equation (1) and so γ tends to 0. Thus based on the value of γ, it is possible to identify whether the difference between a farmer's output and the efficient output is principally due to random errors (γ tends to 0) or the inefficient use of resources (γ tends to 1) (Kalirajan, 1981).

The farm specific technical efficiency is defined in terms of observed output (Y_i) to the corresponding frontier output (Y_i*) using the available technology derived from the result of equation (5) above as:

$$TE = \frac{Y_i}{Y_i*} = \frac{E(Y_i \mid u_i, X_i)}{E(Y_i \mid u_i = 0, X_i)} = E\left[\exp(-Ui/\varepsilon)\right] \qquad \text{………… (6)}$$

Therefore, $TE = \exp(-U_i)$

TE takes values within the interval zero and one (i.e. between 0 and 1), where 1 indicates a fully efficient farm.

Theoretical Framework:

The modelling estimation and application of stochastic frontier production function to economic analysis assumed prominence in econometric and applied economic analysis during the last two decades. Early applications include those of Aigner *et. al. (*1997); in which the applied the model was applied in the analysis of U.S agricultural data. Battese and Corra (1977) applied the technique to the pastoral zone of Eastern Australia. Furthermore, Theingi and Thanda (2005) found an average technical efficiency of 0.64 for small (<5acres) farms in irrigated rice farms in Myanmar Germany using a stochastic frontier production function. Okoruwa *et al.* (2006) reported a mean TE of 81.6 percent among the upland rice farmers in Niger state North Central Nigeria.

The stochastic frontier production functions was also applied to study the production functions of wheat farmers in selected districts of Pakistan following an application of a stochastic frontier production function with time-varying inefficiency effects by Battese *et. al., (*1993). Results indicated that the null hypothesis of no technical inefficiency cannot be rejected only in one district. That is, there are technical inefficiencies in all the districts except one.

Battese and Coelli, (1992) investigated factor which influence the technical inefficiency of Indian farmers using a stochastic frontier production which incorporates a model for technical inefficiency effects and they include: the age and level of education of farmers, farm size and year of observation.

Methodology

Ogun State covers a land area of 16,409,625 square kilometres (Ogun State of Nigeria, 2011). This study was carried out in Abeokuta Metropolis, Ogun state, Nigeria. The metropolis consists of three local government areas namely Odeda, Abeokuta south and Abeokuta North. Geographically, it is situated in the rain forest belt between latitude 6^{o} and 8^{o} North as well as Longitude 2.5^{o} and 5^{o} East of the Equator. The average rainfall in the area is between 1500mm and 1800mm. Large percentage of the population consisting of both men and women engage in agriculture. Some of the inhabitants derive their income or means of likelihood from being civil servants.

Sample size and Sampling Techniques:

A total sample of 80 respondents was used for this study using both simple random sampling and purposive sampling techniques. Simple random sampling technique was adopted to select 45 fish producers using the earthen pond technology out of the 55 producers (listed in the sampling frame obtainable at the Ogun State Agricultural Development Programme.) in the metropolis as at the time of this study. Only one questionnaire administered for earthen pond fish farmers could not be used for meaningful analysis. Complete enumeration technique was used to sample all available fish farmers using the concrete pond technology in the study area, given their relatively low number as at the time of this study. Primary data were collected using structured questionnaire whose questions were based on the objectives of the research study.

Analytical Procedure:

Analytical tools employed in this research study include the descriptive statistics and the Stochastic Frontier Production Function.

Descriptive Statistics:

Frequency and percentages tables were used to describe the socio-economic characteristics of the fish pond farmers that are pertinent to the study.

The Stochastic Production Function Estimation:

This research study adopted Stochastic Frontier Production Function proposed by Battese and Coelli (1995) which assumes the existence of technical inefficiency of different firms in production. However, it differs from the traditional production function in that it consists of two error terms. That is, it has the advantage of accounting for the measurement error in the specification and estimation of the frontier production function.

The Stochastic frontier production function for fish farming operation in Abeokuta metropolis Ogun state is specified below implicitly as:

$$Yi = f(Xi, \beta i) \exp(v_i - u_i) \quad \ldots\ldots\ldots\ldots(7)$$

Explicitly, it is given as:

$$lnYi = ln\beta o + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + \beta_6 lnX_{6i} + v_i - u_i \quad \ldots\ldots\ldots\ldots(8)$$

Where:
Yi = Fish output (kg)
X_1 = Pond size (m^2)
X_2 = Stock size (kg)
X_3 = feeds (kg)
X_4 = Fertilizer (kg)
X_5 = Lime (kg)
X_6 = Labour used (mandays)
β_o = Constant term
β_i = Coefficient to be estimated

v_i = Symmetric error/ measurement error associated with uncontrollable factors related to production process
$u_i \geq 0$ represents firm's technical inefficiency relative to the Stochastic frontier.

The Technical Efficiency Model:

This is defined by:

$$Ui = \delta_o + \delta_i Z_i \quad \ldots\ldots\ldots\ldots(9)$$

Where:
Ui = Technical inefficiency
δ_o = Constant term
δ_i = Coefficient to be estimated
Z_1 = Age of farmers (years)
Z_2 = Years of schooling (years)
Z_3 = Household size (number)
Z_4 = Years of experience (years)
Z_5 = Gender (1 if male, 0 otherwise)

The value of Ui may be obtained from the observable value of $v_i - u_i$ with the assumption that the compose error $v_i - u_i$ is known and it is the best predictor for technical efficiency. The predictor which is presented in Battese and Coelli (1993) is estimated at the maximum likelihood estimates of the parameters of the full frontier inefficiency model stated above.

Results and Discussion

Socio-economic Characteristics of Fish Farmers in the Study Area:

Results indicated that entrepreneurs of concrete pond were predominantly (53.3%) less than 40 years of age, with an average age of 44 years while majority of the operators of earthen pond were between the ages of 31 and 50 years with an average age of 46 years (Table 1). This suggests that larger percentage of operators of pond fish farming in the two technologies were youths. Majority (89.2%) of the fish producers in the two enterprises were males, indicating the popularity of the enterprises among the males. Nearly all the fish producers in the two enterprises were formally educated.

This is expected given the technicality of the principles of fish production in ponds and entrepreneurs need to keep abreast of developments in the field for optimum production. Furthermore, majority (67.6%) of the entrepreneurs in both enterprises had not more that 6 years working experience in fish production. In terms of scale of operation or pond size, 91.9% of the fish farmers had less than 1 hectare of fish pond, this has implication on overall productivity of fish in the study area.

Technical Efficiency of Fish Production Using Stochastic Frontier Production Model:

The maximum likelihood estimation (Table 2) provides estimators which are variance parameters; sigma squared (δ^2) and gamma (γ). It is evident from the table that the estimated sigma squared are 0.0253 and 0.0132 for earthen and concrete pond respectively while the gamma and log likelihood function are 0.7221 and 40.88 respectively for earthen system and it is 0.6272 and 40.85 respectively for concrete system. Gamma represents the total output made on the frontier production function attributable to technical efficiency. The estimated sigma squared for both production systems are significantly different from zero ($\alpha_{0.05}$). This indicates a good fit and the correctness of the specified distributional assumptions of the composite error term. The gamma of 0.7221 and 0.6272 are significantly different from zero ($\alpha_{0.01}$) and imply that 72% technical efficiency level was attained by the farmers using earthen pond system while it is 63% for concrete pond. That is, 72% of the variation in fish output among the fish farmers (earthen pond) is due to differences in their technical efficiencies. While for concrete pond, 63% of the variation in fish output among the fish farmers is due to differences in their technical inefficiencies. The reason for this is the fact that earthen pond is similar to the natural fish habitat and this leads to better performance in fish production relative to input use, given good management (Otubusin, 2011). The generalized log likelihood function (40.88 and 40.85) suggests the presence of the one-sided error component. This generally reflects the goodness of fit of the model.

Results of Maximum likelihood estimates of the Cobb-Douglas-based stochastic frontier production model represented by the elasticity estimates are given in the table 2. The table generally reveals that variable inputs such as stock size, feed and pond size as significant factors influencing the output of fish produced. The estimated coefficient of stock size and feed are positive under the two production technologies. Stock size is significant at one percent probability level (α_{01}). This means that a percent increase in stock size will lead to increase of 0.90% and 0.98% in output for the earthen and concrete pond technologies respectively.

The estimated coefficient of feed is also significant at ($\alpha_{.01}$ and $\alpha_{.05}$ respectively for earthen and concrete pond technologies) and has positive relationship. This implies that a percent increase in the quantity of feed utilisation will lead to 0.59% and 0.03% increase in the quantity of fish output for the earthen and concrete pond technologies respectively. This also implies that fish produced in the earthen pond shows higher feed conversion efficiency relative to those raised in concrete ponds. Pond size is also a significant ($\alpha_{.01}$) factor affecting fish production under the earthen pond technology. The variable is significant and positive and it indicates that a percent increase in pond size will increase fish output by 0.03%.

Elasticity of Fish Production under the Two Technologies:

Following Ajibefun (2002), the Cobb-Douglas based stochastic frontier production model on the maximum likelihood estimates are elasticity values. The production elasticity measures the proportional change in the output resulting from a proportional change in the *ith* input level, with all other input level held constant. The elasticity of mean value of output with respect to the inputs is estimated at the values of the mean of the resources (Ajibefun, 2002). Following this assertion, the elasticity value of output of fish produced (in earthen pond technology) with respect to stock size, feed and pond size are 0.91, 0.06 and 0.03 respectively. From the Cobb-Douglas frontier models, the results show that the elasticity value of output of fish is estimated to be an increasing but inelastic function of stock size, feed and pond size. Elasticity for stock size is within the range of 0- 1 implying that these variables were allocated and used in the stage of economic relevance of the production function, that is, stage II of the production process. With respect to production using concrete pond technology, the elasticity of feed is 0.03 while that of stock size is 0.97. The elasticity of feed in earthen pond technology (0.06) is higher than that of concrete pond technology (0.03), suggesting higher feed conversion efficiency for fish in earthen pond construction.

Elasticity values are also within the range of 0-1 implying that these variables were allocated and used in the stage II of the production process. The general implication of this finding is that the fish farmers still operated in stage II, which is the rational stage of the production process.

Technical Inefficiency Sources:

The results of the estimated coefficients in the inefficiency model indicate that age of the fish farmers is positively related to inefficiency of fish production, that is, as age increases efficiency of fish production in the earthen pond technology decreases (Table 2). The other significant variables on the other hand, contribute positively to efficiency of fish production under the earthen pond technology. These include level of education ($\alpha_{0.05}$) and household size ($\alpha_{0.05}$). Thus, technical efficiency increases in fish production in earthen pond with infusion of younger farmers, with more educational qualification and large household size. For the concrete pond technology, only the variable of gender contributes significantly to the inefficiency of fish production. The negative value of gender coefficient means that female fish farmers were less technically efficient than their male counterpart.

Distribution of Technical Efficiency between the Earthen and Concrete Pond Technologies:

The distribution of technical efficiency score of fish farmers in the study area is presented in table 3. The table shows that majority (70.0% and 68.9%) of the earthen pond and concrete pond technologies respectively, fell into the efficiency class of 0.61-0.70. Therefore, similarity exists in the response of output produced relative to input use in the two technologies. The mean technical efficiency score of 0.64 apiece for the two technologies suggests that the two production techniques operated under a fairly efficient production system. The result indicates that fish farmers have the potential to increase their present level of output by 36% given their present resource mix

Conclusion and Recommendations

Fish farmers in the study area had fairly high level of technical efficiency with ranges of the sample operating between 61% and 70% efficiency levels. The elasticity of mean value of output with respect to input use suggests resource inelasticity among the fish farmers in the two technologies. However, fish produced in the earthen pond technology shows higher feed conversion efficiency relative to those raised in concrete pond. Significant variables affecting fish output in the study area are stock size, feed and pond size. This accentuates importance of these variables in fish production. The study also found out that significant farmer-related factors with propensity to increase technical efficiency of fish output include education, household size and gender in favour of males.

Policy needs to be directed towards encouraging intending investors especially young school leavers to go into fish production given the relatively high technical efficiency. Chief among these is the necessity to encourage young and educated people to go into fish production especially earthen pond fish production as age and education improve technical efficiency in fish production. The significance of the feed variable for both management systems necessitates the need for policies that will ensure availability of feeds to fish farmers at affordable prices.

Furthermore, research into the production of high quality feed and stock with high pedigree should be focused on by research institutes and universities as these have been found to be sine qua non towards increasing technical efficiency of fish production.

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Table 1: Some socioeconomic characteristics of fish farmers in the study area

Parameter	Concrete		Earthen		Total	
Age (years)	**Frequency**	**(%)**	**Frequency**	**(%)**	**Frequency**	**(%)**
<30	7	23.3	4	9.1	1.1	14.9
31-40	9	30.0	13	29.5	22	29.7
41-50	5	16.7	16	36.4	21	28.4
51-60	5	16.7	10	22.7	15	20.3
>60	4	13.3	1	2.3	5	6.5
Total	30	100	44	100	74	100
Sex						
Male	28	93.3	38	86.4	66	89.2
Female	2	6.7	6	13.6	8	10.8
Total	30	100	44	100	74	100
Education						
No-education	-	-	2	4.5	2	2.7
Primary	4	13.3	15	34.1	19	25.7
Secondary	3	10.0	8	18.2	11	14.9
Tertiary	23	76.7	19	43.2	42	56.8
Total	30	100	44	100	74	100
Fish Farming Experience						
<3yrs	5	16.7	12	27.3	17	23.0
4-6	15	50.0	18	40.9	33	44.6
7-9	6	20.0	8	18.2	14	18.9
>10	4	13..3	6	13.6	10	13.5
Total	30	100	44	100	74	100
Pond size(ha)						
<0.5	26	86.7	25	56.8	51	68.9
0.5-<1.0	3	10.0	14	31.8	17	23.0
1.0-<1.5	1	3.3	3	6.8	4	5.4
1.5-<2.0	-	-	1	2.3	1	1.4
>2.0	-	-	1	2.3	1	1.4
Total	**30**	**100**	**44**	**100**	**74**	**100**

Source: Field survey, 2009

Table 2: Result of Maximum Likelihood Estimates of factors affecting technical efficiency and inefficiency of Fish Production in Abeokuta Metropolis, Ogun State.

Variables	**Parameter**	**Earthen**		**Concrete**	
		Coefficient	**t-value**	**Coefficient**	**t-value**
Constant	B_o	0.6744***	(3.06)	0.3201	1.605
Pond size(ha)	B_1	0.0258**	(2.219)	0.0076	0.568
Stock size(N)	B_2	0.9088***	(30.41)	0.977***	32.53
Feed(kg)	B_3	0.0587***	(4.552)	0.030**	2.130
Fertilizer(kg)	B_4	0.00974	(0.116)	0.000	0.000
Lime(kg)	B_5	-0.00143	(-0.0145)	-0.0113	-0.9812
Labour(Manday)	B_6	-0.0092	(-0.789)	0.0146	1.292
Inefficiency Sources					
Variables	Parameter	Coefficient	t-value	Coefficient	t-value
Constant	δ_0	0.1760	0.0662	0.0761	-0.1339
Age	δ_1	0.00451**	2.299	0.0038	0.3322
Level of education	δ_2	-0.0123**	-2.719	-0.1188	-0.9186
Household size	δ_3	-0.00862*	-1.593	-0.0207	-0.5028
Fish Farming Experience	δ_4	-0.00218	-0.508	-0.0130	-0.2739
Gender	δ_5	0.00622	0.1073	-0.0113***	7.4896
Sigma-squared (δ^2)		0.0253**		0.0132**	
Gamma (γ)		0.7221***		0.6272***	
Log likelihood function		40.88		40.85	

Source: Computed from Field Survey Data, 2009

Note:
*** Parameter significant at 1% probability level
** Parameter significant at 5% probability level
* Parameter significant at 10% probability level

Values in parentheses are standard t- values ≥1.5 – 1.9, are flagged at 10% significant level according to Rahji (2005).

Table 3: Distribution of Respondent based on Range of Technical Efficiency.

Technical Efficiency Range	**Concrete Frequency**	**Percent**	**Earthen Frequency**	**Percent**
≤0.60	5	16.7	8	17.6
0.61-0.70	21	70.0	30	68.9
>0.70	4	13.3	7	13.5
Total	30	100.0	45	100.0
Mean Technical Efficiency	0.6429		0.6432	

Source: Field survey, 2009.