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COST EFFICIENCY OF CATFISH (*CLARIAS GARIEPINUS*) PRODUCTION UNDER VARIOUS SYSTEMS IN DELTA STATE, NIGERIA

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Abstract. This study examined the cost efficiency of catfish production under different systems in Delta State, Nigeria. Primary data collected from 360 catfish farmers (comprising 121 concrete pond, 99 earthen pond and 140 plastic/tarpaulin pond systems) provided useful information for the data analysis. Descriptive statistics were used to *describe* the socioeconomic characteristics of the respondents. The stochastic cost frontier (SCF) approach was employed in analyzing the efficiency indices and their determinants. The results showed that the respondents were male dominated (64.44%), young and active, with the majority below 48 years of age. The majority of the respondents (76.67%) had a form of education that could boost their managerial abilities for catfish production. About 67.50% farmers were working full-time and 38.89% of them adopted the plastic/tarpaulin pond method because of ease of management. The average catfish weight produced was 1.50kg, and the average price per kg of mature catfish sold was NGN ₦ 722.77, with an average cost efficiency of 0.70. The study concludes that catfish production under different production systems is a cost efficient and economically viable venture, with the earthen pond method the most cost efficient (0.72). The study therefore recommends that the causes of inefficiencies should be considered and addressed so as to enhance the efficiency of catfish farmers.

Keywords: cost efficiency, production systems, *Clarias gariepinus*, farmers, stochastic cost frontier

INTRODUCTION

Fish is a global source of protein for humans and is included in the diet of some animals (Imade and Ahmadu, 2022). The importance of fish as a source of protein and food to every person cannot be overemphasized in the world today (Ajiboye et al., 2020). Given its high nutritional value, fish is an essential component of the diet of high and low income earners in Nigeria. It contains amino acids, vitamins and minerals (Yaqoob and Fasakin, 2021), and it happens to be the cheapest source of protein available to man (Imade and Ogieva, 2022). Fish production is often viewed as one of the means of increasing food production in food deficient countries like Nigeria. According to the National Bureau of Statistics, Nigeria: NBS (2021), the fishery sector constituted 1.09 percent of the national GDP in 2020 and 0.97% in the third quarter of 2021. The Nigerian Minister of Agriculture and Rural Development stated that Nigeria's total fish production is estimated at 1.123 million metric tonnes (Odioko and Becer, 2022), to which marine catches contributed 36 percent, inland water catches 33 percent and aquaculture 31 percent (FAO, 2021). Akinsorotan et al. (2019) reported that the yearly fish demand of Nigeria is about 2.1 million metric tons, with Nigeria only able to meet about 38.1 percent of this demand from domestic production and dependent on imports to cover the shortfall of about 61.9 percent. In 2021, the Nigerian Ministry of

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Agriculture and Rural Development put the fish demand of the country at 3.6 million metric tonnes, of which the country only meets about 31.19 percent, depending on imports to bridge the huge gap of about 68.80% (Vanguard, 2021). The Food and Agriculture Organization (FAO; 2021) has stated that fish remains an important dietary element for Nigerians, especially in the southern part of the country, where fish is highly valued and is one of the cheapest sources of animal protein available.

Aquaculture, popularly known as domestic fish rearing, involves the rearing of fish under controlled conditions for economic and social benefits (Imade and Egbodon, 2021). Awareness of the potential of aquaculture to contribute to the domestication of fish has continued to increase in Nigeria (Imade and Ahmadu, 2022). There, as in other parts of the world, fish farming occupies a very substantial space in the livestock subsector, as it serves as a source of income and job creation for a considerable number of people, especially in rural areas where agriculture and agriculture-related activities provide the majority of the population with their livelihood (Ajiboye et al., 2020). Many species of fish are cultivated all over the world, but catfish appears foremost due to its uniqueness (Ahmadu and Egbodion, 2017), and particularly its preference and marketability, among other qualities. The favoured cultured catfish species in Nigeria is *Clarias gariepinus*. This species is regarded as an excellent aquaculture species because it grows fast and feeds on a variety of agricultural by-products. It is hardy and can tolerate extreme temperatures (Ahmadu et al., 2021). It is easy to produce in captivity, with a high annual production capacity, has a good feed conversion rate and is healthy for human consumption. Most consumers prefer catfish to other fish species because of its low calories, low carbohydrate content, high protein content, low fat content, low bone content and fine flavor (Ahmadu and Egbodion, 2017). In addition, it is quick and easy to prepare and above all, it has a great taste. These qualities coupled with its high growth rate, its ability to feed on virtually anything and the fact that its market value is higher than those of other fish species (such as tilapia) makes the catfish the pride of most fish farmers in Nigeria (Imade and Ogieva, 2022). To meet the demand for fish, catfish production under different pond systems (concrete ponds, earthen ponds and plastic tank ponds) offers a profitable and ecologically viable alternative to the oceans-as-deserts scenario we are currently facing (Imade and Ahmadu, 2022).

Catfish has the potential to contribute to sustainable development and poverty reduction in Nigeria as a whole, and Delta State in particular by generating income and employment (Imade and Ahmadu, 2022). Thus, the production of food rich in protein such as animal sources like catfish requires efficient harnessing of all production resources. This study therefore examines the application of a stochastic cost frontier (SCF) to catfish production systems with a view to estimating the cost efficiency of catfish production systems in Delta State of Nigeria. The specific objectives of the study are to describe the socio-economic characteristics of the catfish farmers, estimate the cost efficiency level of catfish production systems and identify the factors influencing the cost inefficiency of the farmers in Delta State, Nigeria.

MATERIALS AND METHODS

Delta State, Nigeria lies roughly between longitudes 05° 00' and 06° 45' east of the Greenwich Meridian and latitudes 05° 00' and 06° 30' north of the Equator (Imade and Egbodon, 2021). It covers a total land area of 17,698km^2 with a projected population in 2016 of 5,663,400 people (Imade and Egbodon, 2021). The State consists of twenty-five Local Government Areas (LGAs) which are grouped into the Delta North, Delta Central and Delta South Agricultural Zones by the Delta State Agricultural Development Programme (ADP). The state has a wide coastal belt interlaced with rivulets and streams, which form part of the Niger Delta. The State is blessed with freshwater swamp and other coastline areas that are suitable for fish farmers (Imade and Egbodon, 2021).

The study population consisted of catfish farmers from the three Agricultural Zones in Delta State. A multistage sampling procedure was carried out for the study using structured questionnaires (Imade and Ahmadu, 2022). Purposive sampling of two LGAs from each of the three Agricultural Zones was carried out. The identification of catfish farmers in the LGAs was achieved using a snowball sampling technique that resulted in a population of 372 catfish farmers. However, a total of 360 farmers (comprising 121 catfish farmers using concrete ponds, 99 catfish farmers using earthen ponds and 140 catfish farmers using plastic/tarpaulin pond systems) provided useful information for data analysis. The quantities of inputs used and the socio-economic characteristics of the catfish farmers form the data used for the study.

The data collected were analyzed using descriptive statistics and the Maximum Likelihood Estimates (MLE) of the Stochastic Cost Frontier (SCF).

The descriptive statistics adopted include means, frequency distributions, percentages and standard deviations in tables.

Cost efficiency was achieved using the stochastic cost frontier (Imade and Ogieva, 2022).

The Cobb-Douglas Stochastic Cost Frontier is implicitly specified as:

$$C = f(Q,\beta) + v_i + u_i \quad (1)$$
$$C = \beta Q + v_i + u_i \; i = 1, 2 \ldots n$$

The estimated cost frontier is represented implicitly in log form as:

$$LnC_i = LnC(Y_i, \mathrm{P}_i, \beta) + \varepsilon \quad (2)$$

where:

C_i – the observed cost of the farm i
Y_i – the output vector
P_i – the vector of input prices
B – the vector of parameters to be estimated
$LnC(Y_i, P_i, \beta)$ – the logarithm of the predicted costs of the farm that minimizes production costs
ε_i – the random error term.
$\varepsilon = V + U$.

The Stochastic Cost function was estimated using the log linear form explicitly specified as:

$$LnC_i = \delta_0 + \delta_1 LnQ_i + \delta_2 LnSC_i + \delta_3 LnFC_i + \delta_4 LnLC_i + \delta_5 LnCF_i + \delta_6 LnMC_i + \delta_7 LnTC_i + \delta_8 LnEC_i + \delta_9 LnUL_i + \delta_{10} LnRP_i + (V_i + U_i) \quad (3)$$

where:

subscript i – denotes the i^{th} farmer
C – total cost incurred in catfish production per production cycle (Naira)
Q – output of catfish farm per production cycle (Naira)
SC – unit cost of catfish seed stocking (Naira)
FC – unit cost of fertilizer used (Naira)
LC – unit cost of lime used (Naira)
CF – unit cost of feed consumed by the catfish (Naira)
MC – unit cost of medication used (Naira)
TC – unit cost of transportation used (Naira)
EC – unit cost of energy used (Naira)
UL – unit cost of labour used per day (Naira)
RP – rent on pond used for catfish production (Naira)
δ_o – constant term
δ_i (i = 1….6) are the parameters or regression coefficients estimated in the production function with respect to inputs used
Ln – natural logarithm
V – normally distributed random error term
U – inefficiency component with a half-normal distribution.

The factors affecting the inefficiency of the catfish farmers were estimated using the Inefficiency Model (Imade and Ogieva, 2022).

The inefficiency model is presented as:

$$U_i = \gamma Z_i + \mu \quad (4)$$

where:

U_i – technical inefficiency effect
Z_i – explanatory variables
γ – unknown vector of coefficients
μ – random variable.

The inefficiency model used for this estimation is expressed as:

$$U = \gamma_0 + \gamma_1 Z_1 + \gamma_2 Z_2 + \gamma_3 Z_3 + \gamma_4 Z_4 + \gamma_5 Z_5 + \gamma_6 Z_6 + \gamma_7 Z_7 + \mu \quad (5)$$

where:

U – is the inefficiency index
γ_o – intercept (constant)
Z_1 – age of the catfish farmers (years)
Z_2 – household size (i.e. number of persons residing in the farmers' household)
Z_3 – educational status (years)
Z_4 – catfish production experience (years)
Z_5 – number of ponds used by the catfish farmers
Z_6 – mortality of catfish of the catfish farmers
μ – random (error) term.

RESULTS AND DISCUSSION

Socio-economic characteristics of catfish farmers

The results from table 1 show male dominance (64.44%), a relatively young age distribution (24–59 years, accounting for the ages of 95% of the catfish farmers), high levels of literacy, and a tendency for farmers to operate on a full-time basis (67.50%) with land they have purchased (43.06%), having accumulated an average

Table 1. Socio-economic characteristics of catfish farmers in Delta State

Variables	Delta South		Delta Central		Delta North		Total	
	freq. (120)	% (100)	freq. (120)	% (100)	freq. (120)	% (100)	freq. (360)	% (100)
1	2	3	4	5	6	7	8	9
Sex								
Male	90	75.00	82	68.33	60	50.00	232	64.44
Female	30	25.00	38	31.67	60	50.00	128	35.56
Age (years)								
24–35	29	24.17	28	23.33	46	38.33	103	28.89
36–47	61	50.83	73	60.83	41	34.17	175	48.61
48–59	25	20.83	16	13.33	23	19.17	64	17.50
60–71	5	4.17	3	2.51	10	8.33	18	5
Mean	40.01		39.08		39.14		39.11	
Std. dev.	7.47		7.50		7.84		7.86	
Marital status								
Single	17	14.17	22	18.33	19	15.83	58	16.11
Married	98	81.67	90	75.00	72	60.00	260	72.22
Separated	2	1.67	8	6.67	10	8.33	20	5.56
Widow	–	–	–	–	5	4.17	5	1.39
Divorce	3	3.49	–	–	14	11.67	17	4.72
Household size								
1–4	64	53.33	21	17.50	41	49.17	114	31.67
5–8	52	43.33	90	75.00	59	34.16	213	59.17
9–12	4	3.34	9	7.50	20	16.67	33	9.16
Mean	4		5		5		5	
Level of education								
Non-formal	23	19.17	22	18.33	39	32.50	84	23.33
Primary	4	3.33	12	10.00	10	8.33	14	3.89
Secondary	12	10.00	18	15.00	15	12.50	25	6.94
Tertiary	81	67.50	68	56.67	56	46.67	237	65.84
Nature of catfish production								
Part-time	45	37.50	40	33.33	32	26.67	117	32.50
Full-time	75	62.50	80	66.67	88	73.33	243	67.50
Production experience								
1–7	72	60.00	74	61.67	19	15.83	165	45.83
8–14	43	35.83	37	30.83	81	67.50	161	44.72
15–21	5	4.17	9	7.50	20	16.67	34	9.45
Mean	7		6		8		7	
Std. dev.	3.35		2.54		3.21		3.33	

Table 1 – cont.

1	2	3	4	5	6	7	8	9
Source of finance								
Personal savings	70	58.33	84	70.00	66	55.00	220	61.11
Credit/loan	28	23.33	31	25.83	42	35.00	101	28.06
Government agency	22	18.34	5	4.17	12	10.00	39	10.83
Farm land acquisition								
Communal	24	20.00	7	5.83	17	14.17	48	13.33
Family	58	48.33	31	25.83	54	45.00	143	39.72
Lease/Rent	2	1.67	11	9.17	1	0.83	14	3.89
Purchase	36	30.00	71	59.17	48	40.00	155	43.06
Pond type								
Earthen	34	28.33	34	28.33	31	25.83	99	27.50
Concrete	41	34.17	38	31.67	42	35.00	121	33.61
Plastic/Tarpaulin	45	37.50	48	40.00	47	39.17	140	38.89
Stocking stage								
Fingerlings	8	6.67	–	–	67	55.83	75	20.83
Juvenile	84	70.00	120	100.00	50	41.67	254	70.56
Post Juvenile	28	23.33	–	–	3	2.50	31	8.61
Feed type								
Imported	4	3.33	–	–	3	2.50	7	1.94
Local	95	79.17	106	88.33	97	80.83	298	82.78
Midst	21	17.50	14	11.67	20	16.67	55	15.28
Labour type								
Family	29	24.17	21	17.50	12	10.00	62	17.22
Hired	21	17.50	21	17.50	38	31.67	80	22.22
Both	70	58.33	78	65.00	70	58.33	218	60.56
Water source								
River	33	27.50	22	18.33	35	29.17	90	25.00
Borehole	87	72.50	98	81.67	85	70.83	270	75.00

Source: computed from field survey, 2021.

of 7 years' production experience. The majority of the farmers funded their production from their personal savings (61.11%). It was most common for them to use plastic/tarpaulin ponds (38.89%) and stock more fish at the juvenile stage (70.56%). The results further show that most farmers used locally formulated feed (82.78%) for their catfish, depended heavily on both family and hired labour (60.56%) and used boreholes (75.00%) as their major water source.

Average quantities of inputs and output of catfish production

The results presented in table 2 show that Delta North had the highest average feed quantity (0.73kg per cycle per kg fish) while Delta South had the lowest fertilizer quantity (0.19 kg per cycle per kg fish) for catfish produced in the study area. The average number of catfish produced was 4594.99, with an average catfish weight of 1.50 kg, and the output quantity produced was

Table 2. Input-output quantity distributions per cycle of farmers in Delta State

Variables	Delta State (Mean)			
	Delta South (120)	Delta Central (120)	Delta North (120)	Total (360)
Inputs				
Feed quantity /kg of catfish	0.72	0.69	0.73	0.72
Labour used/kg of catfish	0.002	0.002	0.002	0.002
Fertilizer quantity/kg of catfish	0.19	0.20	0.21	0.20
Outputs				
Average number of catfish/farmer	4 464.89	4 844.23	4 485.72	4 594.99
Average weight/catfish (kg)	1.47	1.57	1.45	1.50
Pond size(M^2)/farmer	627.50	655.83	605.28	629.63
Output (kg)	6 563.39	7 605.44	6 504.30	6 892.48
Price/kg of mature catfish	740.83	730.28	696.91	722.77

Source: computed from field survey, 2021.

6892.48 kg per cycle per 629.63 m^2 of pond. As recorded in Table 2, the average price per kg of mature catfish was NGN ₦ 722.77 in the study area.

Stochastic Cost Function (SCF) for Catfish Production

The result of the maximum likelihood estimates (MLE) function of cost efficiency for catfish production by various production systems in Delta State is presented in Table 3. The results showed significant and positively signed cost inputs, including "stocking unit cost, fertilizer cost, feeding cost, medication cost, transportation cost, energy cost, labour cost and rent on pond," for catfish production across the production systems in the State. The lime cost was also positive but was not a significant determinant of catfish production cost. The catfish output quantity, on the other hand, had a negative influence on the cost of production for the production systems under study.

Level of cost efficiency of catfish farmers

As shown in Table 4, more than 90% of the catfish farmers in the study area had a cost efficiency in the range 0.63–0.76, with an average cost efficiency of 0.70. This implies a cost efficiency gap of 30% that could be bridged by the farmers if the supply and prices of inputs were addressed.

Table 3. Maximum Likelihood Estimates (MLE) cost function for catfish production in Delta State

Variables	Earthen pond	Concrete pond	Plastic/T. pond	Total
	coefficient (standard error)			
1	2	3	4	5
Constant	0.613 (0.365)	0.909 (0.241)	1.387*** (0.273)	0.472*** (0.070)
Output	–0.032*** (0.043)	–0.044*** (0.003)	–0.062*** (0.035)	–0.003*** (0.009)
Stocking unit cost	0.046*** (0.004)	0.034*** (0.003)	0.039*** (0.003)	0.037*** (0.002)
Fertilizer cost used	0.073*** (0.023)	0.077** (0.034)	0.029** (0.020)	0.073*** (0.005)
Lime cost used	0.035 (0.027)	0.031 (0.011)	0.007 (0.029)	0.002 (0.007)
Feeding cost used	0.848*** (0.024)	0.844*** (0.005)	0.859*** (0.006)	0.883*** (0.004)
Medication cost used	0.008* (0.006)	0.006* (0.001)	0.004* (0.004)	0.002* (0.001)
Transportation cost	0.006* (0.004)	0.002* (0.001)	0.002* (0.003)	0.002* (0.001)

Table 3 – cont.

1	2	3	4	5
Energy cost used	0.001* (0.006)	0.012** (0.0001)	0.001** (0.006)	0.003** (0.002)
Labour cost used	0.004*** (0.002)	0.006*** (0.001)	0.003*** (0.004)	0.001*** (0.001)
Rent on pond used	0.048*** (0.004)	0.094** (0.008)	0.059** (0.006)	0.083*** (0.014)
Sigma squared (σ^2)	0.316	0.328	0.315	0.312
Gamma (γ)	0.964	0.903	0.980	0.963
Log likelihood	230.574	324.588	71.181	916.596
Wald $Chi^2(6)$	12 320.09	17 417.62	42 172.30	400 096.72
Prob>chi^2	0.000	0.000	0.000	0.000

***Significant at 1%, **Significant at 5%, *Significant at 10%.
Source: computed from field survey, 2021.

Table 4. Cost efficiency distribution for catfish farmers by production systems

Class	Earthen pond		Concrete pond		Plastic/ T. pond		Total	
	freq.	%	freq.	%	freq.	%	freq.	%
0.49–0.62	5	4.95	7	5.56	20	14.52	32	8.89
0.63–0.76	94	95.05	114	94.44	120	85.48	328	91.11
Total	99	100	121	100	140	100	360	100
Cost eff mean	0.72		0.70		0.66		0.70	

Source: computed from field survey, 2021.

Cost inefficiency parameters of catfish farmers in Delta State

The inefficiency parameters of catfish farmers are presented in Table 5. All the variables were found to have significant effects on the farmers' cost function inefficiency. Only the age and mortality of the catfish were positively and significantly related to the inefficiency at the 1% significance level, while household size, educational level, production experience and the number of ponds used were negative and significant determinants of the farmers' inefficiency.

Table 5. Inefficiency parameters of catfish farmers by production systems in Delta State

Variables	Earthen pond	Concrete pond	Plastic/T. pond	Total
	coefficient (standard error)			
Inefficiency model				
Constant	5.010 (6.415)	–3.964*** (0.832)	8.599 (43.027)	–5.852*** (0.760)
Age	0.587** (0.255)	0.009** (0.021)	1.835** (1.730)	0.034** (0.016)
Household size	–0.130** (0.457)	–0.055** (0.083)	–1.201** (1.609)	–0.123** (0.059)
Educational levels	–0.134*** (0.209)	–0.117*** (0.025)	–0.097*** (0.807)	–0.005*** (0.023)
Production experience	–0.780*** (0.394)	–0.058*** (0.049)	–4.130*** (4.067)	–0.096*** (0.023)
Number of ponds	–0.227*** (0.146)	–0.121** (0.018)	–0.017* (0.071)	–0.362*** (0.142)
Mortality of catfish	0.007*** (0.002)	0.159*** (0.312)	0.005*** (0.002)	0.049*** (0.005)

***Significant at 1%, **Significant at 5%, *Significant at 10%.
Source: computed from field survey, 2021.

CONCLUSIONS

Catfish production under different production systems was a male-dominated enterprise, and this agrees with the findings of Ajiboye et al. (2020), who stated that catfish production is strenuous and requires physical strength. The relatively younger farmers, over 70% of whom were married and had received some form of education, confirmed the findings of Ahmadu et al. (2021) and Olajide and Omonona (2019) that this more literate age group can contribute meaningfully to the development of catfish production in the study area. Over 60% of the respondents were involved in full-time catfish production, used purchased land and relied on their personal savings. These results affirm the findings of Yaqoob and Fasakin (2021) and Michael & Duru (2020) that farming is a major occupation for self-reliance and income generation. Among the various types of pond culture systems (concrete, earthen and plastic/tarpaulin pond systems) used for catfish production in the study area, plastic/tarpaulin ponds (38.89%) was preferred, which agrees with the findings of Imade and Egbodon (2021).

The major inputs used were feed, labour and fertilizer, and the average weight of catfish was 1.50 kg. The average selling price per kg of mature catfish was NGN ₦ 722.77, and this corroborates the findings of Imade and Ogieva (2022), who concluded that catfish farming was profitable. In terms of efficiency, the effects of the majority of the cost inputs used for production were positive and significant. Catfish production was found to be cost efficient, with an average cost efficiency of 0.70. This is corroborated by similar efficiency studies by Olagunju (2020) and Imade and Ogieva (2022), who found that catfish production was cost efficient and profitable if all the necessary inputs were assured.

The study concluded that catfish production under all the production systems considered was a cost efficient and economically viable venture, with the earthen pond method (0.72) being the most cost efficient. The study therefore recommends that more women should be encouraged to participate in catfish production. The policy focus of the Government on youths, who are more efficient than older farmers, should be strengthened. Unemployed youths and potential investors should be encouraged to engage in catfish production since it is cost efficient and economically viable. Government, private and non-governmental organizations, as well as financial institutions, should be encouraged to provide accessible financial support to catfish farmers at affordable rates so as to increase their productivity.

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