Technical Efficiency in Aquaculture in Oyo State, Nigeria

T. T. Awoyemi *, J. O. Amao ** and N. C. Ehirim*

I

INTRODUCTION

The concept of efficiency is at the core of economic theory. The theory of production economics is concerned with optimisation and optimisation implies efficiency. The crucial role of efficiency in increasing agricultural output has been widely recognised by researchers and policy makers alike. It is no surprise, therefore, that considerable effort has been devoted to the analysis of farm level efficiency in the developing countries. An underlying premise behind much of this work is that, if farmers are not making efficient use of the existing technology, their efforts designed to improve efficiency would be more cost-effective than introducing new technologies as a means of increasing agricultural output (Bravo-ureta and Evenson, 1994).

The analysis of production and resource use in farming is at the core of agricultural policies which seek to increase domestic production by ensuring optimal resource utilisation. Increased agricultural productivity is one of the prerequisites of economic progress (Ogunfowora *et al.*, 1974). The issue of determining the pattern and the efficiency of resource use in traditional farming arises in the context of formulating development strategies designed not only to raise the productivity of resources already committed to farming but also to ensure that the newly created resources in the agricultural development efforts are allocated to areas and/or enterprises in which their productivities are higher.

The term aquaculture refers to the rearing of desirable aquatic organisms under controlled conditions for economic or social benefits (Shang, 1981). Aquatic organisms, include aquatic animals and plants. The aquatic animal group comprises all kinds of fin fish and shell fish, whether they are herbivorous, carnivorous or omnivorous. Aquatic plants consist of various kinds of sea weed and fresh water algae. To be economical, agriculture must be conducted under specific conditions. The culturist must be able to control water quality and ensure proper nutrition, promote breeding and protect fish from disease and predators (Shang, 1981).

True fish are aquatic vertebrates that breathe by means of gills. Other animals that live in water are sometimes termed fish. However, shell fish and cray fish are not true

_____

*Department of Agricultural Economics, University of Ibadan, Ibadan, Nigeria and **Department of Agricultural Economics and Extension, Ladoke Akintola University of Technology Ogbomoso, Oyo State, Nigeria, respectively.

fish because they do not possess a backbone. Whales and porpoises are vertebrates living permanently in water, but are mammals breathing through lungs and suckling their young (Miller and Loates, 1997). Fish consumption has declined by 2 kg per person annually in Oyo State, Nigeria over the past few years from a per caput supply of 8.8 kg to 6.8 kg (live weight equivalent) from 1984 to 1994. This is due to rapid population growth, a drop in imports aggravated by weaker purchasing power, and the ever-smaller share of domestic production retained for the local markets as artisan fisheries increasingly turn to lucrative export markets (FAO ,1997).

Fish production is subject to uncontrollable and unpredictable factors such as weather and disease, which affect the yield of fish and invariably affect the income of the farmers. This study sampled the technical efficiency of fish farmers with special emphasis on economic factors and efficiency of resource use. The study therefore, aimed at investigating technical efficiency in aquaculture in Nigeria, Oyo State. It was also hypothesised that there is no constant returns to scale.

II

STUDY AREA AND DATA

Oyo State is one of the major aquaculture zones of Nigeria that is located in the southwestern part. With basically a tropical climate of 11^0C - 39^0C (minimum and maximum daily temperatures), the state receives an average of 120 cubic centimetres per annum. It can also record a very high relative humidity of above 70 per cent. Although there are few drainage facilities available in the state, it has a high potential for fish and livestock production. With the few captured fishing (wild fishing) in the inland water or drainage, the government has equally made concerted effort to organise a controlled fishing environment that will necessitate a sustainable fishing as well as preserve the ecosystem in the state.

The state is divided into four distinct agricultural zones, viz., Ibadan/Ibarapa, Oyo/Iseyin, Shaki and Ogbomoso. Due to high concentration of fish farmers in Oyo/Iseyin zone, it was considered for the study. In Oyo State, there are five species of fish: Tilapia, Heterotis, Ophocephalus, Clarias and Carp species. But four out of these five species were found in the study area : Carp,Tilapia, Heterotis and Clarias. The culture period was between 6 and 12 months. Data pertaining to the production of fish in Oyo/Iseyin agricultural zone of the state, were collected from 46 respondents selected on a proportionate random sampling basis for the year 2001. If there is availability of water, fish can be produced all year round in the state.

III

THE ECONOMETRIC MODEL

The estimates of production frontiers has proceeded along two general paths; full-frontier which force all observations to be on or below the frontier and hence where all deviations from the frontier is attributed to inefficiency; and stochastic frontier where deviation from the frontier is decomposed into statistical noise and a component reflecting inefficiency.

Following Aigner *et al.* (1977) the method of estimating a stochastic frontier production function in which the disturbance term ($\in$) is composed of two parts, a systematic (V) and one-sided (U) components, a Cobb-Douglas production function of the following form was specified.

$$\ln Y = \ln A + \in i \ln Bi \ln Xi + \in i \qquad \qquad .... (1)$$

where Y = total output of fish in kilogramme, X_i = total capital in naira (pond contruction cost, dyke cost, tranportation cost, cost of labour and cost of feed/chemicals), X_2 = pond size in hectares, X_3 = fingerlings in kilogramme, X_4 = chemical/feed in kilogramme, X_5 = labour in man-days, ln = natural logarithms and ($\in i$) is defined as

$$\in i = Vi - Ui \qquad \qquad .... (2)$$

i = 1, 2, …. n farms.

(i) V accounts for random variation in production due to factors outside the farmer's control, e.g, whether crop diseases, natural disaster and luck, error in measurement and other statistical noise, $-\alpha < V < \alpha$. (ii) it is assumed to be independently and identically distributed as $V \sim N(0, \sigma^2 v)$. U is a one-sided efficiency component of U > 0, which reflects inefficiency component relative to stochastic frontier. It captures technical inefficiency of the farmer because it measures the shortfall in output, from its maximum value given by the stochastic frontier, f (X:β) + V. Thus U = 0, for a farm whose production is on the frontier, U > 0 for one whose production is above the frontier.

Assuming Ui is identically and independently distributed as $[N(0\sigma^2 u)]$: i.e., the distribution of U is half normal. The population average technical inefficiency is

$$\in (e^{-u}) = 2e^{\sigma^2}u/2[1 - F(\sigma u] \qquad \qquad ....(3)$$

where F is the standard normal distribution. The measurement of farm level inefficiency e^{-u}, requires first, the estimation of non-negative error U, i.e., decomposition of the error term $\in$ into two individual error components U and V. Jondrow *et al.* (1982), suggest a technique for the decomposition of U given $\in$. The conditional mean of U given $\in$ is shown to be

$$\in (Ui/\in i) = \sigma^* [f^* (\in \lambda/\sigma)/1 - F^* (\in \lambda/\sigma) - \in \lambda/\sigma] \qquad \qquad .... (4)$$

where, $\sigma^* = \sigma u\,\sigma v/\sigma$,

$\qquad \sigma^2 = \sigma^2 u + \sigma^2 u$,

$\qquad \lambda = \sigma u/\sigma v$,

$\qquad$ f* = standard normal density function,

$\qquad$ F* = standard normal distribution function.

For $\in$, the estimated values are used to evaluate the density function (f) and the distribution function (F), by replacing $\in$, λ, σ by their estimate in equation (1), the values of U and V can be evaluated (Jondrow *et al.*, 1982).

IV

RESULTS

Ordinary least squares (OLS) estimates of the parameters which shows the average performance of the sample farms are presented in Table 1. With the adjusted R^2 value of 0.92, the inputs used in the model were able to explain 92 per cent of the variation in aquaculture production for the state. The coefficients of total capital, pond size, fingerlings and chemicals were highly significant, but labour was not significant. This is due to the fact that labour does not contribute much to the production of fish in the study area. The insignificance of labour could be due to low use of labour, and the capital intensive nature of labour use in the enterprise. Labour productivity is relatively low due to the higher skilled or higher paid labour requirement for aquaculture. The family labour utilisation is low and proved inefficient since they may not be part of the trained culturist.

TABLE 1. OLS ESTIMATE OF AVERAGE PERFORMANCE USING
COBB-DOUGLAS PRODUCTION FUNCTION

Variables (1)	Parameters (2)	Coefficients (3)
Constant	β_0	0.978 (0.723)
Total capital (X_1)	β_1	0.217* (0.067)
Pond size (X_2)	β_2	0.223* (0.066)
Fingerlings (X_3)	β_3	0.490* (0.068)
Chemicals (X_4)	β_4	0.166* (0.064)
Labour (X_5)	β_5	0.026 (0.040)

Source: Field Survey, 2001.

D = 1.76, R^2 = 0.92, R^{-2} = 0.92, F = 97.69, N = 46

Figures in parentheses are standard errors.

* Significant at 5 per cent.

On the other hand, the estimates of the stochastic frontier which shows the best practice performance, i.e., efficient use of the available technology is presented in Table 2 (Tadesse and Krishnamoorthy, 1997). It is evident from the table that the

estimate of λ (1.3144) and σ (0.1986) are large and significantly different from zero, indicating a good fit and correctness of the specified distributional assumption. Similarly, the estimate of Y, which is the ratio of the variance of farm-specific technical efficiency to the total variance of output was 0.6333. This would mean that more than 63 of the variance in output among the farms is due to the differences in technical efficiency.

TABLE 2. MAXIMUM LIKELIHOOD ESTIMATES OF THE STOCHASTIC
FRONTIER PRODUCTION FUNCTION

Variables (1)	Parameters (2)	Coefficients (3)
Constant	β_0	1.47* (1.03)
Total capital (X_1)	β_1	3.18* (0.079)
Pond size (X_2)	β_2	0.23* (0.071)
Fingerlings (X_3)	β_3	0.50* (0.050)
Chemicals (X_4)	β_4	0.15** (0.087)
Labour (X_5)	β_5	0.03* (0.055)
	λ	1.3144*
	γ	0.6333
($\sigma u + \sigma v$) = θ		0.1986*
Log-likelihood		21.230
	N	46

Source: Field Survey 2001.
Figures in parentheses are standard errors.
* and ** Significant at 5 and 10 per cent level respectively.

With an upward shift in the constant term, the coefficient of total capital, pond size, fingerlings and chemicals remained significant in the Cobb-Douglas stochastic frontier production function, implying that the farmers could be advised to use more fingerlings and pond size to increase production (Tadesse and Krishnamoorthy, 1997). Moreover, it was also observed that the farm-specific technical efficiency varied between 6 and 61 with a mean of 24 (Table 3). Two farmers fell within the highest efficiency level of above 61 per cent efficiency, while only 2 farmers were having very low efficiency level. Majority of the farmers fell within the range of minimum and maximum efficiency. This implies that for an average efficient farmer to achieve the technical efficiency level of its most efficient counterpart, he could realise about [1 - 24/61] savings in cost or increase in production. This gives about 61 per cent increase in production or save in cost. The least efficient farmer can now save a cost or increase in production of 90 per cent to achieve the required technical efficiency of the most efficient farmer in the state.

TABLE 3. FREQUENCY DISTRIBUTION OF FARM-SPECIFIC TECHNICAL
EFFICIENCY OF AQUACULTURE IN OYO STATE

Technical Efficiency (per cent) (1)	State $\mu = 46$ (2)	Relative frequency (3)
0 - 10	2	4.3
11 - 20	19	41.3
21 - 30	14	30.4
31 - 40	8	17.4
41 - 50	1	2.2
51 - 60	0	0
61 - 70	2	4.3
71 - 80	0	0
81 - 90	0	0
91 - 100	0	0
Average technical efficiency	0.24	
Maximum technical efficiency	0.61	
Minimum technical efficiency	0.06	

Source: Field Survey 2001.

The function coefficient which measures the rate of returns to scale (elasticity of production) is almost the same in the two estimators with each having a proportion of 1.1 per cent. The slight deviation from unit elasticity of production means that there is increasing returns to scale. This implies that it pays to use more of the input in the production of fish since the more input employed given a marginal increase in the output of fish.

The F-statistics showed a greater value than the F value at 5 per cent significance level. The F-statistics is above 98 while F-value at 5 per cent level of significance is 4.02. This implies that the null hypothesis (that there is no constant returns to scale and that the parameter estimates are significantly different from zero is accepted. The high significance value of the F-statistics test indicates that the estimator is consistent with the theory and can be adopted.

TABLE 4. ELASTICITY OF PRODUCTION AND RETURNS TO SCALE ANALYSIS

Variables (1)	Marginal physical product (2)	Returns to scale (3)	Elasticity of production (4)
Total capital (X_1)	0.17	0.22	-
Pond size (X_2)	69.6	0.22	-
Fingerlings (X_3)	6.74	0.48	1.12
Chemicals (X_4)	0.23	0.17	-
Labour (X_5)	0.03	0.03	-

Source: Field Survey, 2001.

V

CONCLUSION

The results of our study showed that, with the use of more fingerlings and pond size, fish production could be increased. The contribution of pond size in increasing production is more prominent. The farmers were over using labour in fish production. The frontier showed a gross inefficiency level of 0.03 per cent as most of the farmers are grossly over using the inputs available for aquaculture in the state.

Overall, the mean technical efficiency of 24 per cent was recorded and a range of 6 per cent to 61 per cent technical efficiency was recorded for minimum efficient and maximum efficient farmers in the state respectively. This implies that a cost saving of 61 per cent is required by an average farmer to become efficient while about 90 per cent cost saving is required by the least efficient farmers to increase its efficiency at optimum level of efficiency.

Furthermore, the elasticity of production showed an increasing returns to scale. Elasticity of production of about 1.12 showed that increase in unit input by 1 per cent gives an additional increase of 0.12 per cent.

On the basis of the findings of the study, the following policy recommendations are made for the improvement in fish production, and in motivating the fish farmers:

(i)   Since the results showed that fish farmers are technically inefficient, there is a need for very high technological innovation in aquaculture as this can assist the farmers to achieve a very high competent technological efficiency in meeting up with the required output.

(ii) There is a very low skilled labour utilisation in the area. Fish farmers should endeavour to employ more technically skilled manpower to assist in increasing the level of output and in the enhancement of the available resource for a better performance.

(iii) Improvement in the activities of the fishery extension unit of the State Ministry of Agriculture and Oyo State Agricultural Development Programme (OYSADEP) to enhance regular visits to the farmers.

REFERENCES

Aigner, D.J.; A.K. Lovell and P. Schmidt (1977), "Formulation and Estimation of Stochastic Production Function Model", *Journal of Econometrics*, Vol. 6, pp. 21-34.

Bravo-ureta, B.E and R.E. Evenson (1994), "Efficiency in Agricultural Production: The Case of Peasant Farmers in Eastern Paraguay", *The Journal of the International Association of Agricultural Economics,* Vol. 10, No. 1, pp. 27-28.

Food and Agriculture Organization of the United Nations (1997), *The State of World Fisheries and Aquaculture*, Italy, Rome, pp. 24-25.

Jondrow, J.; C.A. Lovell, V.I. Malcro and P. Schmidt (1982), "On the Estimation of Technical Efficiency in the Stochastic Frontier Production Function Model", *Journal of Econometrics,* Vol. 19, pp. 233-238.

Miller, P.J. and M.J. Loates (1997), *Fish of Britains and Europes*, Collins Pocket Guide, Harper Collins Publishers, London Press.

Ogunfowora, O.; S.M. Essang and S.O. Olayide (1974), "Resource Productivity in Traditional Agriculture: A Case Study of Four Agricultural Divisions in Kwara State of Nigeria", *Journal of Rural Economics and Development*, Vol. 9, No. 2, pp. 119-124.

Shang, C.Y. (1981), *Aquaculture Economics: Basic Concepts and Methods of Analysis*, Westview Press, London, p. 153.

Tadesse, B. and S. Krishnamoorthy (1997), "Technical Efficiency in Paddy Farmers of Tamil Nadu: An Analysis Based on Farm Size and Ecological Zone", *Journal of Agricultural Economics,* Vol. 16, p. 188.