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Production Function Analysis of Fish Production in Amansie-West District of Ghana, West Africa

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Authors' contributions

This work was carried out in collaboration between both authors. Author CC research was thispart of Dissertation; he carried out the survey, carried out the analysis and reported the results. Author IGU engaged in proof-reading, updating the literature, managed the abstract, tables, figures, references and general structure of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

The study aimed to obtain the estimates of a production function for fish production in the Amansie-West District of Ghana, West Africa, using primary data collected from 45 registered farmers. Factor elasticities and returns to scale were estimated, as well as the coefficients for various factors of production. The results indicate that the total area of ponds, weight and size of fingerlings and feed had a significant and positive relationship with fish output (P<.01), in the production of fish in the study area. The production technology used in the district also exhibited increasing returns to scale. There is therefore the need to carry out a wider estimation of the cost functions and economic efficiency of fish production, to enable farmers minimize the cost of production toward efficient and profitable optimum. We recommend changes in public policy to promote improved yields for existing fish ponds in the area with reference to the total pond area, feed and the number or weight of fingerlings, which have strong correlation with fish output (yields). Such policies will go a long way to boost fish production in the Amansie-West District, with a broader focus on fish farmers in other areas within the country.

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Keywords: Production function; econometric analysis; fish production; Amansie-west; Ghana; West Africa.

1. INTRODUCTION

Global population demand for aquatic food products is increasing, the production from capture fisheries has leveled off, and most of the main fishing areas have reached their maximum potential. Sustaining fish supplies from capture fisheries will, therefore, not be able to meet the growing global demand for aquatic food. [1] recorded that aquaculture appears to have the potential to make a significant contribution to this increasing demand for aquatic food in most regions of the world.

World fish production has grown tremendously during the last fifty years from a production of less than a million tons in the early 1950s to 59.4 million tons by 2004. This level of production had a value of US$70.3 billion [2]. 41.3 million tons, or 69.6 percent, of the world production, was produced in China and 21.9 percent from the rest of Asia and the Pacific region. Aquaculture in sub-Saharan Africa contributed only 1.6 percent (93,500 tons) of the total fish production from this region in 2004 [1].

In terms of volume and value, Nigeria, followed by Madagascar, South Africa, Tanzania, Uganda and Zambia are the top six countries in the region, and the only ones with production above five thousand (5,000) tons. These countries produce over 80 percent of the total fish from the sub-Saharan Africa region [2].

This raises questions about the contribution of Ghana, endowed with the vast Gulf of Guinea, the Volta River that runs diagonally through the land, and the many inland water bodies. Aquaculture has only recently been adopted as an assured way of meeting the deficit in Ghana's fish supply. Thus, there has been no appreciable increase in annual fish production over the years. In 2003, Ghana produced only 51.7 percent of its requirements from its domestic sources and in 2004, achieved 68.1 percent of its fish requirement through domestic production and imports [3]. Again, in 2004, total production from fish farming was 950 tonnes valued at ¢14.25 billion (US$ 1.5 million) as compared to 325 tonnes in the 80s. The importance of fish to the average Ghanaian cannot be overemphasized. According to Aggrey- Fynn [4], fish is recognized as the most important source of animal protein in Ghana. This assertion has also been confirmed by the FAO, as it pegged the average per capita consumption of fish in Ghana in 2004 at 27.2 kg/head/year [1].

Despite such improvement and strides made in the sector over the past few years, the sector is constrained with as high cost of feed, inadequate fingerling production; poor road network and improper siting of ponds which hinder the growth of aquaculture. The government in the interest of farmers has put measures in place to help the development of aquaculture. These include fingerling production for sale to fish farmers, provision of free extension services, and training in fish farming techniques [1].

A review of the literature and numerous interviews with extension agents, suggest that a major constraint to successful fish farming is the wide gap between actual yields achieved by small-scale farmers and the potential yields indicated by field trials. In order to develop successful public policy regarding extension practices and input availability where applicable, knowledge of aquaculture production must be improved. The objective of this work was to respond to this requirement by obtaining econometric estimates of a Cobb-

Douglas production function for the aquaculture technology used by fish farmers in Ghana, using the Amansie West District of the Ashanti Region as the case study.

According to the GSS [5], a one percent (1%) growth in the population of the country requires a 3-4 % growth in the economy to maintain the present standard of living. However, the average annual population growth rate in Ghana between the years 1984 and 2000 was 2.7 %. This requires an increased economic growth rate in order to maintain the present standard of living. Nonetheless, the real Gross Domestic Product (GDP) growth over the same period was on average 4.53 %. This means that the population is growing faster than the economy which can have some undesirable long-term consequences. One consequence of this is that the excess of demand over the supply of fish is likely to increase with time if the production from capture fisheries does not keep pace with population growth. This makes the aquaculture industry to have a very crucial role in bridging the gap between demand and supply.To feed the growing population, there has to be a corresponding increase in food production whether from agriculture or aquaculture. The basic options to increase production in agriculture include; expansion of the production area and intensifying production. With increasing global population, the first option becomes less likely on land. However, aquaculture still has an advantage over agriculture as there are still the open waters of the sea to expand into. But as FAO [6], has noted, given the present and anticipated increases in world population, not to mention current and projected environmental problems and ecological stress from agriculture, further agricultural intensification will be needed. This applies as well to aquaculture. Intensification implies improved technology, improved strains but does not always mean increased amount of inputs. For practical purposes, intensification occurs when there is an increase in the total volume of agricultural production that results from a higher productivity of inputs, or agricultural production is maintained while certain inputs are decreased [6]. How to enable farmers to intensify and enjoy the benefits of aquaculture and how to minimize and mitigate environmental problems are some of the issues that this work sought to address.

Aquaculture, probably the fastest growing food-producing sector, now accounts for almost 50 percent of the world's food fish and is perceived as having the greatest potential to meet the growing demand for aquatic food. With the ever-increasing prices of inputs for fish production, it is not surprising that the output from such ventures is equally low. There is a great potential for fish farming in Africa, but many African countries (including Ghana) do not have a quantified long term or even mid-term national plan for their aquaculture sectors [7], making it difficult to develop production targets for the sector.

The study aimed to address the problem of inefficient use of resources and to identify the optimum combination of the various inputs used in the industry by fish farmers in the Amansie-West District of Ghana, by estimating the parameters of a functional Cobb-Douglas production function. The study aimed to make recommendations to help improve the status of fish farming in Ghana, West Africa.

2. PRODUCTION FUNCTIONS

A production function describes a mapping from the quantities of inputs to quantities of an output as generated by a production process.It shows the relationship between a firm's inputs and its outputs[8]. The production frontier characterizes the minimum number of the necessary combinations of inputs for the production of diverse products, or the maximum output with various input combinations and a given technology [9]. It indicates, in either short-run input elasticities and the marginal rate of technical substitution in mathematical or graphical form; what outputs can be obtained from various amounts and combinations of factor inputs. In particular, it shows the maximum possible amount of output that can be produced per unit of time with all combinations of factor inputs, given the current factor endowments and the state of available technology. Unique production functions can be constructed for every production technology and this work extends this to include districts; in other words, different production functions could exist for different districts due to likely differences in technology or micro-climates. The relationship is nonmonetary, that is, a production function relates physical inputs to physical outputs. Prices and costs are not considered [10].

The production function is a purely technical relationship which describes how firms transform inputs into outputs. It is assumed that a relationship exists between inputs and outputs that can be written in a mathematically convenient form:

$$\mathrm{Y}(\mathrm{z}) = 0 \tag{1}$$

where z is a real-valued m-dimensional vector containing both inputs used and outputs produced in a given time period. Equation (1) can be re-written to separate inputs and outputs into separate categories to improve its intuitive appeal as follows:

$$\mathrm{Y}(\mathrm{y}, \mathrm{x}) = 0 \tag{2}$$

where the vectors x and y consist of nonnegative inputs and outputs
In the context of this analysis, (2) can be re-written for the case of a single output as:

$$Y = (fx) \tag{3}$$

where f*(x)* is single valued; in other words, the production function assumes that the output realized from a set of inputs is the maximum as prescribed by the technological relationship between inputs and outputs.

3. METHODOLOGY

This study was conducted in the Amansie-West District of the Ashanti Region of Ghana in April, 2009. The choice of the study area was due to the high number of registered fish farmers in the region with the highest prevalence of farmed fish in Ghana[11]. The area is one of the 30 districts in the Ashanti Region of Ghana and covers an area of 1,364 square kilometers, with a population of 108,726 people [12].Fifty (50) out of 70 registered fish farmers in the Amansie West District of Ghana were selected for the study. Primary data were obtained through the use of structured questionnaires and interviews. Data on all 70 registered fish farmers in the district were obtained from the Ashanti Regional offices of the Ministry of Fisheries. The registered fish farmers in the district were categorized into different groups such as: small (0.01-0.10 ha), medium (0.11-0.20 ha) and large (>0.20 ha). There were 39 small-sized farms, 16 medium farms and 15 large farms. Fifty (50) respondents were randomly selected for interviewing; however, forty-five (45) availed themselves for interview. This study was constrained by the high cost of transportation and difficulty to reach the sparsely distributed fish farmers in the area. Moreover, some of the fish farmers in the district had no records and had to respond from their memories, which they sometimes found difficult to do. This difficulty, however, was reduced by the extension agent who had records on the production of fish by farmers. For instance, some of the farmers could not tell the sizes of their fish ponds and the total harvests for the last production season and had to rely on the records of the extension agent for such information. The bad road network in some parts of the district was also a constraint to the data collection. A Cobb-Douglas function was assumed as the functional form of the production function. This was because it is linear in its logarithmic form, and therefore easy to estimate by using ordinary least squares estimation technique (OLS). Moreover, the Cobb-Douglas function has been widely used for production function analysis by many authors [13].

The empirical production function is:

$$Y = aFg^{\beta 1}Fd^{\beta 2}Lb^{\beta 3}Ft^{\beta 4} + e \quad (4)$$

Taking the natural log on both sides of the equation gives:

$$\text{Ln Y} = \ln a + \beta_1 \ln Fg + \beta_2 \ln Fd + \beta_3 \ln Lb + \beta_4 \ln Ft + e \quad (5)$$

Where

Y=Fishoutput in kg
Fg = fingerlings stocked per pond in kilograms (kg).
Fd = feed fed to the fishes per season in kg.
Lb= labour in per-man hours.
Ft = fertilizer used in ponds per season in kilograms (kg).
a, $\beta_{1...}$ β_4 are parameters to be estimated and *e* is an error term

The parameters were estimated using the ordinary least squares technique (OLS), while the Z distribution was employed to test hypotheses of the significance of individual estimated coefficients with the E-Views software (version 3.1).The F distribution was employed to test joint hypotheses, while the Chi-square Test was used to test the independence of the input variables.

4. RESULTS AND DISCUSSION

4.1 Estimates Obtained for the Production Functions

In order to avoid bias in the estimation procedure and to ensure that the chosen model or production function fits the data obtained from the fish farmers in the Amansie-West District, linear and Cobb-Douglas (log-log) production functions were estimated using the Ordinary Least Squares Method. Appropriate test was conducted on the error term to ensure consistency before the results were discussed.

4.2 Linear Production Function

The Linear Production Functionassumes a linear relationship between the dependent and independent variables and is specified as;

$$Y = a + \beta_1 fg + \beta_2 fd + \beta_3 ft + \beta_4 lb + \beta_5 ta + e \quad (6)$$

Where

Y= Fish output in kg
Fg = number of fingerlings
Fd = feed in kg
Lb= labour in man-days
Ft = fertilizer in kg
Ta = total pond area in ha
a, $\beta_{1...}$ β_5 are parameters to be estimated and e is an error term

The analysis of the linear relationship between the input variables; Ta, Lb, Ft, Fg and Fd, and the dependent variable Y as explained in equation 6, is presented in appendix 1. The result shows a positive relationship between Fish output (Y) and the input variables; Ta, Lb, Fg and Fd, and a negative relationship between Ft, with an R-squared value of 0.789671. The multiple regression model shows the relationship as presented in equation 7, below:

$$\boldsymbol{Yd = -484.9672 + 1259.829Ta + 0.2522Lb - 2.3136Ft + 0.0908Fg + 0.1822Fd} \quad (7)$$

$$\boldsymbol{R^2 = 0.79, F - stat. = 29.28(Prob.: 0.0000), N = 45}$$

(See full results presented as appendix 1)

4.2 Data Exploration

Under this section, the aim was to find out the behavior of the independent variables in relation to the dependent variable, and to achieve this aim, simple scatter diagrams were plotted as shown in Figures 1, 2, 3 and 4, presented in the appendix section. However, it can be seen from all the scatter diagrams that most observations are concentrated near the origin and begin to spread out unevenly about the line of best fit. The uneven spread about the line of best fit is most evident in the graph of LB against YD. This shows that labour was not evenly distributed among the fish farmers in the district. Vast differences apparently seem to exist among the labour input per respondent. This variation can be seen from the other graphs. To determine statistically whether or not the residuals were also evenly distributed about their mean values, a normality test was carried out.

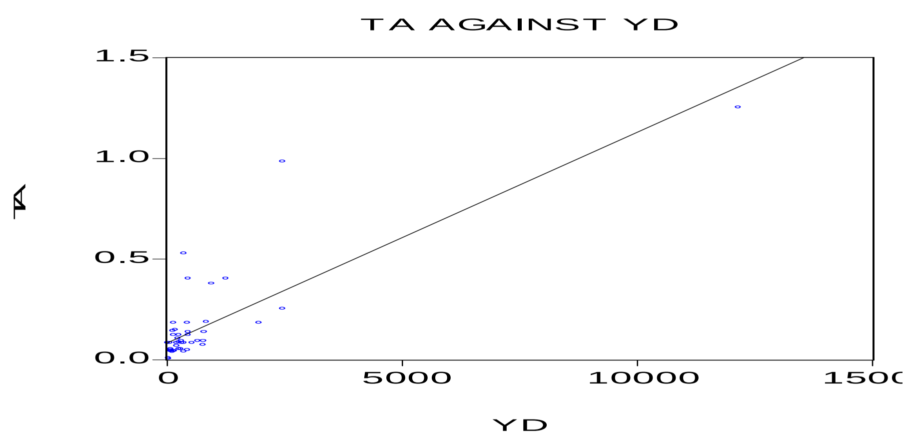


Figure 1. Graph of total pond area against yield of fish in the Amansie- West District

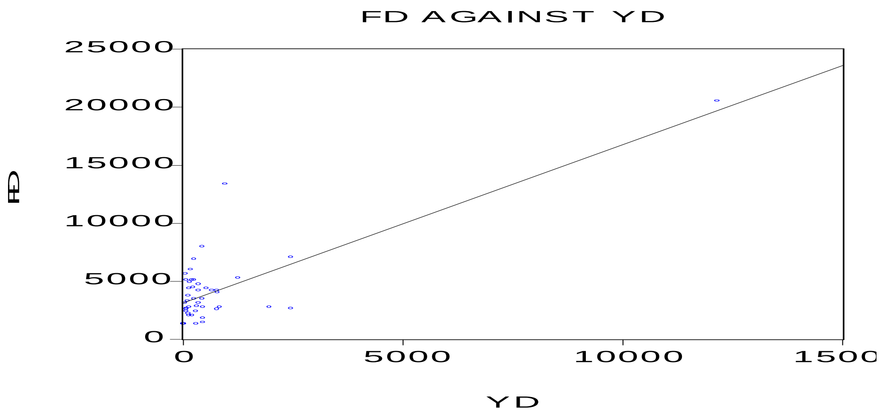


Figure 2. Graph of feed against yield of fish in the Amansie- West District

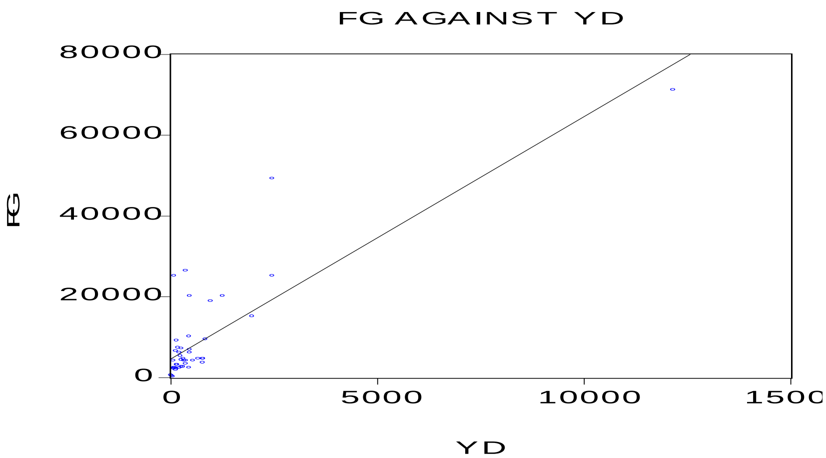


Figure 3. Graph of number of fingerlings against yield of fish

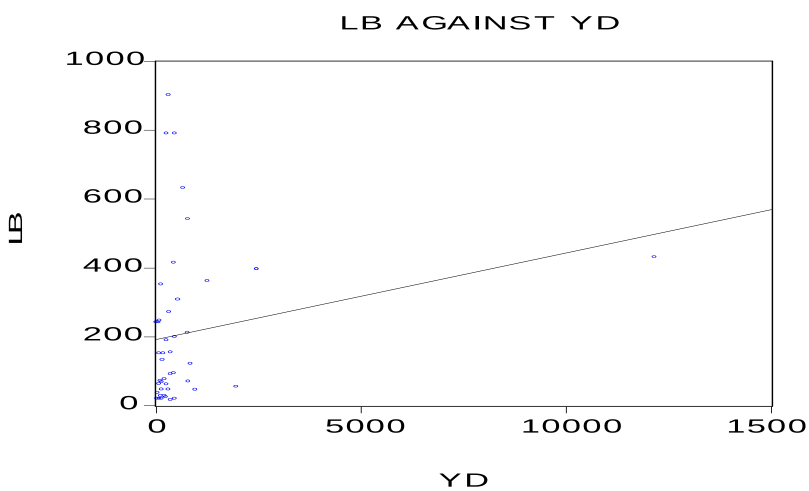


Figure 4. Graph of labour against yield of fish in the Amansie- West District

4.3 Normality Test

The normality test is used to test the following hypothesis:

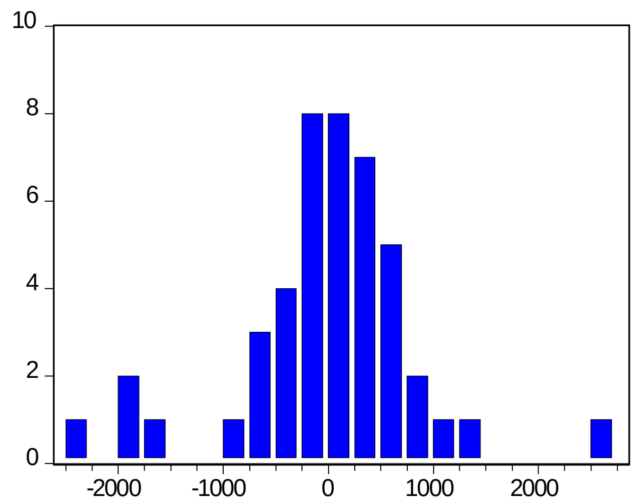
Ho: The residuals are normally distributed
H_1 : The residuals are not normally distributed

From Figure 5, the Jarque-Bera statistic reported was 10.84 with a probability of 0.0044. The probability value indicates that the Jarque-Bera value is highly significant at 1% and hence the null hypothesis is rejected in favor of the alternative hypothesis. This implies that the residuals are not normally distributed about their mean. With this assumption about the error term violated as far as the data obtained from fish farmers in the Amansie-West District is concerned, the results obtained should be interpreted with caution. Since the Normality test is a non-constructive test, it does not correct the anomaly detected, it only gives an indication of the anomaly. It is also expedient in econometric analysis to find out the correlation among the variables used in the analysis. Thus the next section tackles this aspect of the analysis.

4.4 Test for Heteroskedasticity

For the estimates obtained to be consistent and reliable, the residuals are expected to have a constant variance. To test whether or not this assumption is violated, the following hypotheses were tested:

Ho: Heteroskedasticity is absent among residuals
H_1: Heteroskedasticity is present among residuals



Series: Residuals	
Sample 1 45	
Observations 45	
Mean	-2.22E-13
Median	47.45815
Maximum	2673.697
Minimum	-2260.526
Std. Dev.	840.3037
Skewness	-0.217438
Kurtosis	5.364808
Jarque-Bera	10.84019
Probability	0.004427

Figure 5. Normality test

Appendix 2 presents the result of the White Heteroskedasticity Test. The result shows Obs*R-squared value of 39.22 with a probability value of 0.0000 and thus is highly significant at 1%. It is therefore concluded that the null hypothesis be rejected; heteroskedasticity is present and that the error terms do not have a constant variance. With all these assumptions about the error term violated by the data used in the analysis, it indicates that the estimates obtained from the linear production function may be biased, inconsistent and inefficient. Therefore, it implies that the linear production function does not efficiently fit the data obtained from fish farmers in the Amansie-West District and therefore will not be discussed anymore henceforth. Attention is henceforth focused on the Cobb-Douglas production function.

4.5 The Cobb-Douglas Production Function

This production function is a power production function of the form

$$Y = a\,Fg^{\beta 1}\,Fd^{\beta 2}\,Lb^{\beta 3}\,Ft^{\beta 4}\,Ta^{\beta 2}e \tag{8}$$

Taking natural logarithm on both sides of the equation gives:

$$LnY = Lna + \beta_1 LnFg + \beta_2 LnFd + \beta_3 LnLb + \beta_4 LnFt + \beta_5 LnTa + e \tag{9}$$

Where

Y= Fish output in kg
Fg = number of fingerlings stocked per pond
Fd = feed (kg)
Lb= labour (man-days)
Ft = fertilizer (kg)
Ta = total area in ha
Ln = natural logarithm
a, $\beta_{1\ldots}\ \beta_5$ are parameters to be estimated and *e* is an error term

The estimated model for the relationship described in equation 9, is presented in equation 10, the result shows a positive relationship between LnY and LnTa, LnLb, LnFg and LnFd, with a negative coefficient for LnFt.

$$\boldsymbol{LnY = 2.17774 + 0.3987LnTA + 0.0783LnLB - 0.2595LnFT + 0.3303LnFG + 0.3487LnFD} \tag{10}$$

$$\boldsymbol{R^2 = 0.61, F - stat. = 12.07297(Prob.: 0.0000)}$$

(See full results in Appendix 3).

4.6 Data Exploration

The discussion of estimates obtained from the model is preceded by data exploration. Under this section, the aim was to find out the behavior of the independent variables in relation to the dependent variable, and to achieve this aim simple scatter diagrams were plotted as shown in Figures 6, 7, 8 and 9, presented in the appendix section.

Unlike in the case of the linear production function, the scatter diagram for the Cobb Douglas Production function shows the observations spread almost evenly about the regression line. Like the linear function, however, all the independent variables are shown in the graphs to have a positive relationship with the dependent variable. These indicate that linearizing the Cobb-Douglas production function with logarithm gives a better representation of the relationships that exist among the variables than the normal linear model discussed above. Having explored the data, the various diagnostic tests on the error term were conducted. These tests included the heteroskedasticity test and the normality test.

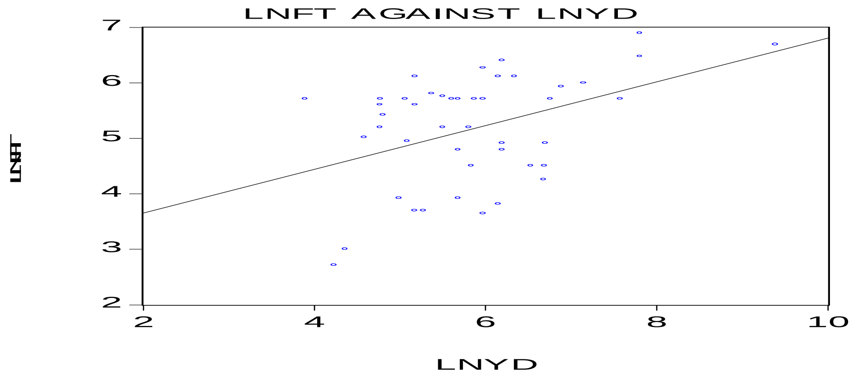


Figure 6. Graph of LnFT against LnYD

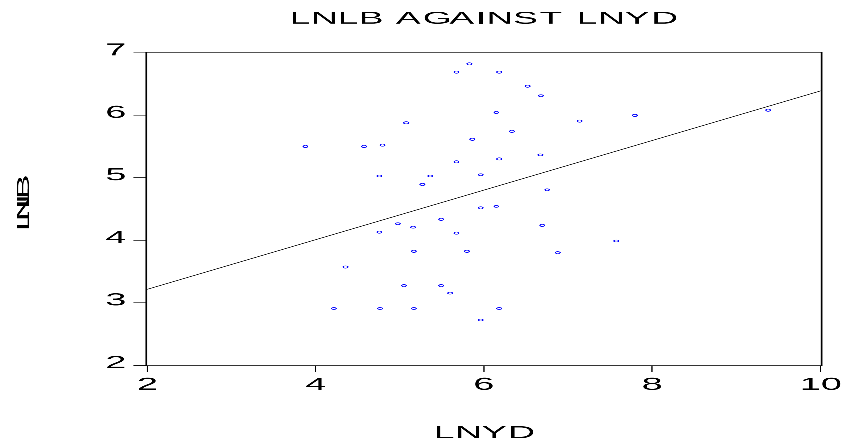


Figure 7. Graph of lnLB against lnYD

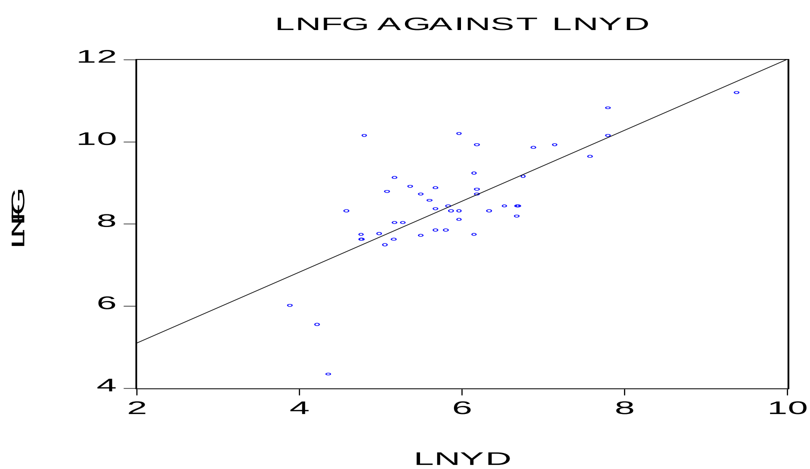


Figure 8. Graph of LnFG against LnYD

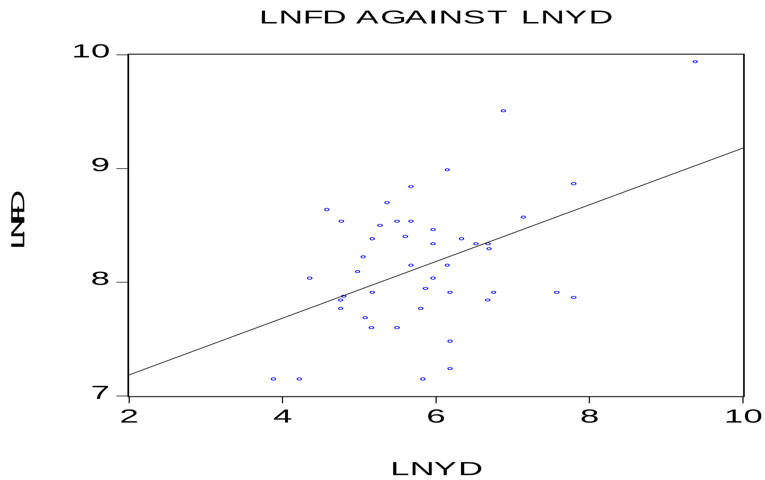


Figure 9. Graph of LnFD against LnYD

4.7 Normality test

One assumption about the residuals is that they are normally distributed; violation of this assumption renders the estimates obtained from the estimation of the production inconsistent, inefficient and biased. The following hypotheses were tested:

Ho: The residuals are normally distributed
$H_{1:}$ The residuals are not normally distributed

As shown in Figure 10, the Jarque-Bera value is 0.192 with a probability of 0.908 indicating that it is insignificant even at 10%. The null hypothesis is subsequently not rejected and it is concluded that the residuals are normally distributed. This is contrary to that of the linear model where the residuals were not normally distributed about their mean value. Since the Cobb-Douglas Production did not violate the normality assumption, it means that the estimates obtained are consistent, efficient and not biased. The test for heteroskedasticity is conducted to ascertain this claim, nonetheless.

4.8 Test for Heteroskedasticity

For the estimates obtained to be consistent and reliable, the residuals are expected to have a constant variance. To test whether or not this assumption is violated, the following hypotheses were tested:

Ho: Heteroskedasticity is absent among residuals
H_1: Heteroskedasticity is present among residuals

As shown in appendix 4, the probability value of 0.036 of the Obs*R-squared value of 19.28 indicates nonsignificance at the 1% level (though it may be argued that this is significant at 5%). The null hypothesis which states that the residuals are homoskedastic or that heteroskedasticity is absent is subsequently not rejected. Since the heteroskedasticity assumption is also not violated at 5%, it is an indication that the estimates obtained are consistent, efficient and not biased.

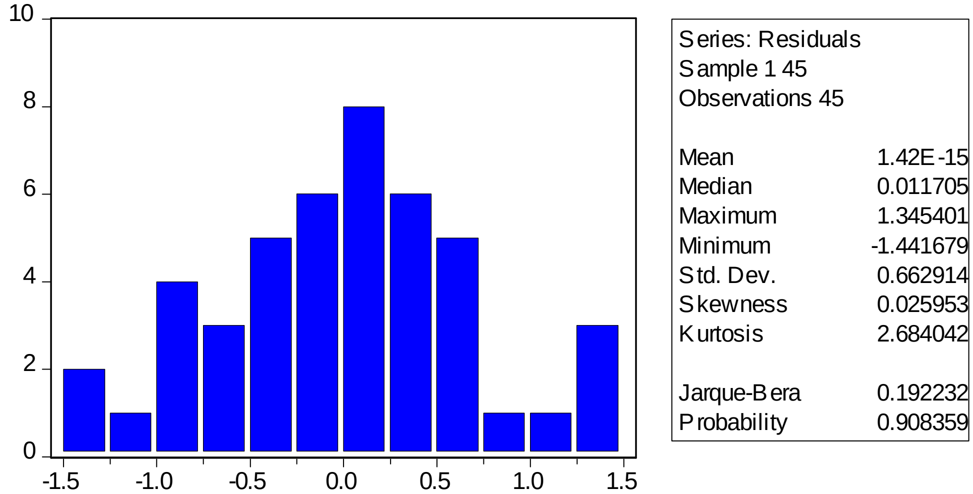


Figure 10. Normality test

4.9 Discussion of Results from the Cobb-Douglas Production Function

The results obtained from the Cobb-Douglas production function in appendix 3, indicate that total pond area, number of fingerlings and feed are significant inputs to fish production in the Amansie-West District. These results are in agreement with those of Kurbis[14], obtained from a Cobb-Douglas estimation for fish production in Honduras. [14]also reported that output of fish is significantly influenced by feed, fertilizer and fingerlings. [14]obtained an adjusted R^2 value of 0.48, indicating that of the variations in fish yield, 48% is attributable to the number of fingerlings stocked, the feed amount and the quantity of fertilizer used. The results from this study indicate that of the variations in the output of fish in the Amansie-West District, about 61% was attributable to the number of fingerlings stocked, the feed amount and the total pond area. In Kurbis [14], fertilizer was found to be positively related to output while the total pond area was not significant as far as fish production in rural Honduras was concerned. Contrary to Kurbis' findings, it was realized from this research work that fertilizer was not a significant input while the total pond area was a significant input to fish production. The R^2 obtained from this estimate was 0.61 indicating that the estimates are reliable and that the significant variables to a large extent affect the variation in the dependent variable (yield of fish).

4.9.1 The f-test

The F-statistic helped us to test the hypothesis that none of the explanatory variables helped explain the variation of Y about its mean. In other words, the F-statistic was used to test the following joint hypotheses:

Ho: $\beta_1=\beta_2= \beta_3=\beta_k=0$.
H_1: $\beta_1\neq\beta_2\neq \beta_3\neq\beta_k \neq 0$.

According to Pindyck and Rubinfeld [15], if the null hypothesis is true, then we would expect R^2 and F to be close to zero. Thus, from the F-value of 12.07 with a probability value of 0.000 obtained from this work, the null hypothesis would be rejected and it is concluded that there are significant differences among the coefficients of the explanatory variables (at 1%)

and that the significant variables jointly influence the variation in the yield of fish in the study area.

4.9.2 The t-test

The t-test was performed to test the following hypotheses:

Ho: $\beta_i=0$
H_1: $\beta_i \neq 0$

As shown in Table 1, the t-values of all the independent variables have been outlined. Based on their respective probability values, fertilizer and labour were not significant even at 10%, and hence for these two variables the null hypothesis would not be rejected, and the conclusion is that the effects of these two variables on the yield of fish are not statistically significantly different from zero. The probability values of the t-values of all the three significant variables indicate significance at 10%. This shows that the null hypothesis in each case would be rejected in favour of the alternative that the coefficient of each variable is significantly different from zero and that each of them influences the yield of fish in the district significantly. The results obtained show that the log-linearized Cobb-Douglas Production function for the study area is as summarized in equation 11;

$$\boldsymbol{lnYD = 0.399LnTA + 0.330LnFG + 0.349LnFD + 2.177} \quad (\mathbf{11})$$
$$(\mathbf{0.239})(\mathbf{0.196})(\mathbf{0.207})$$

(Figures in parenthesis are respective standard errors, see full results in appendix 3)

One special feature of the Cobb-Douglas production function is that the coefficients of the independent variables are their respective elasticities. From the equation (11) above, a 10% increase in the total pond area would result in about 40% increase in the yield of fish in the Amansie-West District, *ceteris paribus.* In the same context, a 10% increase in the number of fingerlings stocked would lead to an increase of 33% in the yield of fish, holding all other things constant and an increase of about 35% in fish yield would result from an increase of 10% in the feed amount. As a follow up to find out about the scale of production at which the fish farmers are operating, the elasticities of the three significant inputs to the fish production technology used were computed, as shown in Table 2. From the relation; $Є=\sum є_i$, elasticity of scale is 1.078. The elasticity of scale measures the responsiveness of output to the changes in the inputs in a production process. The elasticity of scale of 1.078 is greater than unity (1) and it indicates that there is increasing returns to scale in the fish production technology used by fish farmers. This means, scaling all the significant inputs by a factor, α (where α >1), results in more than proportionate increase in the output of fish in the district.

Table 1. T-values of significant inputs to fish production in the Amansie-West District

Variable	**Tvalue**	**Probability**
ln Ta	1.664515	0.1040
ln Fg	1.686226	0.0997
ln Fd	1.683836	0.1002

Source: Analysed from survey data, 2009

Table 2. Factor elasticities of significant inputs to fish production in the Amansie-West District

Variable	Estimated Coefficient	10% significance
Fg	0.330	0.0997
Fd	0.349	0.1002
Ta	0.399	0.1040
∑є	1.078	

Source: Analysed from survey data, 2009

5. CONCLUSION

It is of interest to extension agents, and farmers whose inputs are significant to the production process, and, of those inputs, which have a greater per-unit effect on total production relative to the other inputs. The inputs specified in the production function in initial regressions were feed, fertilizer, fingerlings, labour and pond size. Econometric estimation indicated that the effects of fertilizer and labour on fish production were not statistically significant even at 10%. This implies that extensionists should focus more on inputs other than fertilizer and labour when suggesting strategies for production increases. Final regression results showed that feed, total pond area and the fingerling stocking rate were significant inputs to fish production. The coefficients obtained for the three significant variables indicated that a 10% increase in the total pond area would result in a 40% increase in the yield of fish in the Amansie-West District, *ceteris paribus.* In the same context, a 10% increase in the number of fingerlings stocked would lead to an increase of 33% in the yield of fish holding all other things constant and an increase of about 35% in fish yield would result from an increase of 10% in the feed amount. Extensionists may wish to use this information to assist in improving yields where inefficient production is suspected. Of the three inputs determined to affect fish production the significance of the coefficient of total pond area has considerable policy implications given the high spatial cost component of pond construction and the fact that increasing the total pond area could result in increasing yield. Also feed has a relatively higher influence on yield and hence more feed should be given to the fishes to increase yield rather than over-stock ponds relative to the feed consideration. Extension efforts to improve yield should focus on inputs of feed, total pond area and seed fish, which were found to be statically significant inputs to fish production. There is also the need to subsidize the cost of improved feeds by the government to make them affordable to farmers. Assuming future budgetary outlays for public investment in hatcheries, it may be desirable to build a larger number of small, geographically dispersed hatcheries as opposed to a smaller number of large-sized facilities owned by the Ministry of Fisheries in Kumasi. Whether this would be an appropriate strategy depends in part on whether fingerling production exhibits increasing, decreasing or constant returns to scale. The estimation of the production and cost functions for seed fish production in fish hatcheries, is therefore important to enable farmers manage the cost of production toward efficient and profitable fish production. We therefore recommend changes in public policy to promote improved yields for existing fish ponds in the area with reference to the total pond area, feed and number of fingerlings, which have strong correlation with fish output (yields). Such policies will go a long way to boost fish production in the Amansie-West District, with a broader focus on fish farmers in other areas within the country.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Appendix 1. Estimated Linear Production Function

Dependent Variable: YD
Method: Least Squares
Sample: 1 45
Included observations: 45

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TA	1259.829	1959.644	0.642887	0.5241
LB	0.252163	0.651707	0.386927	0.7009
FT	-2.313645*	1.165217	-1.985592	0.0541
FG	0.090838***	0.033070	2.746875	0.0091
FD	0.182159***	0.060564	3.007696	0.0046
C	-484.9672	355.9286	-1.362541	0.1808
R-squared	0.789671	Mean dependent var		771.9556
Adjusted R-squared	0.762706	S.D. dependent var		1832.259
S.E. of regression	892.5454	Akaike info criterion		16.54960
Sum squared resid	31068855	Schwarz criterion		16.79049
Log likelihood	-366.3659	F-statistic		29.28477
Durbin-Watson stat	1.706032	Prob(F-statistic)		0.000000

** denotes significance at 5%*
**** denotes significance at 1*
Source: Analysed from survey data, 2009

Appendix 2. White Heteroskedasticity Test

F-statistic	**23.05314**	**Probability**	**0.000000**
Obs*R-squared	**39.21619**	**Probability**	**0.000023**

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample: 1 45
Included observations: 45

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	118579.6	391840.3	0.302622	0.7640
TA	-7576219.	4336351.	-1.747142	0.0896
TA^2	11042331	7336520.	1.505118	0.1415
LB	380.8970	1437.963	0.264886	0.7927
LB^2	-0.887887	1.745013	-0.508814	0.6142
FT	-297.4736	1849.783	-0.160815	0.8732
FT^2	-0.177447	2.891932	-0.061359	0.9514
FG	247.7876	69.18371	3.581589	0.0011
FG^2	-0.005040	0.002392	-2.106754	0.0426
FD	-175.8038	132.4890	-1.326931	0.1934
FD^2	0.026958	0.009922	2.717060	0.0103

Source: Analysed from survey data, 2009

Appendix 3. Least Squares Estimates obtained from the Cobb-Douglas Production Function

Dependent Variable: LnYD
Method: Least Squares
Sample Size: 145
Included observations: 45

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LnTA	0.398735*	0.239551	1.664515	0.1040
LnLB	0.078309	0.103456	0.756932	0.4536
LnFT	-0.259472	0.183383	-1.414919	0.1650
LnFG	0.330285*	0.195872	1.686226	0.0997
LnFD	0.348686*	0.207078	1.683836	0.1002
C	2.177385	2.861204	0.761003	0.4512
R-squared	0.607507	Mean dependent var		5.882570
Adjusted R-squared	0.557187	S.D. dependent var		1.058136
S.E. of regression	0.704128	Akaike info criterion		2.259852
Sum squared resid	19.33604	Schwarz criterion		2.500740
Log likelihood	-44.84666	F-statistic		12.07297
Durbin-Watson stat	2.133816	Prob(F-statistic)		0.000000

** denotes significance at 10%*
Source: Analysed from survey data, 2009

Appendix 4. White Heteroskedasticity Test

F-statistic	**2.549500**	**Probability**		**0.020413**
Obs*R-squared	**19.28355**	**Probability**		**0.036805**
Test Equation:				
Dependent Variable: RESID^2				
Method: Least Squares				
Sample: 1 45				
Included observations: 45				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	1.280321	10.86666	0.117821	0.9069
LNTA	-1.060745	0.531710	-1.994968	0.0541
LNTA^2	-0.167306	0.102788	-1.627683	0.1128
LNLB	0.368295	0.577778	0.637433	0.5281
LNLB^2	-0.038314	0.060362	-0.634736	0.5298
LNFT	1.555981	1.118098	1.391632	0.1731
LNFT^2	-0.165820	0.114357	-1.450023	0.1562
LNFG	-4.327618	1.586419	-2.727916	0.0100
LNFG^2	0.282971	0.096162	2.942636	0.0058
LNFD	2.221226	2.949225	0.753156	0.4565
LNFD^2	-0.130049	0.177536	-0.732524	0.4689
R-squared	0.428523	Mean dependent var		0.429690
Adjusted R-squared	0.260442	S.D. dependent var		0.563912
S.E. of regression	0.484951	Akaike info criterion		1.599047
Sum squared resid	7.996018	Schwarz criterion		2.040676
Log likelihood	-24.97856	F-statistic		2.549500
Durbin-Watson stat	1.643172	Prob(F-statistic)		0.020413

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