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A Comparative Analysis of the Technical Efficiency of Artisanal Fishermen affected by Oil Spill and Non-oil Spillage in Bayelsa State

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ABSTRACT: This study examined the productivity and technical efficiency of artisanal fisherman in Bayelsa State who produce in waterways affected by both crude and non-crude oil spills. The study included 200 respondents (100 from crude oil spilled areas and 100 from non-crude oil spilled areas) chosen through a multistage selection procedure using a questionnaire. The acquired data was analyzed using descriptive statistics and the Cobb-Douglas stochastic frontier production function. The study's main findings were that men made up the majority of respondents (77% in both locations tested), 55% and 56% were recorded as being between the ages of 45 and 55, and 60% had completed their secondary education. In all areas, the mean years of experience ranged from 25.4 to 26.2, and the respondents' average household size was six. Significant factors influencing productivity included labour, household size, educational attainment, fishing experience, and fish processing ($p < 0.05$). Among them, labour, bait, and boat repairs were all negative for the crude oil spill area. Bait, boat repair, and labour were positively correlated in the non-crude oil spilled area. However, educational attainment, household size, and fishing experience were statistically significant at the $p<0.05$ level. The study also found that none of the artisanal fishing households attained 100% technical efficiency. All of them performed with varied degrees of efficiency. The mean, minimum, and maximum efficiency levels in places where crude oil has been spilled are 0.97, 0.80, and 1.0, respectively; in non-crude oil spilled areas, the equivalent values are 0.83, 0.00, and 1.0. The main barriers to artisanal fishing in areas affected by crude oil spills were water pollution, fish deterioration, a lack of extension services, and health concerns. This study suggests that in order to mitigate the issues and promote artisanal fishing for sustainability, government agencies, private citizens, and cooperative bodies should develop policies that improve respondent education through an enhanced extension service, thereby increasing output and making the practice more lucrative.

Keywords: Technical efficiency, artisanal fishermen, oil-spill, non-oil-spilled, Bayelsa

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INTRODUCTION

The business environment is an important factor in production. In addition to the business environment in which production occurs, technical measures of entrepreneur efficiency and producer skill in allocating limited resources also have an impact on productivity. The study considered in this paper compares the technical efficiency of the artisanal fishermen in the oil-rich riverine environment of Bayelsa State. A comparison is made between those operating in waterways affected by oil pollution and those not affected by oil pollution. Most of the inland waterway fishing in Bayelsa State is done by artisanal fishermen, who are distinguished by their low capital, small-scale fishing methods, and use of local gear like nets, hooks, small canoes, cast nets, landlines, basket traps, longlines, set gill nets, and purse seines (Garcia, 2009). Their catches, such as fish, crayfish, periwinkles, oysters, etc., are usually (in most cases) not processed and are mainly for local consumption. Bayelsa State is home to numerous waterways that provide much of the population with a living through fishing and other activities. Crude oil exploitation by oil-producing industries has affected most waterways and rivers where artisanal fishermen carry on their business activities to provide for their immediate family and income. According to Kabiamowei and Ajibola (2017), oil operations in Bayelsa hurt the environment and the lives of the host communities. These effects include reduced economic activity and water contamination.

This study is being done because artisanal fishermen need to have the technical know-how to deal with the problems caused by oil spills in the water if they want to continue in business. According to Greene (1993), an entrepreneur's technical efficiency can be determined by comparing his actual production to a potential or ideal production. The specific technical efficiency of a firm is determined by the deviations of observed outputs from the best or most efficient production frontier. The ability of a fisherman to produce the most output given a set of inputs and production technology is known as technical efficiency, according to Anang et al. (2016). Additionally, they mentioned that a firm's output could differ and fall short of the production frontier, which is the maximum output. According to Otitoju (2008), technical efficiency refers to a fisherman's capacity to use the best production techniques to ensure that more input is not used than is necessary to produce the highest output quality. According to Norman (1982), variations in a firm's technical efficiency can be attributed to a variety of non-technical factors as well as managerial skill, the use of varying degrees of technology, and environmental circumstances.

According to Heady (1960), technical efficiency can be improved through improved production techniques. This could suggest that, as production technology advances, factor proportions will change because of substitution under a particular technology. This denotes a shift in the process of production itself, whereby an increase in technology and production techniques are combined to produce more with the same amount of resources, or whereby an increase in production volume is achieved with fewer resources than previously. There are various procedures used in measuring technical efficiency and productivity. Examples include the Cobb-Douglas production function, data envelopment analysis (DEA), total factor productivity indices (TEPI), least squares econometric production models (LSEPM), and stochastic frontier production function (SFPF) (Ogundari, 2006). According to Ajibefun (2008), SFPF analysis and DEA became the most used methods, with SFPF being the most preferred. The main reason SFPF is so widely used is that it considers the measurement of errors and other noise in data. SFPF is based on Farrell (1957) concept of efficiency. Farnsworth (2015) added that the SFPF is the basic theory behind the econometric estimation of technical efficiency and developed the basic stochastic frontier analysis (SFA) model.

Previous empirical studies on production efficiency examined the technical efficiency of fish farming using the stochastic frontier production function; Dey et al. (2000) discovered a mean technical efficiency of 83% among tilapia grow-out operations in ponds in the Philippines, and that total farm area, education, and farmer age are some of the factors influencing technical efficiency. The mean technical efficiency of small-scale fish production in the West Tripura district of India was found to be 66% by Singh et al. (2009) using the stochastic production frontier approach. They also found that an important factor influencing technical efficiency was seed quality. The mean technical efficiency for tilapia fish in Ghana was found by Essifile and Crentsil (2014) to be 73.8%. The fish output was positively influenced by labour, fingerlings, type of feed, and regional location; on the other hand, inefficiency was negatively impacted by formal education level, marital status, membership in fish farmer groups, and extension contacts. Applying the translog stochastic frontier, Mussa et al. (2020) discovered that the factors influencing tilapia output in Malawi were farm size, fertilizer input, and seed, with a mean technical efficiency of 66%. The primary factors that impact the level of efficiency among tilapia producers are the gender of the producer, their age, the size of their household, their access to credit, training, and extension.

This study was therefore carried out to attain the following objectives: describe the socio-economic characteristics of the artisanal fishermen in crude oil spilled and non-oil spilled areas; determine the level of technical efficiency of the artisanal fishermen in both areas and determine the factors that affect the technical efficiency of the artisanal fishermen in both areas.

MATERIALS AND METHODS

The study area was Bayelsa State, located in the core of the Niger Delta region. It has a projected population of 2,278,000 people using an annual growth rate of 2.91% per year (National Population Commission (NPC), 2006). There are eight local government areas (LGAs) in Bayelsa State, which include Brass, Ekeremor, Southern Ijaw, Kolokuma/Opokuma, Nembe, Ogbia, Sagbama and Yenagoa LGAs. The area has a riverine and estuarine setting with bodies of water within the state. In addition to being the economic activities of the region, the petroleum industry, farming, fishing, tapping palm wine, and producing local gin dominate the state's economy.

A multistage random sampling technique was used to select 200 artisanal fishermen (100 from oil spilled areas and 100 from non-crude oil spilled areas) for the study. At stage I, four local government areas—Southern Ijaw, Brass, Yenagoa, and Ogbia—were purposefully selected because of their incessant crude oil spillage. At stage II, the four local government areas were stratified into crude oil-spilled and non-spilled areas. At stage III, five communities were purposely selected from the four LGAs to arrive at 20 communities. In stage IV, a total of 200 artisanal fishing households were sampled, with 10 fishing households randomly selected from each community based on areas where crude oil had spilled and those that had not.

Stochastic Frontier production function

The stochastic frontier production function model of the Cobb-Douglas functional form was employed to estimate the artisanal household technical and resource use efficiencies and determine relevant factors affecting artisanal fishing in the study area. The Cobb-Douglas functional form was chosen because it is frequently used to calculate factors and farm productivity in both developed and developing nations. The functional form meets the requirement of being self-dual, allowing an examination of economic efficiency (Kopp and Smith, 1980). The Cobb-Douglas production functional form which specifies the production technology of the ith artisanal household, is expressed as follows:

$Y_i = X_i\beta_i + (V_i - U_i)$

Where:
Y_i = output of the ith fishing household
X_i = a vector of input quantities of the ith fishing household
β_i = a vector unknown parameter to be estimated
V_i = a random variable that is independent and identically distributed with zero mean and constant variance, $(0, \delta^2)$
U_i = a non-negative random variable, called the inefficiency effect which is independent of V_i

The Cobb-Douglas functional form for artisanal households will be employed in this study. It is stated explicitly as:

$Ln\ Y = \beta_o + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 LnX_4 + Vi - Ui$

Where:

Y = Quantity of fish caught (kg)
X_1 = Labour used per household head/week (man-days)
X_2 = Baits used in fishing (kg)
X_3 = fish processing (kg)
X_4 = crude oil spillage (dummy, crude oil spillage =1, otherwise = 0).
β_0 = constant
β_1-β_4= estimated coefficients of the explanatory variables Xi
Ln =natural logarithm
V_i = random error due to statistical noise
U_i = randomness (technical inefficiency) due to the farmer's socio-economic characteristics (has ahalf-normal or exponential distribution) (Battese and Coelli (1995).

The Cobb-Douglas inefficiency (socio-economic characteristics) model is defined as
$Ln\ Y = \delta o + \delta_1 Ln\ Z_1 + \delta_2 Ln\ Z_2 + \delta_3 Ln\ Z_3 + \delta_4 Ln\ Z_4 + \varepsilon_i$
$\mathcal{E}i = Vi - Ui$

Where:
δ are the parameter estimates.
Z_1= age of household head (years)
Z_2 = Education level of household head (years)
Z_3 = Household size
Z_4 = Fishing experience of household head (years)

RESULTS AND DISCUSSION

Socio-economic characteristics of artisanal fishermen in crude oil-spilled areas

Gender of the artisanal fishermen

Artisanal fishing in the area was mostly dominated by males. Table 1 shows that (77%) of the artisanal fishermen were males while (23%) of them were females. It can be implied that the enterprise has been seen as an occupation for men in Bayelsa State, Nigeria. This finding agrees with previous work on artisanal fishing in the riverine showing that males dominate the enterprise (Tasie et al., 2020).

Age of artisanal the fishermen

The table showed that the respondent's mean age was49 and 50 years respectively. Age parameter is an important demographic factor in any productive enterprise because it affects productivity and profitability. The age ranges showed that the elderly was mostly engaged in the enterprise implying that artisanal fishing in the study area was carried out by mostly aged fishermen corroborating the works of Tasie and Wilcox (2018), Tasie et al. (2020) and Anyanwu et al. (2022).

Educational attainment of the artisanal fishermen

Education opens the space for enlightenment, effective communication and understanding to adopt innovations that can enhance productivity and profitability in agricultural enterprises. Table 1 presents the educational attainment of the respondents in the area. It was observed that the majority (60%) of the respondents had secondary education, 14% and 11% had primary education, and 16% and 14% of the respondents had tertiary education. This implies that over 85% of the respondents had one form of formal education or the other which will enhance the adoption of technology that could improve productivity and profitability.

Household size of the artisanal fishermen

Household size has its positives and negatives. The large household size provides labour and reduces the cost of hiring labour for sole proprietor enterprises (Daudu et al., 2014). It also reduces the quantity of the product that will be brought to the market for sale because much of it will be consumed. This is in line with Unongo (2010), Nlerum and Bagshaw (2015) and Tasie et al., (2017). Table 1 indicates a mean household size of 7 persons from both sides respectively.

Fishing experience of artisanal fishermen

Long years of experience develop skills for better

Table 1: Socioeconomic Characteristics of the Artisanal Fishermen in the Study Areas

		Crude oil spilled area			Non-oil spilled areas		
Variables		**Frequency (n=100)**	**Percentage**	**Mean**	**Frequency (n=100)**	**Percentage**	**Mean**
Gender	Male	77	77.0		77	77.0	
	Female	23	23.0		23	23.0	
Age (years)	Less than 34	2	2.0		1	1.0	
	34-44	25	25.0		17	17.0	
	45-55	55	55.0		56	56.0	
	56-66	18	18.0	49	26	26.0	50
Educational Level	Illiterates	10	10.0		15	15.0	
	Primary	14	14.0		11	11.0	
	Secondary	60	60.0		60	60.0	
	Tertiary	16	16.0		14	14.0	
Household Size	Less than 5persons	15	15.0		18	18.0	
	5-6 persons	40	40.0		37	37.0	
	7-8 persons	35	35.0		35	35.0	
	9 persons and above	10	10.0	7	10	10.0	7
Years of Fishing Experience	Less than 10	6	6.0		4	4.0	
	10-19	24	24.0		20	20.0	
	20-29	41	41.0		43	43.0	
	30-39	13	13.0		19	19.0	
	40-49	10	10.0		8	8.0	
	50 years and above	6	6.0	25	6	6.0	26

Source: Field Survey, 2023.

Table 2: Maximum likelihood estimation of the stochastic production frontier function coefficient.

Production Frontier	Parameters	Crude oil spilled areas		Non-oil spilled areas		Pooled	
		Coef.	t-value	Coef.	t-value	Coef.	t-value
Constant	β0	4.118053	619.41***	4.288436	12.28***	4.260046	27.63***
Labour (hired)	β1	-.0508219	-40.85***	.0610593	4.35***	-0.5437766	
Bait	β2	-.0056118	-10.13***	.066216	1.18	-0.3736175	
Fish Processing	β3	.0478441	156.48***	.0313366	0.33	.0448255	5.76***
Crude oil spillage	β4	-0.3788	-3.57***			-0.1603	-3.53***
Inefficiency factors							
Constant	δ0	61.72302	0.64-	-2.566124	-6.71**	25.66938	0.51
Age (z_1)	δ1	56.62983	1.09	-11.56456	-3.86**	-19.25553	
Edu level (z_2)	δ2	64.88717	1.94**	2.030577	5.35**	51.61476	2.62**
HH Size (z_3)	δ3	-193.0329	-2.55**	1.424776	5.68**	-110.8975	-2.81**
Exper. (z_4)	δ4	76.93654	2.58**	.3316451	4.49**	38.61637	2.69
Gamma	γ	0.7664		0.8432		0.8218	
Sigma square	δ^2	0.61		0.69		0.66	
Log Likelihood		41.81		170.99		154.89	

Source: Estimated from Field survey,2023 data. **= 5% level of significance

management of resources and enterprises. Table 1 reveals that 25 years was the average of fishing experience on both sides. This implies that the respondents had good years of experience and could have better skills to manage the oil spill challenge.

Cobb-Douglas production function of the artisanal fishermen

The Cobb-Douglas stochastic frontier production function was used to determine the efficiency of artisanal fishermen for both the crude oil-spilled areas and the non-crude-oil-spilled areas and presented in (Table 2). Labour contributed significantly to the fishing activity in the oil spilled area as it had a negative coefficient (-0.0508) but a positive coefficient (0.0610) in the non-crude oil spilled areas. Both were statistically significant at $p<0.001$ probability level. The implication is that if labour is increased by 10%, productivity will fall by 0.5% in the crude oil spilled area. In non-crude oil spilled areas, an increase in labour by 10% will increase productivity by 0.6% which are marginal increase. This positive significance conforms with the findings of Frank et al. (2018). The coefficients of bait (-0.0056) were negative and significant at 1% in oil-spilled areas. This means that if baits are increased by 10%, the artisanal fisherman's productivity will decrease by 0.06% (a very marginal decrease). This might be due to the high cost of bait for hook-and-line fishing. Fish processing had a coefficient of 0.0478 in crude oil spilled areas, which was significant at 1%. This result means that if fish processing is improved by 10%, artisanal fishers' productivity will increase by 0.48%. The crude oil spillage had a coefficient of -0.3788 and was significant at a 1% level. This implies that if crude oil spillage is increased by 10%, productivity will decrease by 3.79kg. Hence, crude oil spillage on fishing waters in the study areas reduced the productivity of artisanal fishermen.

Table 3: Resource use efficiency of inputs in the study areas.

Resources used	Elasticity of Production		
	Crude oil spilled areas	Non-oil spilled areas	Pooled
Labour	-0.0508	0.0611	-0.0038
Bait	-0.0056	0.662	-0.0036
Fish processing	0.0478	0.0313	0.0448
Crude oil spillage effect	-0.3788		-01603
Return to scale (RTS)	-0.1269	0.2154	0.0632

Source: Estimated from Field survey, 2023 data.

Determinants of technical inefficiency

The technical inefficiency variables were estimated by using the one-stage estimation approach of the frontier model to identify the sources of technical inefficiency. The predictors used were age (Z_1), educational level (Z_2), household size (Z_3) and experience (Z_4).

The results in Table 2 show that age was insignificant in the oil-polluted waterways as against the nonpolluted waterways and was significant at $p<0.05$ probability level. For the nonpolluted areas, a decrease in the ages of the fishermen will reduce inefficiency by -11.56 units.

Education had a positive significance for both areas of operation. Both were significant at $p<0.05$ probability level. An increase of 5% in literacy level will increase inefficiency and lead to a loss of approximately 64.89 units and 51.64 units respectively.

Furthermore, Table 2 shows that household size was statistically significant at $p<0.05$. Household size was negative for the crude oil spilled area. This means that if household size increases, it will reduce inefficiency by 193.03 units, while it will increase inefficiency in the non-spilled areas by 1.42 units.

Experience will bring about efficiency in production. Inefficiency in years of fishing experience in the study areas shows a decrease in productivity by 76.94 units and 0.33 units in the oil-polluted and non-polluted waterways at the $p<0.05$ probability level respectively. The estimated sigma square (δ^2) in Table 2 was 0.6081 in crude oil spilled and 0.6975 in non-crude oil spilled rivers, statistically significant at $p<0.05$ probability level. Hence, confirming the good fit of the model. The gamma (γ) values were 0.7664 and 0.8432 which were statistically significant at $p<0.05$ probability level in both crude oils spilt and non-spilt areas respectively. This implies that 76.64% and 84.32% of the artisanal fishermen's production inefficiencies in both crude oils spilled and non-spilt areas were basically due to fishers' inefficiency.

Resource use efficiency

Table 3 shows the production elasticity and return to scale of resources used in artisanal fish production in the study areas. Returns to scale measure the proportionate change in output of artisanal fishery production if all resources are changed simultaneously by 1%. Return to scale (RTS), represents the total of all elasticity of production concerning all the actual factors used in artisanal fish production in the study areas.

Returns to scale can be expressed as follows: increasing returns to scale where the elasticity of production is greater than unity, Ep>1; constant returns to scale (Ep=1) and decreasing returns to scale (Ep<1). The total elasticity of production, with respect to actual inputs used in this study, was -0.1269 for crude oil spilled, and 0.2154 for non-crude oil spilled areas respectively. These results mean that the artisanal fishermen in non-spilt areas, operated at stage I, with a decreasing return to scale (0.2154). i.e. if all resources used were increased by 10% simultaneously, artisanal fishing output would increase by 2.15% only. Artisanal fish production in non-crude oil spilled areas was in stage one implying that an increase in fish production is still possible but at a decreasing rate. In crude oil spilled areas, the return to scale (RTS) -0.1269 was negative. Therefore, in stage three where the marginal product is less than zero. If all inputs were increased by 10%, artisanal fishing output, will reduce by 1.27% and this is caused by the negative effect of crude oil spillage. This goes to confirm that crude oil spillage had a negative effect on artisanal fishing in polluted rivers of Bayelsa State.

Estimated technical efficiency levels of artisanal fishermen

Technical efficiency levels derived from the analysis of the stochastic production function are shown in (Table 4). The variations among the respondents in the study area show that for both the oil-spilled area and non-oil spilled area, the variations range between 0.00 and 1.00. The modal class (0.91-1.00) had the highest level of efficiency than the lowest classes of 0.61-0.70 and 0.21-0.30. The table further shows 0.89, 0.0036 and 0.9930 as mean, minimum and maximum values. The Table also shows the level of technical efficiency for oil spilled area with variations ranging between 0.00-1.00. It is observed that 0.91-1.00 had the highest efficiency level than the lowest class of 0.21-0.30 with 0.83, 0.0 and 1.0 as the mean, minimum and maximum levels of efficiency. For the non-oil spilled area in (Table 4), 0.91-1.0 is the modal class with the highest efficiency level, while 0.71-0.80 had the

Table 4: Estimated technical efficiency levels of the artisanal fishers in the study areas.

	Oil-Spilled Area		Non-Oil-Spilled Area		Pool	
Efficiency levels	frequency	percentage	frequency	percentage	frequency	percentage
0.00 - 0.10	3	3	0	0	3	1.5
0.11 - 0.20	0	0	0	0	0	0
0.21 - 0.30	1	1	0	0	1	0.5
0.31 - 0.40	0	0	0	0	0	0
0.41 - 0.50	0	0	0	0	0	0
0.51 - 0.60	0	0	0	0	0	0
0.61 - 0.70	0	0	0	0	1	0.5
0.71 - 0.80	32	32	1	1	34	17
0.81 - 0.90	30	30	5	5	45	22.5
0.91 - 1.00	34	34	94	94	116	58
Total	100	100	100	100	100	100
Mean	0.83		0.97		0.89	
Minimum	0		0.8		0.0036	
Maximum	1		1		0.9933	

Source: Estimated from Field survey, 2023 data.

lowest level, with 0.97, 0.80 and 1.0 as the mean, minimum and maximum levels of efficiency. This is an implication that varying levels of efficiency were attained. None of the fishermen reached 100% efficiency. The difference in the efficiency estimates indicates that most of the fishermen had not yet achieved optimal mix in their fishing activities as such opportunity towards improving their levels of efficiency still exists. This can be improved by improving on the inefficiency factors in the area, as well as making better use of available production resources with the present state of technology.

The results in (Table 4) also show that more than 94% of the artisanal fishermen operated at an efficiency level between 0.91-1.00 which were the highest technical efficiency levels in non-crude oil spilled areas and crude oil spilled areas. Of those in the crude oil spilled areas, only 34% had a high level of technical efficiency. Therefore, artisanal fishers in non-crude oil spilled areas were technically more efficient than those in the crude oil spilled areas of the study areas. This could be due to the crude oil spillage on the rivers of Bayelsa state.

Conclusion and Recommendations

The results of the study showed that artisanal fishermen from both areas of operation were inefficient. The Cobb-Douglas production function indicated that labour contributed significantly to the fishing activity in the oil spilled area as it had a negative coefficient (-0.0508) but a positive coefficient (0.0610) in the non-crude oil spilled areas. Education, household size and fishing experience all had significant effects on the inefficiency of the Artisanal fishermen. The total elasticity of production, with respect to actual inputs used in this study, showed a negative return to scale for the crude oil spilled area and decreasing returns to scale for the non-crude oil spilled areas respectively. It is therefore recommended that the fishermen improve their education. This can be achieved through extension education to improve their efficiency. Improved gear and techniques: Providing access to better fishing gear like more efficient nets and traps, along with training on using them and more sustainable fishing practices, can significantly increase catches. Encouraging the formation of fishing cooperatives can allow artisanal fishermen to share knowledge, techniques, and resources, improving overall efficiency and Providing access to loans or microfinancing can help fishermen invest in better equipment, technology, and storage facilities.

Conflict of Interest

There is no conflict of interest from any of the authors in this work.

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