TECHNICAL EFFICIENCY OF CATFISH PRODUCTION IN ANAMBRA STATE, NIGERIA: A TRANSLOG STOCHASTIC FRONTIER PRODUCTION FUNCTION APPROACH

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Abstract

The study highlighted the technical efficiency of catfish production by large and small scale farms in Anambra State, Nigeria using the translog stochastic frontier production function approach. A multistage random sampling technique was used to select 256 catfish farmers for the study. However, 204 returned useful questionnaires used to collate data for analysis. Results indicated mean technical efficiency scores of 0.89 and 0.94 for the large and small scale farms respectively. This implies that the small scale farms are technically more efficient than the large scale farms, hence the large scale farms possess higher capacity (11%) for expansion than the small scale farms (6%). Household size and feeding method negatively and significantly influenced the inefficiency of catfish farming by large and small scale farms respectively at 5% level of probability. More so, returns to scale was 1.05 at par signifying constant returns to scale for both farm groups. Technical efficiency could be increased by the minimization of use of family labour; encouraging the use of quality seeds, feeds and intensive feeding; and the adoption of improved technologies and better management practices for any of the farm groups.

Key words: catfish farming, technical efficiency analysis, translog production function, Anambra State, Nigeria

INTRODUCTION

Central to the economic activities in Nigeria, the agricultural sector made up of crop, livestock, fisheries and forestry sub-sectors, accounts for about 31% to 42% of Gross Domestic Product (GDP) between 2005 and 2008 (Central Bank of Nigeria (CBN), 2007; Food and Agriculture Organisation (FAO), 2007; Fresh Plaza, 2008). The contribution of the fisheries sub-sector to this GDP figure which was 1.1% in 1995 increased to 3.2% in 2007 and it is expected to reach 5% in 2020 (Davies et al., 2009). This contribution of the fisheries sub-sector came mostly through artisanal coastal/inland waters (81.6%), aquaculture/fish farming (10.0%) and industrial/coastal fish and shrimps (8.4%) as at year, 2003.

The contribution from capture fisheries (i.e. artisanal coastal /inland waters) to total fish output has been declining. For instance from 90% in 1990 (Tobor, 1990) to 84.2% in 1994 (CBN, 1994), and then to 81.6% in 2003 (CBN, 2003). The decline continued unabated down to 40% in 2006 resulting to about 300 000 metric tonnes (Global Agriculture Information Network (GAIN), 2007). This drop was primarily attributed to insecurity along Nigeria's coasts and waterways, higher energy costs and over-fishing (Adekoya and Miller, 2004; Inoni, 2006). In the face of strong consumer demand and dwindling global fish stocks, the Government of Nigeria at various levels (federal, state and local) has been collaborating with local and external stakeholders to increase supply through aquaculture which has been proven to possess high yield potentials to meet the current national demand of about 2.6 million metric tonnes estimated for 2007 (Osawe, 2007).

Fish farming is part of aquaculture. It provides lucrative returns to the farmers, employment in rural areas, besides supplying good quality protein diet for the people (Onoja, 2005). In addition to fish protein which is ranked cheapest among the animal protein sources, fish provide high quality calories, fats and vitamins (Samson, 1997). Furthermore, fish culture generates income for all categories of people involved in it as well as foreign exchange for the nation.

Among the culturable species of food fish in Nigeria (carp, tilapia, catfish, etc.), catfish is the most sought after. It is very popular with fish farmers and commands very good commercial value in the markets. Consequently the catfish is vital to the sustainability of the aquaculture industry in the country having in possession the following good qualities identified by Osawe (2004) as: they survive in different culture systems and diverse environments, grow very fast, have high fecundity, improved survival of the fry and adaptation to supplemental feed.

These qualities have placed catfish farming in good position to serve as the only way of boosting fish production and thereby move the country towards self-sufficiency in food fish supply. To achieve economic optimum output and thus profitability, resources have to be optimally and efficiently utilized. The efficiency of input utilization in any agricultural enterprise enhances the profitability of such enterprise. The ability of catfish farmers to adopt new technology and achieve sustainable production depends on their level of technical efficiency. Efficiency studies help countries to determine the extent to which they can raise productivity by improved efficiency with the existing resource base and available technology.

In Nigeria, many studies have been done to determine the technical efficiency levels of different crops. Only a few of such studies were in livestock production and virtually none in production of food fish. For instance, recent efficiency studies by Chukwuji (2006), Ike and Inoni (2006), Akinleye (20007), Oluwatayo et al. (2008), and so on, were on crops. Ojo (2003), Yusuf and Malomo (2007), Ojo and Ogundari (2008) worked on livestock efficiency, while Ojo and Fagbenro (2006) investigated fish (tilapia). This implies that the existing knowledge of technical efficiency in catfish production is highly limited in Nigeria, and Anambra state in particular, thus justifying the study. The study, thus broadly examined the technical efficiency of catfish production in Anambra state, Nigeria using a one-step stochastic frontier production function ran with the computer programme FRONTIER 4.1 by Coelli (1994). Specifically, the study determined the efficiency levels of different catfish farm scales (large and small), their returns to scale and factors that determined technical efficiency.

MATERIALS AND METHODS

The study area

The Federal Republic of Nigeria (FGN) is made up of 36 States of which Anambra State is one of them. It is made up of 21 Local Government Areas (LGAs) and derives its name from the Anambra River. The 2006 estimated population of over 4 million for the State (FGN, 2006), makes it one of the most populous States in the South-Eastern geo-political zone of the country. It occupies an area of 4416 square kilometers, seventy percent of which is arable land. The State is situated on a fairly flat land with tropical vegetation. The climate is humid with substantial rainfall and mean temperature of 87°F. It has a weak soil that is easily eroded, thus accounting for over 500 erosion sites of varying depth and length (State Economic Empowerment Development Strategy (SEEDS), 2006). Fish farming and capture fisheries constitute major food fish production methods in the State with capture fisheries accounting for about 70 percent. However, recent declines in supplies from capture fisheries and encouraging government policy on agriculture have boosted the growth of the fish farming sub-sector (SEEDS, 2006).

Sampling method and data collection

A multistage random sampling technique was employed to draw samples of 256 catfish farmers for the study, however, 204 of them returned useful questionnaires. Six LGAs that shared boundaries with the Niger-Anambra river complex banks were purposely dropped. This is because they are noted for artisanal activities and lack observable evidence of serious fish farming. The multistage random sampling technique involved sampling 8 LGAs out of the remaining 15 LGAs, 4 communities from the 8 LGAs and then 8 farmers from each of the 4 communities, giving a total of 256 farmers.

Data collection was through primary sources using interview instruments, observations and memory recall. Data collection was for a production period of 12months and in this case January to December, 2009. Data were collected on socio-economic characteristics of the farmers, farm size scales, production units (concrete or earthen pond), production system (intensive or semi-intensive feeding system), water supply system (flow-through or stagnant),quantities of output and inputs (i.e. farm size, number of fingerlings stocked, labour, capital, and catfish feeds).

Analytical models

The study adopted a single step translog stochastic frontier production function model to estimate the technical efficiency levels of small and large scale catfish farms as well as the inefficiency factors. The model is specified as follows:

$$
\begin{aligned}
Ln(Y_i) = {} & \beta o + \beta_{fs}\ln(Fs_i) + \beta_l \ln(L_i) + \beta_c \ln(C_i) + \\
& \beta_f \ln(F_i) + \Psi_{fs}\ln(Fs_i)^2 + \Psi_l \ln(l_i)^2 + \Psi_c \ln(C_i)^2 + \\
& \Psi_{cf}\ln(CF_i)^2 + \Psi_{fsl}(\ln(FS)\ln(L)) + \Psi_{fsc}(\ln(FS) \\
& \ln(C)\,) + \Psi_{fsf}(\ln(FS)\ln(F)) + \Psi_{lc}(\ln(L)\ln(C)) + \\
& \Psi_{lf}(\ln(L)\ln(F)) + \Psi_{cf}(\ln(C)\ln(F) + V_i - U_i
\end{aligned}
$$

Where:

Y_i = catfish output (kg)

Fs = farm size (number of catfish seeds stocked)

L = labour (man-days)

C = capital (number of capital items-ponds, farm structure, equipments, etc)

F = catfish feeds (kg)

The technical efficiency is empirically measured by decomposing the deviation into a random component (V_i) and an inefficiency component (U_i). The technical efficiency of an individual farm-firm is defined in terms of the observed output (Y_i) to the corresponding frontier output (Y_i*) given available technology, that is:

$$TE = \frac{Y_i}{Y_i^*} = \frac{f(X_i; B_i)\exp(V_i - U_i)}{f(X_i; B_i)\exp(V_i)}$$

TE = exp ($-U_i$)

So that, $0 \leq TE \leq 1$. If TE = 1, the farm-firm is said to be technically efficient and its output is on the frontier. Otherwise, that is, if TE < 1, the firm is technically inefficient because it could have produced more outputs with the given level of inputs irrespective of input prices.
Vi = random or stochastic disturbance term which captures the effect of weather, luck, and other factors outside the control of the farmer.
Ui = farmer and farm specific characteristics related to production efficiency (technical inefficiency effects). The model for the inefficiency variables (*Ui*) is stated as:

$$Ui = \delta_0 + \delta_1 AGE + \delta_2 EDU + \delta_3 EXP + \delta_4 HOS + \delta_5 GEN + \delta_6 ACC + \delta_7 PDU + \delta_8 PDS + \delta_9 WSS + \varepsilon_i$$

Where:
AGE = farmers' age (years)
EDU = farmers' educational level (year)
EXP = farmers' farming experience (years)
HOS = household size in units
GEN = farmers' gender (dummy; male = 1; female = 0)
ACC = access to credit by farmer (dummy: accessed credit = 1; otherwise = 0)
PDU = farmers' pond type (dummy: concrete = 1; earthen = 0)
PDS = production system (dummy: intensive = 1; semiintensive = 0)
WSS = water supply system (dummy: flow-through = 1; stagnant = 0)
δ_0, δ_i = parameters that were estimated
ε_i = random disturbance term

The estimates for all the parameters of the stochastic frontier production function and the inefficiency model were simultaneously obtained using the computer programme FRONTIER 4.1 (Coelli, 1994). The output elasticities for the individual inputs were determined by running a log linear Cobb-Douglas production function. The returns to scale then became the sum of individual elasticities of farm size, labour, capital and catfish feeds.

RESULTS AND DISCUSSION

Technical efficiency distribution of catfish farmers

The distribution of technical efficiency scores among large and small scale catfish farms is shown in Table 1. Majority of the farms (i.e., 80.77% of the large farms and 97.19% of the small farms) recorded technical efficiency scores within the range of 81–100 percent. The respective mean, minimum and maximum efficiency scores for the large farms were 0.89, 0.73, and 0.99, while 0.94, 0.73 and 0.98 represented mean, minimum and maximum efficiency scores for the small farms respectively. This high degree of technical efficiency suggests that very little marketable outputs are sacrificed to resource waste. It also suggests that both the large and small scale farms are currently operating approximately on the frontier. The mean technical efficiency scores of 0.89 and 0.94 for the large catfish farms and small catfish farms respectively implies that on the average, the observed outputs of the large and small farms are 11% and 6% less than the maximum outputs which can potentially be achieved from the existing input levels. These values account for the levels of inefficiency for the 2 farm groups which can be attributed to technical production constraints, socio-economic and environmental factors.

Therefore, there exists 11% and 6% potentials for increasing output by the large and small farm groups respectively. The large farms possess higher capacity for expansion than the small farms and can achieve so by adopting improved technology and better management practices. This result corroborates Zen et al. (2002) that

Tab. 1: Distribution of catfish farmers' technical efficiency score according to farm scales

Technical efficiency range (%)	Large farms		Small farms	
	freq.	%	freq.	%
41–50	–	–	–	–
51–60	–	–	–	–
61–70	–	–	–	–
71–80	5	19.25	5	2.81
81–90	8	30.77	4	2.25
91–100	13	50.00	169	94.94
Total	26	100	178	100
Mean	0.89		0.94	
Minimum	0.73		0.73	
Maximum	0.99		0.98	

Source: Field Survey (2009)

every high level of technical efficiencies indicate that increasing production would require new innovations or a high level of technology to be introduced.

Estimated translog stochastic frontier production function

The Maximum Likelihod (ML) estimates of the stochastic frontier production function for catfish production in Anambra State, Nigeria are presented in Table 2. The log-likelihood values show that the translog function provides good fit for data from the large and small farm groups, however, none of the estimated coefficients of the factors are statistically significant. The coefficients of labour and catfish feeds, though not significant, positively influenced technical efficiency in both the large and small farm groups. On the contrary, the coefficients of farm size and capital were also not insignificant, but

Tab. 2: Estimated stochastic frontier model for catfish farm scales

Variables frontier	Parameter	Large farms		Small farms	
		coef.	T	coef.	T
Constant	βo	–0.45	–0.55	–0.39	–0.30
Ln farm size	β_{fs}	–0.22	–0.34	–1.06	–1.44
Ln labour	β_l	0.19	0.33	0.59	0.15
Ln capital	β_c	–0.72	–0.37	–0.38	–0.89
Ln catfish feeds	β_{cf}	0.41	0.56	0.18	0.31
Ln(farm size)2	ψ_{fsfs}	0.40	0.13	–8.50	–0.12
Ln(labour)2	ψ_{ll}	0.44	0.20	–1.25	–1.12
Ln(capital)2	ψ_{cc}	–0.30	–0.22	2.80	0.24
Ln(catfish feeds)2	ψ_{cfcf}	–0.60	–0.86	0.20	0.16
Ln(farm size)Ln(lab.)	ψ_{fsl}	–0.11	–0.80	2.88	0.37
Ln(farm size)Ln(cap.)	ψ_{fsc}	–0.69	–0.38	0.12	0.15
Ln(farm size)Ln(feed)	ψ_{fsf}	–0.48	–0.35	–0.18	–0.12
Ln(labour)Ln(cap.)	0.11	0.15	1.41	0.12	
Ln(labour)Ln(feed)	ψ_{lf}	0.46	0.36	–5.35	–0.50
Ln(capital)Ln(feed)	ψ	0.15	0.39	–0.13	–0.23
Efficiency					
Constant	δ	–8.53	–0.30	–0.13	–0.17
AGE	δ	36.53	0.65	–60.81	–0.13
EDU.	δ	–85.55	–0.19	91.69	0.71
EXP.	δ	90.31	0.16	1.34	0.60
HOS.	δ	–305.18	–5.36	2.74	0.10
GEN.	δ	–8.10	–0.15	0.12	0.76
ACC.	δ	–1.79	–0.87	0.29	0.16
PDU.	δ	0.22	0.34	–0.12	–0.66
PDS.	δ	6.96	0.20	–1.20	–9.18*
WSS.	δ	–9.63	–0.15	0.81	0.12
Sigma squared	$\sigma^2 = \sigma_v = \sigma_u$	41.60	0.44	3.38	0.44
Gamma	$\gamma = \sigma_{u/}\sigma^2$	0.98	0.29	0.66	0.64
Log Likelihood function	L(Hi)	0.42		0.1	

*significant P < 0.5
Source: Field survey (2009)

negatively signed. This implies that increasing labour and catfish feeds and reducing capital and farm size might not have any serious influence on productivity and output of both farm groups.

With regards to the inefficiency factors, only the coefficients of household size and production system were negatively signed and significant at 5% level of probability for both the large and small scale farms respectively. This means that large household size retarded inefficiency in large scale farms, while intensive feeding system depressed inefficiency in the small scale farms. All the other factors were not significant, however, they individually exerted either a positive or negative influence on inefficiency.

The gamma (γ) measures total variations in output from the frontier attributable to technical efficiency. The values of γ for the large and small scale farms (i.e., 0.98 and 0.66 respectively) were insignificant and positive but not significant at 5% level of probability. This suggests that 98% and 66% of the discrepancies between the observed and frontier values of output for the large and small farms respectively were due to technical inefficiencies. That is, the shortfall of realized output from the frontier was primarily due to factors within the farmers' control.

Interpretation of factor coefficients using their elasticities was also done in order to give a better picture of individual and collective influence of the factors on output and technical efficiency. Table 3 below shows the output elasticities of all the inputs and their returns to scale for the large and small scale farms.

The output elasticities of farm size were 0.307 and 0.364 for the large and small catfish farms respectively. This means that catfish output for the large and small farms increased by 0.31% and 0.36% respectively for every percent increase in farm size. The output elasticity for labour was negative for the large farms (–0.98) and positive (0.101) for the small farms. This implies that too much labour was being used by the large farms than the small farms. A 1% increase in labour led on the average to about a 0.10% increase in output of the small farms, all other inputs being held constant. Again, the output elasticities of capital and catfish feeds were positive for both the large and small farm groups. That is, holding the other 3 factors constant, a 1% increase in capital or catfish feeds led on the average to about a 0.01% and 0.02% increase in output in the case of capital or 0.72% and 0.56% increase in output in the case of catfish feeds for large and small farms respectively. These figures signify higher elastic influences on the outputs of small farms than those of large farms. Ogunbadejo et al. (2007) recorded positive output elasticities for labour and capital in their study on Labour Artisanal Fish Farming in Ogun State, Nigeria. On returns to scale, the addition of the output elasticities of the four inputs gave a figure of 1.05. This is an indication of constant returns to scale. By implication, doubling the inputs will double the output, thus placing the large and small catfish farmers at the cross-road between Stage I and Stage II of the traditional production function. This result contrasts with the increasing returns to scale posited by Ogunbadejo et al. (2007).

Tab. 3: Estimated output elasticities and returns to scale for the farm groups

Farm groups	Variable	Beta	T-statistic	Sign.	F-statistic	Sign.	R^2	R^2adj.
All large farms	Constant	0.20	1.19	0.247	150.70	0.000	0.966	0.960
Farm size	X1	0.31	3.30	0.003				
Labour	X2	–0.10	–1.82	0.083				
Capital	X3	0.01	0.09	0.933				
Catfish feeds	X4	0.72	7.30	0.000				
	RTS	1.05						
All small farms	Constant	0.11	1.57	0.119	684.04	0.003	0.941	0.989
	X1	0.36	10.84	0.000				
	X2	0.10	3.83	0.000				
	X3	0.02	0.87	0.386				
	X4	0.56	15.62	0.000				
	RTS	1.05						

RTS = Returns to scale
Source: Field Survey (2009)

CONCLUSIONS

This study examined the technical efficiency of catfish production by large and small scale catfish farms in the study area. It found that the small scale farms were technically more efficient than the large scale farms having recorded a mean technical efficiency of 0.94 which was higher than the value of 0.89 scored by the large farms. This implies that the large farms possess higher capacity for expansion than the small farms and could do so by insignificantly reducing farm size and capital and increasing labour and catfish feeds. However, a better approach could be to include equally the adoption of improved technology and better management practices in new strategies.

The output elasticities of farm size, labour, capital and catfish feeds exerted higher influences on the output of small farms than the large farms. However, returns to scale was 1.05 at par, showing constant returns to scale for the two groups of catfish farms. The large and small catfish farm groups were therefore operating at the end of Stage I of the traditional production function and approximately on the frontier. Technical efficiency in catfish production could be improved by adopting the use of quality seeds and feeds, intensive feeding method, improved technologies and better management practices.

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