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Technical Efficiency of Non-Integrated Aquaculture Farms in Rivers State, Nigeria: A Stochastic Frontier Production Function

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Abstract

Underutilization and overutilization of inputs is a major problem in aquaculture production in Nigeria. Hence, resource use efficiency is critical to aquaculture production. The study examined the technical efficiency of non-integrated aquaculture farms in Rivers State, Nigeria using a stochastic frontier production function. The non-integrated fish farmers buy feeds and fingerlings outside their farm to produce table fish while the integrated fish farmers produced feeds and fingerlings that were used on their farms. Several stages of sampling were adopted which resulted in the selection of 119 non-integrated aquaculture farms used. Primary data were collected using a structured questionnaire and interview schedule. Descriptive statistics such as frequency as well as stochastics frontier production function was used. The findings showed that the technical efficiency of the non-integrated aquaculture farms range from 88-98% with a mean of 93%. This shows that the fish farmers still need 7% increases in productivity to achieve 100% efficiency. Stock size, feed, fertilizer, water, and labour were found to have positive coefficients meaning that they have direct relationship with the output of fish among non-integrated aquaculture farmers while pond size, fingerlings, lime and depreciation cost were found to have negative coefficients meaning that they have indirect relationship with the yield of fish. Age and educational level of the farmers negatively affect technical inefficiency. It was therefore suggested that non-integrated aquaculture farms can be increased by adding more stock size, feed, fertilizer, water and labour during aquaculture production.

Key words: Non-integrated aquaculture, Stochastic frontier production model, Sustainable resource management, Technical efficiency

1.0 Introduction

Fish is important as it provides the human body with animal protein that is low in fat for healthy growth. In mature production, activities like fingerling and feed production, processing, and drying were involved. Based on these activities, we have full integration, partial integration and non-integration aquaculture production. The full integration fish farmers produced feeds and fingerlings. In partial integration, the firm producing fingerlings buys feeds from another farm which is used in the production of mature fish. The non-integration farms buy all the feeds and fingerlings used in mature fish production from sister farms (Dobashi *et al.*, 1999). In Nigeria, the output of aquaculture is inadequate and this may not be unconnected with the inefficiency of the fish farmers (Onoja and Achike, 2011; Ideba *et al.,* 2013; Olasunkanmi and Yusuf, 2014). There exist differences in efficiency and fish price between integrated and non-integrated farms. According to Benson (2018), fish production in Rivers State, Nigeria, where resources such as pond size, stock size, fingerlings, labour, fertilizer, lime, depreciation cost, feed and water were used, and the cost of mature fish was sold at 477.74 Nigerian naira by the non-integrated fish farmers against 314.65 naira among the full integration fish farmers because of inefficient use of resources.

Five types of efficiency exist namely; economic, technical, allocative, marketing and managerial efficiency (Battese and Coelli, 1995). For the purpose of agricultural production, Farrel (1957) made use of three types of efficiency namely; economic, allocative and technical efficiency to measure the efficiency measures. Economic efficiency is the term used to describe the overall efficiency allocative and technical efficiency being its component parts. Allocative efficiency (price efficiency) refers to the adjustment of inputs and outputs to reflect relative prices (price efficiency) under a given technology (Ellis, 1988). Alternatively, it can be stated as the willingness and ability of an economic unit to equate its marginal cost (MC) (Kalirajan and Shand, 1999). Technical efficiency is defined as the maximization of the ratio output to input, given a range of alternative technologies available without taking into consideration the prices (Arene and Okpukpara, 2006). Olasunkanmi and Yusuf (2014) stated that in Rivers State, Nigeria, resource use efficiency is very important in aquaculture production. The output of aquaculture is inadequate and this may not be unconnected with the low efficiency of the aquaculture farms (Onoja and Achike, 2011).

The specific objectives of this study were to:

(i) describe the socio-economic characteristics of non-integrated aquaculture farmers in Rivers State, Nigeria, and
(ii) estimate the technical efficiency of non-integrated aquaculture farms.

There is hope that the result will help in improving and also solve the falling efficiency of non-integrated aquaculture farms (Orewa and Izekor,2012).

2.0 Materials and Methods

2.1 Description of the Study Area

The work was carried out in Rivers State which is located in the South-South geopolitical zone of Nigeria and therefore has great potential for sustainable aquaculture development (Anyanwu *et al*,2007). Its geographical coordinates are 4°47'22" North and 6°59'55" East. The land mass is about 11, 077km^2 with a number of 7, 492, 366 people (National Population Commission, 2023). Rivers State comprises 23 Local Government Areas. Majority of the fish farmers are males (age range of 41-50 years) and use concrete fish tanks for aquaculture farms. The total mean annual production of cultured fish is about 41,000 metric tons (Ibemere and Ezeano, 2014). Most of the fish farmers sourced their fingerlings from government hatchery and few oil companies like Nigeria Agip Oil Company (Agip), Total Exploration and Production (Elf) and Shell Petroleum Development Company of Nigeria Limited (SPDC) also provide fingelings as part of their corporate social responsibility to host communities. The water used for fish production is obtained from bore holes. Most information concerning fish farming is obtained from friends/fellow farmers (Ibemere and Ezeano, 2014). Aquaculture production in Rivers State is affected mostly by high cost of inputs, especially feeds and irregular electricity which affect water supply. Other factors that are impediment to aquaculture production in the Rivers State include cannibalism, losses to bird predation, the incidence of infectious disease/pest, poaching/theft, flooding during the rainy season, market price fluctuation, preservation/storage/processing problem and poor finance (Olasunkanmi and Yusuf, 2014, Ibemere and Ezeano, 2014).

2.2 Sampling Procedure

The list of aquaculture farms were obtained from the Rivers State Agricultural Development Programme. The list was divided into integrated aquaculture farms and non -integrated aquaculture farms (Dobashi *et al.,* 1999). The population of study comprises 357 non – integrated farms in the study area. Two types of sampling were adopted to select the 119 farms. The first one involved the purposive sampling of three Agricultural Development Programme zones in Rivers State, namely: Nchia, Degema and Ahoada. The three zones have the largest number of fish farmers in the state which called for the purposive sampling. Furthermore, 7 out of 9 area offices in the study area, namely: Ahoada East, Bori, Degema, Eleme, Ikwerre, Okrika, and Rumuduomaya (Bonny and Port Harcourt offices have no list of aquaculture farms) were selected. Nchia zone is made up of Ikwerre, Okrika, Rumuduomaya, Eleme and Bori. Degema is made up of Degema alone while Ahoada is made up of Ahoada East. Lastly, 119 non – integrated aquaculture farms were selected using the random sampling technique from the 7 functional area offices in the following order: Ahoada East (30 out of 95farms), Bori (10 out of 28farms), Degema (12 out of 36 farms), Eleme (30 out of 99 farms), Ikwerre (14 out of 47 farms), Okrika (15 out of 32 farms) and Rumuduomaya (8 out of 20 farms). The list of farmers in the area offices were gotten from Port Harcourt head office and were used to visit the farmers to elicit information.

2.3 Method of Analysis

Data were analyzed using descriptive statistics and stochastic frontier production model. Yearly depreciation value of each farm asset was calculated using the straight – line method (Ebong, 2007) which is explained as follows:

$AD = (OC - SV)/UL$ ……………………………………………………………Equation 2.1

Where:

AD = Annual Depreciation

OC = Original Cost of asset at the time of purchase

SV = Salvage Value

UL= Useful Life

The model Specification for the purpose of this study is the production technology specified by the Cobb – Douglas production function as stated below:

$$LNQ = b_o + b_1 \ Ln \ X_1 + b_2LnX_2 + b_3LnX_3 + b_4 \ LnX_4 + b_5LnX_5 + b_6LnX_6 + b_7LnX_7 + b_8LnX_8 + b_9LnX_9 + V_i - U_i \quad \text{...... Equation 2.2}$$

Where:

Q = Value of fish output in naira

X_1 = Pond size of measured in square metres

X_2 = Stock size (total number of fingerlings stocked by the farmer)

X_3 = Quantity of fingerlings measured in naira

X_4 = Is the quantity of labour used in aquaculture production in man days

X_5 = Quantity of fertilizer in naira

X_6 = Quantity of lime in naira

X_7 = Depreciation cost on fixed inputs of farm in naira

X_8 = Quantity of feed in naira

X_9 = Quantity of water used in naira

Vi = Random error

Ui = Technical efficiency

The technical inefficiency model is specified using the following equation:

$$TE = \eth_o + \eth_1 \ Z_1 + \eth_2Z_2 + \eth_3Z_3 + \eth_4Z_4 + \eth_5Z_5 + \eth_6Z_6 + e_1 \quad \text{....... Equation 2.3}$$

Where:

TE = Technical efficiency of farmers

Z_1 = Age of farmers (years)

Z_2 = Experience in fish farming in years

Z_3 = Level of education of farmers

Z_4 = Frequency of contact with extension agent

Z_5 = Gender of the farmer (male = 1) (Female = 0)

Z_6 = Household size

e_i = Error term assumed to be randomly and normally distributed.

While $\eth_o$, $\eth_1$, $\eth_2$ ------------ $\eth_6$ are the parameters to be estimated

3.0 Results and Discussion

3.1 Socio-economic Characteristics of Respondents

The socio-economic characteristics of the non – integrated fish farmers were as presented in Table 3.1. The result revealed that the non-integrated fish farmers recorded more male aquaculture farmers (90.8% percent) while the female respondents were few (9.2 percent). This implies that there are more males in aquaculture production than female. The result agrees with the finding of Olawoye (2001) who observed same in Oyo State. The age distribution involved in aquaculture production were more in the range 41-50 years (60.5 percent), next ≤20-30years (21.8 percent) and 51-60 years with (8.4 percent). The age range of 31-40 years had (5.9 percent) and 61 years and above was the least (3.4 percent). The study showed that the age range of 41-50 years engaged more in non-integrated aquaculture production. This implies that at 41-50 years, any farmer has the energy to produce and can bear risk in investment. This result agrees with the finding of Bolorunduro (2003) who observed same in Niger State, Nigeria. Concerning marital status, majority of the non-integrated fish farmers were married.

This shows that aquaculture production is mostly undertaken by married men and women. This finding agreed with Ifejika and Ayanda (2005) who observed the same at the Kainji Lake Basin of Nigeria. With regard to household size, majority of the fish farmers family size were within 6-10 persons (75.6 percent), next ≤1-5 (24 .4 percent). None of the respondents agree that family size of 11 – 15 persons were engaged in aquaculture production. The finding showed that majority of the non-integrated aquaculture farms were with a family size of 6-10 persons. This shows the same result with that of Ibemere and Ezeano (2014). This implies that the existing family size is big enough to help in farm labour supply.

Concerning the experience of the fish farmers, the non-integrated respondents had ≤1-5 years' experience of (50.4 percent), next 6- 10 years' experience representing (28.6 percent), 16 and above years of experience had (12.6 percent) and 11-15 years of experience (8.4 percent). The result showed that majority of the non-integrated fish farms had ≤1-5 years' experience. Concerning the level of education, majority of the non-integrated aquaculture farms went to secondary school (79.0 percent), next is tertiary education (18.5 percent) and primary education (2.5 percent) were mostly secondary school leavers.

Table 3.1: Socio-economic characteristics of the non-integrated aquaculture farms

Characteristics	Frequency	%
Sex		
Male	108	90.8
Female	11	09.2
Age (in years)		
≤20- 30	26	21.8
31 – 40	07	05.9
41-50	72	60.5
51-60	10	08.4
61 and above	04	03.4
Marital status		
Single	04	03.4
Married	115	96.6
Family size		
≤1 -5	29	24.4
6 – 10	90	75.6
11 – 15	00	0.0
Experience (years)		
≤ 1 – 5	60	50.4
6 – 10	34	28.6
11 – 15	10	08.4
16 and above	15	12.6
Level of education		
No formal education	00	0.0
Primary	03	2.5
Secondary	94	79.0
Tertiary	22	18.5
Extension contact per month		
0	11	09.7
1	41	34.5
2	67	56.3
3	00	0.0
5	00	0.0
Main occupation		
Fishing only	98	82.4
Fishing with other jobs	21	17.6

Source: Field data (2024)

Majority of the non-integrated fish farmers in the study area were educated people with secondary and tertiary education that can easily adopt innovations. This is in agreement with the report of Ibemere and Ezeano (2014). Concerning the extension contact, most of the non-integrated aquaculture farms had extension agent who visited twice (56.3 percent), followed by those who were visited once (34.5 percent) and those not visited at all (9.7 percent). None of the respondents had three or five times of extension contact in a month. The study revealed that the non-integrated aquaculture farms had more extension contact.

Concerning the occupation, the non-integrated aquaculture farms accepted that majority (82.4 percent) of them did non-integrated fish farming only while the remaining respondents (17.6 percent) agreed that aquaculture farming was combined with other jobs. This implies that non-integrated fish farmers could be practiced on a part time basis as the business is not time consuming compared with the integrated aquaculture farming.

3.2 Distribution of Technical Efficiency of the Non-Integrated Aquaculture Farms

3.2.1 Maximum Likelihood Estimates (MLE) for Parameters of the Stochastic Frontier Production Function of Non-Integrated Aquaculture Farms

Table 3.2 reveals the Maximum Likelihood (MLE) for parameters of the stochastic frontier production functions of non-integrated aquaculture farms in Rivers State. In the table estimated parameters and related statistics tests obtained from the analysis of the non-integrated aquaculture farms. The Sigma Square (δ^2) has the value (0.00052) which is highly significant at 1% level of probability. This means that variation occurs as the technical efficiency of the non-integrated aquaculture farms is caused by 0.052% of the errors term (measurement error).

Table 3.2: Maximum Likelihood Estimates (MLE) for Parameters of the Stochastic Frontier Production Function of Non-Integrated Aquaculture Farms.

Variables	Parameters	Coefficients	T-ratios
Stochastic frontier			
Constant	β_0	0.55096	0.72316
Pond size (X1)	β_1	-0.02191	-0.89393
Stock size (X2)	β_2	0.10464	3.30042***
Fingerlings (X3)	β_3	-0.01915	-0.88779
Labour (X4)	β_4	0.01345	0.33289
Fertilizer (X5)	β_5	0.01984	0.56529
Lime (X6)	β_6	-0.00441	-0.08833
Depreciation cost (X7)	β_7	-0.00727	-0.58200
Feed (X8)	β_8	0.04140	1.05986
Water (X9)	β_9	0.01458	0.60267
Diagnostic Statistics			
Sigma-square	δ^2	0.00052	6.63927***
Gamma	γ	0.99998	9.13076***
Log (likelihold)		0.28379	
LR test		0.92537	
Sample size		119	

***Significant at % ** at 5% * 10%

Source: Field data, (2024)

Table 3.2 also revealed that the estimated of Gamma (γ) is 0.99998 which is also highly significant at 1% level of probability. This means that the 100% of the variation in output among the non-integrated aquaculture farms is due to differences in technical efficiency. This justifies the use of the stochastic frontier production function. Stock size has the estimated coefficient of 0.10464 which was positive and statistically significant at 1% level of probability. The positive coefficient indicates stock size has direct relationship with the yield of fish among non-integrated aquaculture farms in the study area. This means output of fish could be increased by stocking more fingerlings. The larger the stock size the more efficient a fish farm becomes. This agrees with the finding of Ugwumba (2010) who asserted that catfish production in Anambra State, Nigeria was positive and significantly influenced by stock size. Only stock size had a positive coefficient and significant effect. Pond size, fingerlings, labour, fertilizer, lime, depreciation cost, feed, and water were either positive or negative but not significant at any of the levels of probability stated for use.

3.2.2 Estimated Determinants of Inefficiency in Non–Integrated Aquaculture Farms

Table 3.3 reveals the estimated determinants of efficiency in fish production in non- integrated aquaculture farms in Rivers State. The Table shows resulting determinants of efficiency in fish production among the non- integrated aquaculture farmers. Inefficiency factors considered in this study were those relating to the farmers socio-economic characteristics. These factors include age, experience of fish farmers in years, education level, extension contact, gender, and household size. The sources of inefficiency were examined by using the estimated ð-coefficient associated with the explanation variables in the model of inefficiency effect. A negative sign shows that the variable increases efficiency. On the other hand, a positive sign signifies decreases in technical efficiency and increased inefficiency.

Table 3.3: Estimated determinant of inefficiency in non-integrated aquaculture farms

Variables	Parameters	Coefficients	T-ratios
Constant	δ_0	0.06991	2.31512**
Age (Z_1)	δ_1	-0.00259	8.34868***
Experience (Z_2)	δ_2	-0.00020	-0. 42878
Education (Z_3)	δ_3	-0.00417	-5.99881**
Extension contact (Z_4)	δ_4	0.00273	0.79563
Sex (Z_5)	δ_5	0.004270	0.51065
Household size (Z_6)	δ_6	-0.00197	-1.21732

***Significant at 1% ** at 5% *10%

Source: Field data, (2024)

The estimated coefficient of -0.00259 for age is negative and statistically significant at 1% level of probability. This is an indication that there is direct relationship between age and the yield of fish among non-integrated aquaculture farms in the study area. This means that most of the respondents were of the virile age bracket capable of increased productivity. The estimated coefficient of -0.00020 for farming experience is negative and not significant at the different levels of probability stated for use. The negative coefficient shows the direct relationship between farming and yield of fish. Years of experience increase the output of fish. This is in consonance with *a priori* expectations because as the farmer's experience increases, he gets used to farm production processes and techniques and hence increased technical efficiency. The result agrees with the finding of Penda *et al* (2013) who asserted that farming experience has a negative coefficient of 0.55 among the aquaculture farmers who made use of earthen ponds in Benue State, Nigeria. The estimated coefficient of -0.00417 for education is negative and statistically significant at 1% level of probability. This tell us that as educational level of the non-integrated fish culture farmers increase which was adequate, efficiency in resource use also increases while inefficiency decreases. The fact that education was significant at the 1% probability level signifies that education is a very important factor needed in the production of fish. The level of education acquired by the farmers of non-integrated aquaculture farms was enough to exert significant influence in fish production. The finding is in consonance with the report of (Kumbhakar *et al.,* 1991; Battese and Coelli, 1995; Coelli and Battese, 1996; Weir, 1999; Ebong, 2005; Ezeh *et al.,* 2012; Antia-Obong *et al.,* 2021) who asserted that farmers' education not only increase productivity but also enhances farmers' ability to understand and evaluate new production techniques. Extension contact coefficient of 0.00273 is positive and not significant at all levels of probability stated for use. This is an indication that extension contact was over utilized. This result agrees with the finding of Ezeh *et al.* (2012) and Penda *et al.* (2013) who asserted that extension contact has a positive coefficient among the farmers using earthen ponds in catfish production in Benue State, Nigeria. The estimated coefficient of 0.00426 is positive and not significant at all levels of probability stated for use. This is an indication that gender is not an important factor in fish production in the study area. The male as well as the female could produce fish on equal basis. Whereas the estimated coefficient of household size is -0.00197 which is negative and not significant at all the levels of probability stated for use. This is an indication that household size has a direct relationship with the output of fish among the non-integrated fish culture farms in the study area. This is in consonance with *a priori* expectations that large family size eases labour constraint leading to increase in productivity and income.

3.2.3 Distribution of Technical Efficiency of Non-integrated Aquaculture Farms

Table 3.4 shows the distribution of technical efficiency of the non-integrated aquaculture farms in Rivers State. The table reveals the frequency distribution of technical efficiency of the non-integrated aquaculture in the study area. The result shows that all the sample fish farmers were efficient in the use of their resources since a farm is termed efficient from the indices of 0.50 while 0.88 was the minimum obtained as indicated in Table 3.4.

Table 3.4: Distribution of technical efficiency of non-integrated aquaculture farms

Technical Efficiency Range	Frequency	Percentage
0.85 – 0.88	1	0.84
0.89 – 0.92	45	37.82
0.93 – 0.96	62	52.10
0.97 - 1.00	11	9.24
Total	119	100.00
Mean Efficiency = 0.93		
Minimum Efficiency = 0.88		
Maximum Efficiency = 0.98		

Source: Field data, (2024)

The mean technical efficiency (0.93) for the aquaculture farms is very high. This implies that considering the mean, the aquaculture farms get 93% yield from a given mix of production inputs. Within a short -time there is hope that the aquaculture farmers can increase output by 0.07% by adopting the techniques and technologies employed by the best non-integrated aquaculture farms. There exists a narrow gap between the "maximum" the most technically efficient aquaculture farm (0.98) and the "mean" aquaculture farm (0.93). The non-integrated aquaculture farms had more than 61% of the farms with indices of 0.93 – 1.00 above the mean efficiency. The result reveals that more than 99% of the non-integrated fish farmers were efficient given a least efficiency of a farm as 0.50 (Ebong, 2005).

4.0 Conclusion and Recommendations

The technical efficiency of non-integrated aquaculture farms in Rivers State range from 88-98% with the mean of 93%. The study showed that only stock size had a significant effect, as stocking of more fingerlings could lead to increase in yield of non-integrated aquaculture farms. Age and level of education were the socio-economic characteristics with significant and negative effect on farmers' technical inefficiency. Most of the respondents have maximum efficiency level of 93% but still need 7% increases in productivity to achieve 100% technical efficiency. The non-integrated aquaculture farms are therefore technically efficient. It was therefore recommended that technical efficiency of non-integrated farms can be attained by addressing the factors found to be responsible for the inefficiency.

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