

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

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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.

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.

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

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

40 This raises questions about the contribution of Ghana, endowed with the vast Gulf of
41 Guinea, the Volta River that runs diagonally through the land, and the many inland water
42 bodies. Aquaculture has only recently been adopted as an assured way of meeting the
43 deficit in Ghana's fish supply. Thus, there has been no appreciable increase in annual fish
44 production over the years. In 2003, Ghana produced only 51.7 percent of its requirements
45 from its domestic sources and in 2004, achieved 68.1 percent of its fish requirement through
46 domestic production and imports [3]. Again, in 2004, total production from fish farming was
47 950 tonnes valued at ₵14.25 billion (US\$ 1.5 million) as compared to 325 tonnes in the 80s.
48 The importance of fish to the average Ghanaian cannot be overemphasized. According to
49 Aggrey- Fynn [4], fish is recognized as the most important source of animal protein in
50 Ghana. This assertion has also been confirmed by the FAO, as it pegged the average per
51 capita consumption of fish in Ghana in 2004 at 27.2 kg/head/year [1].

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

58 A review of the literature and numerous interviews with extension agents, suggest that a
59 major constraint to successful fish farming is the wide gap between actual yields achieved by
60 small-scale farmers and the potential yields indicated by field trials. In order to develop
61 successful public policy regarding extension practices and input availability where
62 applicable, knowledge of aquaculture production must be improved. The objective of this
63 work was to respond to this requirement by obtaining econometric estimates of a Cobb-
64 Douglas production function for the aquaculture technology used by fish farmers in Ghana,
65 using the Amansie West District of the Ashanti Region as the case study.

66 According to the GSS [5], a one percent (1%) growth in the population of the country
67 requires a 3-4 % growth in the economy to maintain the present standard of living. However,
68 the average annual population growth rate in Ghana between the years 1984 and 2000 was
69 2.7 %. This requires an increased economic growth rate in order to maintain the present
70 standard of living. Nonetheless, the real Gross Domestic Product (GDP) growth over the
71 same period was on average 4.53 %. This means that the population is growing faster than
72 the economy which can have some undesirable long-term consequences. One consequence
73 of this is that the excess of demand over the supply of fish is likely to increase with time if the
74 production from capture fisheries does not keep pace with population growth. This makes
75 the aquaculture industry to have a very crucial role in bridging the gap between demand and
76 supply. To feed the growing population, there has to be a corresponding increase in food
77 production whether from agriculture or aquaculture. The basic options to increase production
78 in agriculture include; expansion of the production area and intensifying production. With
79 increasing global population, the first option becomes less likely on land. However,
80 aquaculture still has an advantage over agriculture as there are still the open waters of the
81 sea to expand into. But as FAO [6], has noted, given the present and anticipated increases
82 in world population, not to mention current and projected environmental problems and
83 ecological stress from agriculture, further agricultural intensification will be needed. This
84 applies as well to aquaculture. Intensification implies improved technology, improved strains
85 but does not always mean increased amount of inputs. For practical purposes, intensification
86 occurs when there is an increase in the total volume of agricultural production that results
87 from a higher productivity of inputs, or agricultural production is maintained while certain
88 inputs are decreased [6]. How to enable farmers to intensify and enjoy the benefits of
89 aquaculture and how to minimize and mitigate environmental problems are some of the
90 issues that this work sought to address.

91 Aquaculture, probably the fastest growing food-producing sector, now accounts for almost
92 50 percent of the world's food fish and is perceived as having the greatest potential to meet
93 the growing demand for aquatic food. With the ever-increasing prices of inputs for fish
94 production, it is not surprising that the output from such ventures is equally low. There is a
95 potential for fish farming in Africa, but many African countries (including Ghana) do not have
96 a quantified long term or even mid-term national plan for their aquaculture sectors [7],
97 making it difficult to develop production targets for the sector.

98 The study aimed to address the problem of inefficient use of resources and to identify
99 the optimum combination of the various inputs used in the industry by fish farmers in
100 the Amansie-West District of Ghana, by estimating the parameters of a functional

101 Cobb-Douglas production function. The study aimed to make recommendations to
102 help improve the status of fish farming in Ghana, West Africa.

103

104 2. Production functions

105

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

121 The production function is a purely technical relationship which describes how firms
122 transform inputs into outputs. It is assumed that a relationship exists between inputs and

123 outputs that can be written in a mathematically convenient form: $Y(z) = 0$

124 (1)

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

$$128 \quad Y(y, x) = 0 \quad (2)$$

129 where the vectors x and y consist of nonnegative inputs and outputs

130 In the context of this analysis, (2) can be re-written for the case of a single output as:

$$131 \quad Y = (fx) \quad (3)$$

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:

$$Y = aF_g^{\beta_1} F_d^{\beta_2} L^{\beta_3} F_t^{\beta_4} + e \quad (4)$$

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

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

168

169 Where Y= Fish output in kg

170 Fg = fingerlings stocked per pond in kilograms (kg).

171 Fd = feed fed to the fishes per season in kg.

172 Lb= labour in per-man hours.

173 Ft = fertilizer used in ponds per season in kilograms (kg).

174 a, $\beta_1, \dots, \beta_4$ are parameters to be estimated and e is an error term

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

180

181

182 4.0 RESULTS AND DISCUSSION

183

184 4.1 Estimates Obtained for the Production Functions

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

190

191 Linear production function

192 The Linear Production Function assumes a linear relationship between the dependent and
 193 independent variables and is specified as;

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

195 Where Y= Fish output in kg

196 Fg = number of fingerlings

197 Fd = feed in kg

198 Lb= labour in man-days

199 Ft = fertilizer in kg

200 Ta = total pond area in ha

201 $\alpha, \beta_1, \dots, \beta_5$ are parameters to be estimated and e is an error term
 202 The analysis of the linear relationship between the input variables; Ta, Lb, Ft, Fg and Fd ,
 203 and the dependent variable Y as explained in equation 6, is presented in **appendix 1**. The
 204 result shows a positive relationship between Fish output (Y) and the input variables; $Ta, Lb,$
 205 Fg and Fd , and a negative relationship between Ft , with an R-squared value of 0.789671.
 206 The multiple regression model shows the relationship as presented in equation **7, below:**
 207
$$Yd = -484.9672 + 1259.829Ta + 0.2522Lb - 2.3136Ft + 0.0908Fg$$

 208
$$+ 0.1822Fd \quad (7)$$

 209 $R^2 = 0.79, F - stat. = 29.28 (Prob.: 0.0000), N = 45$
 209 (See full results presented as appendix 1)

211 4.2 Data Exploration

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

223 4.3 Normality Test

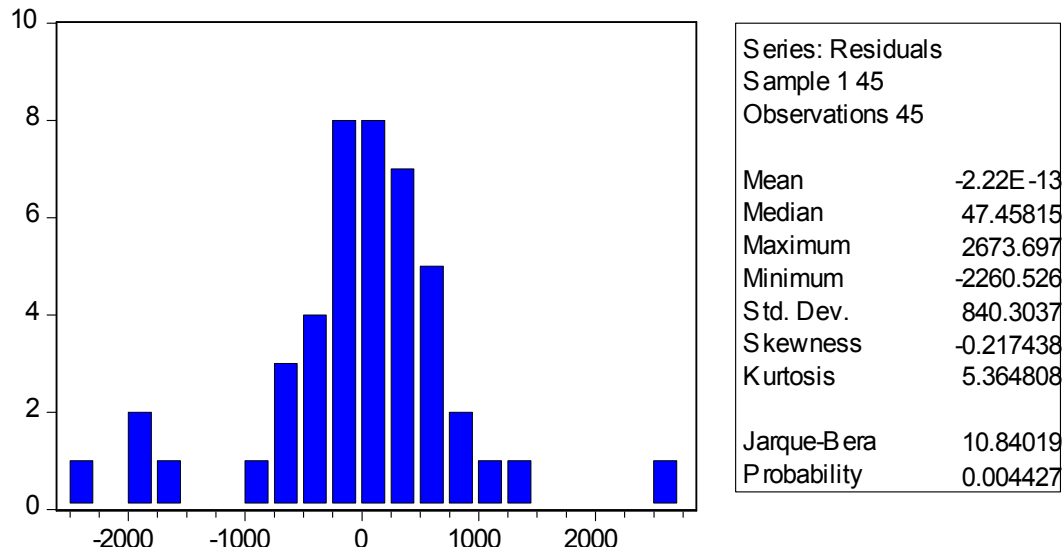
224 The normality test is used to test the following hypothesis:

225 **Ho:** The residuals are normally distributed

226 H_1 : The residuals are not normally distributed

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

235 correlation among the variables used in the analysis. Thus the next section tackles this
 236 aspect of the analysis.



237
 238 Figure 5. Normality test

239
 240

241 4.4 Test for Heteroskedasticity

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

245 H_0 : Heteroskedasticity is absent among residuals

246 H_1 : Heteroskedasticity is present among residuals

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

257

258 4.5 The Cobb-Douglas Production Function

259 This production function is a power production function of the form

$$260 Y = a Fg^{\beta_1} Fd^{\beta_2} Lb^{\beta_3} Ft^{\beta_4} Ta^{\beta_5} e \quad (8)$$

261 Taking natural logarithm on both sides of the equation gives:

$$262 \ln Y = \ln a + \beta_1 \ln Fg + \beta_2 \ln Fd + \beta_3 \ln Lb + \beta_4 \ln Ft + \beta_5 \ln Ta + e \quad (9)$$

263 Where Y = Fish output in kg

264 Fg = number of fingerlings stocked per pond

265 Fd = feed (kg)

266 Lb = labour (man-days)

267 Ft = fertilizer (kg)

268 Ta = total area in ha

269 Ln = natural logarithm

270 a, $\beta_1, \dots, \beta_4$ are parameters to be estimated and e is an error term

271 The estimated model for the relationship described in equation 9, is presented in equation

272 10, the result shows a positive relationship between LnY and LnTa, LnLb, LnFg and LnFd,

273 with a negative coefficient for LnFt.

274

$$275 \ln Y = 2.17774 + 0.3987 \ln TA + 0.0783 \ln LB - 0.2595 \ln FT + 0.3303 \ln FG + \\ 276 0.3487 \ln FD \quad (10)$$

$$277 R^2 = 0.61, F - stat. = 12.07297 (Prob.: 0.0000)$$

278 (See full results in Appendix 3).

279

280 4.6 Data Exploration

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

285 Unlike in the case of the linear production function, the scatter diagram for the Cobb Douglas
286 Production function shows the observations spread almost evenly about the regression line.

287 Like the linear function, however, all the independent variables are shown in the graphs to
288 have a positive relationship with the dependent variable. These indicate that linearizing the
289 Cobb-Douglas production function with logarithm gives a better representation of the
290 relationships that exist among the variables than the normal linear model discussed **above.**

291 Having explored the data, the various diagnostic tests on the error term were conducted.
292 These tests included the heteroskedasticity test and the normality test.

293

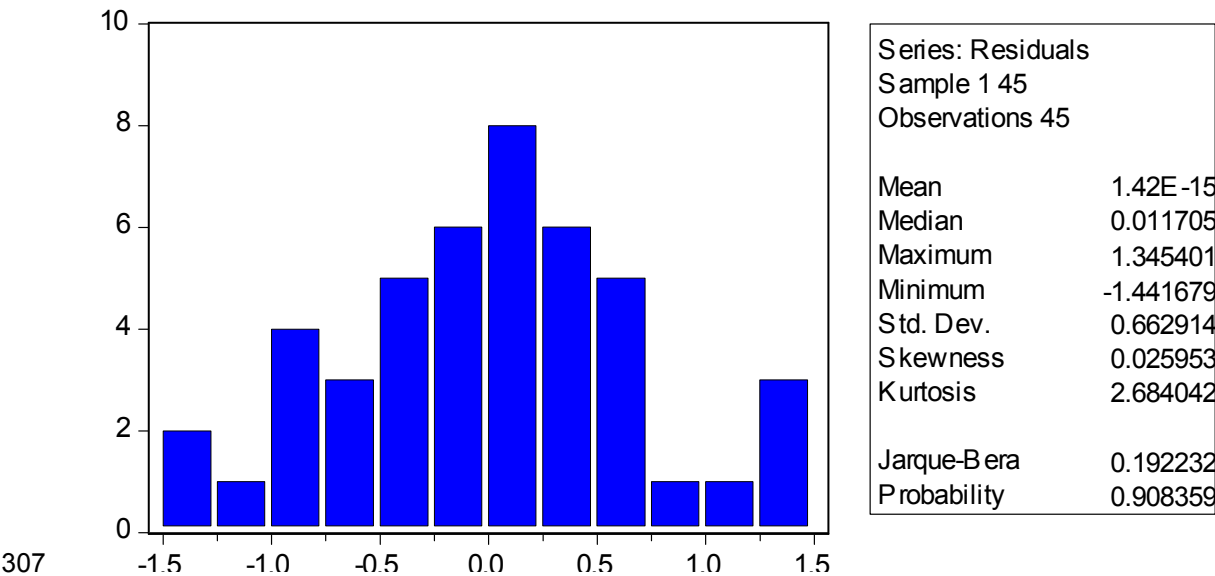
294 **4.7 Normality test**

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

298 H_0 : The residuals are normally distributed

299 H_1 : The residuals are not normally distributed

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



307
308 Figure 10: Normality test

309

310

311 **4.8 Test for heteroskedasticity**

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

315 H_0 : Heteroskedasticity is absent among residuals

316 H_1 : Heteroskedasticity is present among residuals

317 As shown in appendix 4, the probability value of 0.036 of the Obs*R-squared value of 19.28
318 indicates nonsignificance at the 1% level (though it may be argued that this is significant at
319 5%). The null hypothesis which states that the residuals are homoskedastic or that
320 heteroskedasticity is absent is subsequently not rejected. Since the heteroskedasticity
321 assumption is also not violated at 5%, it is an indication that the estimates obtained are
322 consistent, efficient and not biased.

323

324 **4.9 Discussion of Results from the Cobb-Douglas Production** 325 **Function**

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

342

343

344 **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:

$H_0: \beta_1 = \beta_2 = \beta_3 = \beta_k = 0.$

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

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.

The t-Test

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

$H_0: \beta_i = 0$

$H_1: \beta_i \neq 0$

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;

$$\ln YD = 0.399 \ln TA + 0.330 \ln FG + 0.349 \ln FD + 2.177 \quad (11)$$

$(0.239)(0.196)(0.207)$

(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; $\epsilon = \sum \epsilon_i$, 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 $\alpha > 1$), 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	t-value	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
$\sum \epsilon$	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.

ACKNOWLEDGEMENT

The authors acknowledge the various assistance provided by Dr. J. A. Bakang, Mrs Irene Idun, Dr. S. C. Fialor and Dr. Victor Owusu at various stages of this research.

COMPETING INTERESTS

The authors declare that no competing interests exist.

AUTHORS' CONTRIBUTIONS

This research was part of author CC's B.Sc. 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.

REFERENCES

1. Food and Agriculture Organization of the United Nations Organization (FAO). *State of World Aquaculture, 2006*. F.A.O Fisheries Technical Paper 500., Rome.
2. Food and Agriculture Organization of the United Nations Organization (FAO). *Results of the 2003-2004 Baseline Survey of Ghanaian Fish Farmers*. F.A.O Regional Office for Africa, Accra. 2005: 77.
3. Food and Agriculture Organization of the United Nations Organization (FAO). *National Aquaculture Sector Overview, Ghana*, 2008. Accessed 15 April 2009. Available at: http://www.fao.org/fishery/countrysector/naso_ghana/en
4. Aggrey-Fynn E. The Contribution of the Fisheries Sector to Ghana's Economy. Paper Prepared on behalf of the FAO as an input into the Sustainable Fisheries Livelihood Study, 2001. Accessed 5 April 2009. Available at: www.fao.org.
5. Ghana Statistical Service(GSS). Population Data analysis, 2005. Accessed 3 May 2009. Available at: <http://www.statsghana.gov.gh/nada/index.php/catalog/5/sampling>
6. Food and Agriculture Organization of the United Nations Organization (FAO). *Inland Water Resources and Aquaculture Service Aquaculture Extension in Sub Saharan Africa*, 2004. F.A.O Fisheries Circular no. 1002, Rome.
7. Coche AG, Haight B and Vincke M. *Aquaculture development and research in sub-Saharan Africa: Synthesis of national reviews and indicative action plan for research*. CIFA Technical Paper. No. 23:1994:151. Accessed 5 April 2009. Available at: <http://www.fao.org/docrep/005/T3340E/T3340E00.htm>
8. Akpan OE. Economics of Production: Theory, Principles and Applications. Calabar: Wusen Press Limited, 2006.
9. Constantin PD, Martin LM and Rivera EBBR. Cobb-Douglas, Translog Stochastic Production Function and Data Envelopment, *Journal of Operations and Supply Chain Management*; 2009; 2 (2): 20 - 34, International Conference of the Production and Operations Management Society.
10. Mohaddes S.A and Mazhari M. *Total and Input Factor Productivity Analysis of Poultry Production in Khorasan Province, Iran*. American-Eurasian J. Agric. & Environ. Sci., 2 (Supple 1): 2008: 151-154.

- 478 11. Cobbah MA. *State of Fish Farming in the Amansie-West District*. Unpublished Bachelor
479 of Science Dissertation, 2008. Faculty of Renewable Natural Resources, KNUST,
480 Kumasi, Ghana.
- 481 12. Ghanadistrict. Amansie West, Ashanti Region of Ghana. Accessed 7 December 2013.
482 Available: <http://www.ghanadistricts.com>
- 483 13. Seyoum ET, Battese GE and Fleming EM. *Technical efficiency and productivity of*
484 *maize producers in eastern Ethiopia: A study of farmers within and outside the*
485 *Sasakawa-Global 2000 project*. Agricultural Economics, 1998; (19): 341-348.
- 486 14. Kurbis G. *An Economic Analysis of Tilapia Production by Small-scale Farmers in Rural*
487 *Honduras*. Unpublished Master of Science Thesis. Department of Agricultural
488 Economics and Farm Management University of Manitoba Winnipeg, Manitoba, 2000.
- 489 15. Pindyck RS and Rubinfeld DL. *Econometric Models and Economic Forecasts*, 4th Ed.
490 Boston: McGraw-Hill, 1997.

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492 **Appendix1.: 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

493 * denotes significance at 5%

494 *** denotes significance at 1

495 Source: Analysed from survey data, 2009.

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Appendix2.: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.

Appendix3. 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.

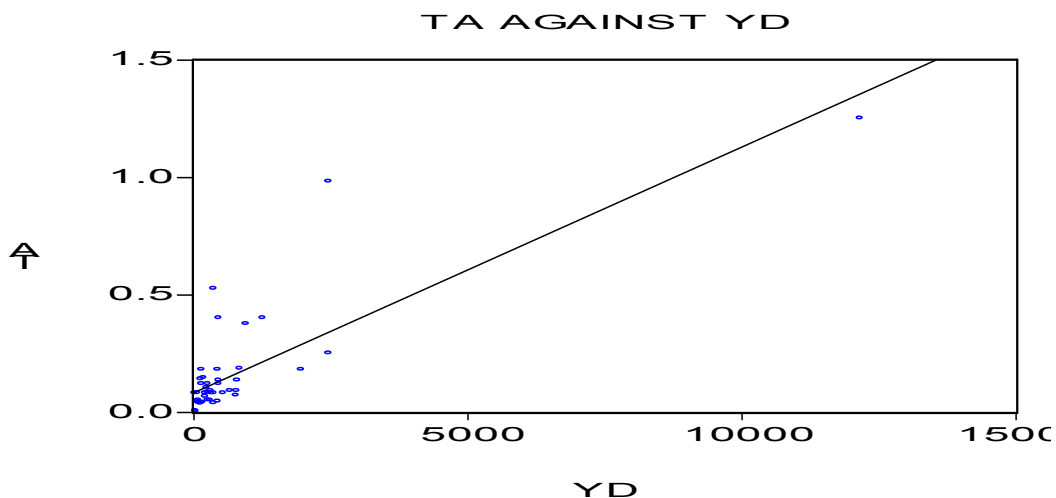
Appendix 4: White Heteroskedasticity Test:

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

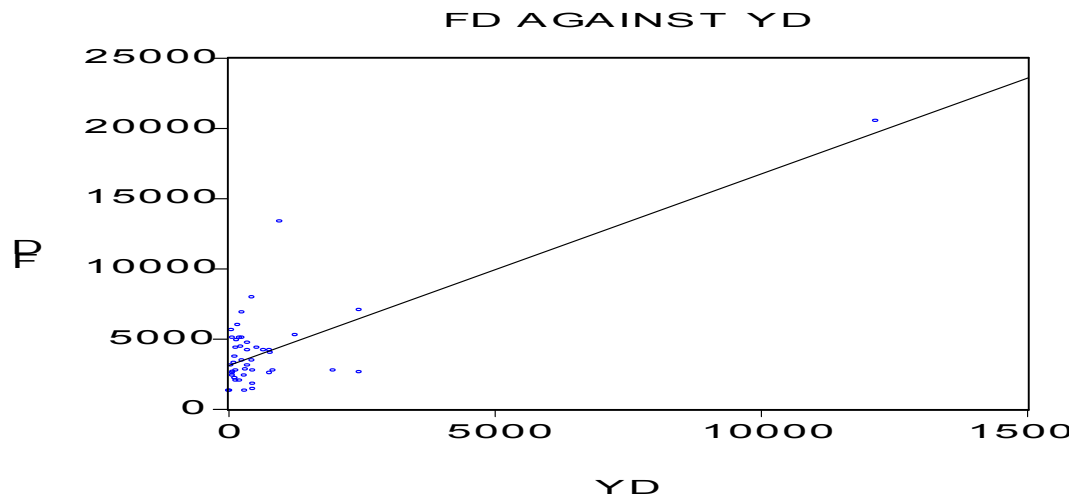
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Fig 1. Graph of total pond area against yield of fish in the Amansie- West District

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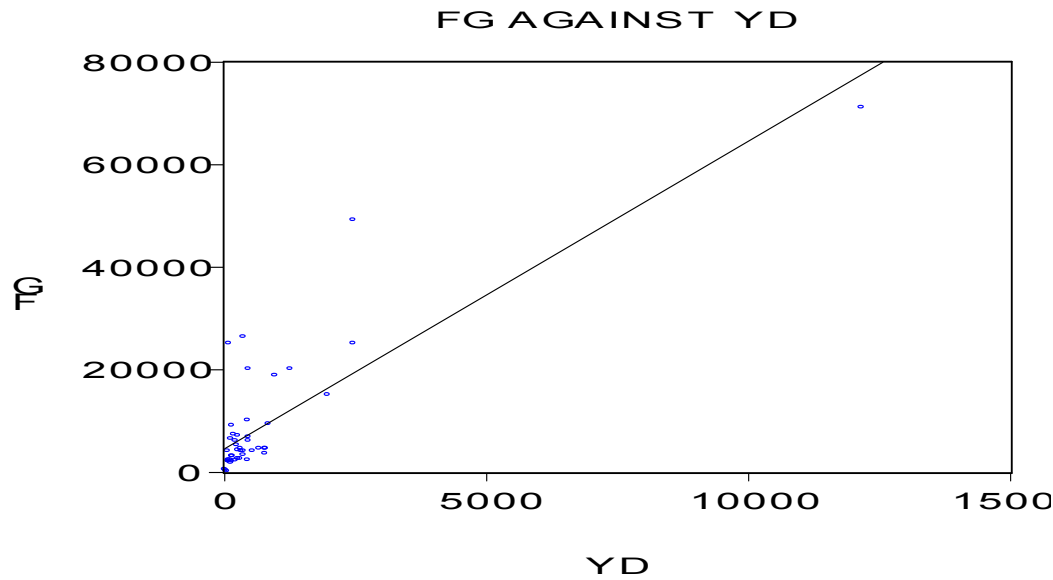
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Fig 2. Graph of feed against yield of fish in the Amansie- West District

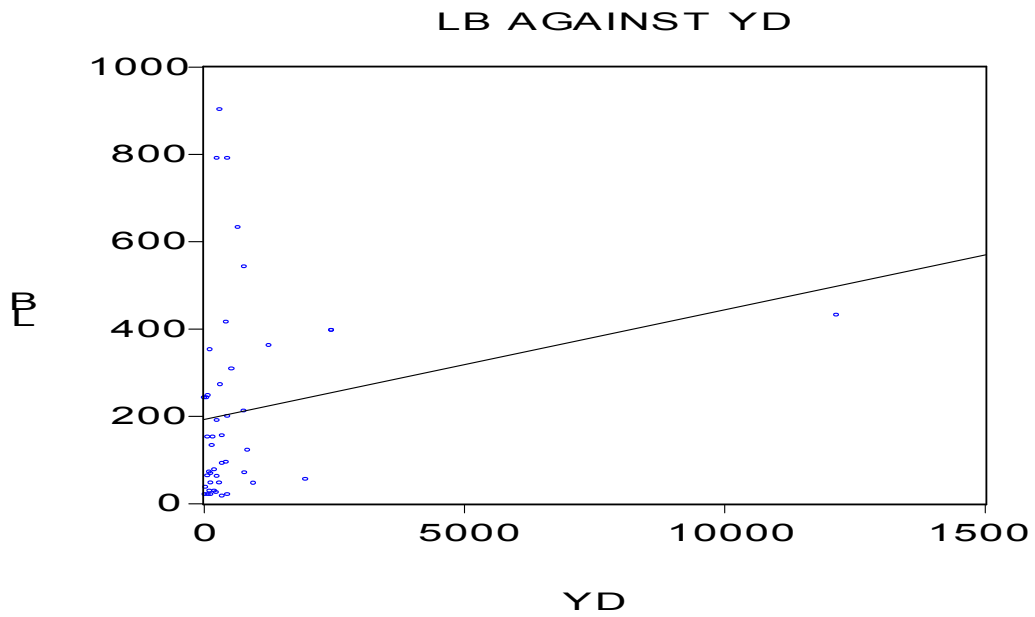


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Fig 3. Graph of number of fingerlings against yield of fish



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

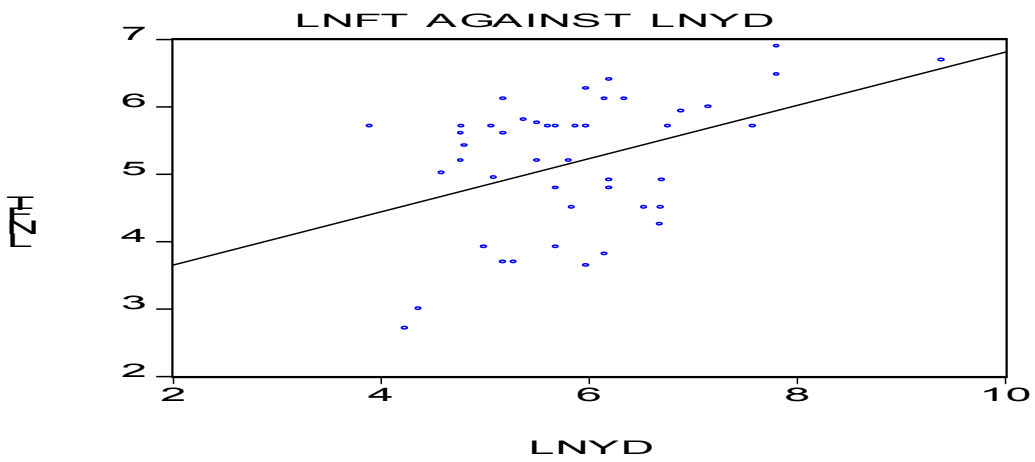
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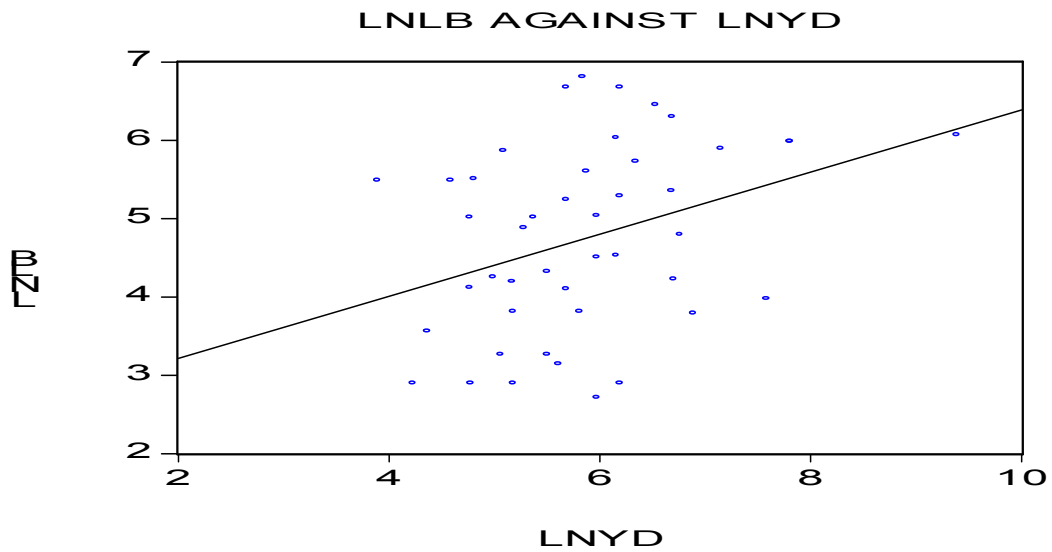
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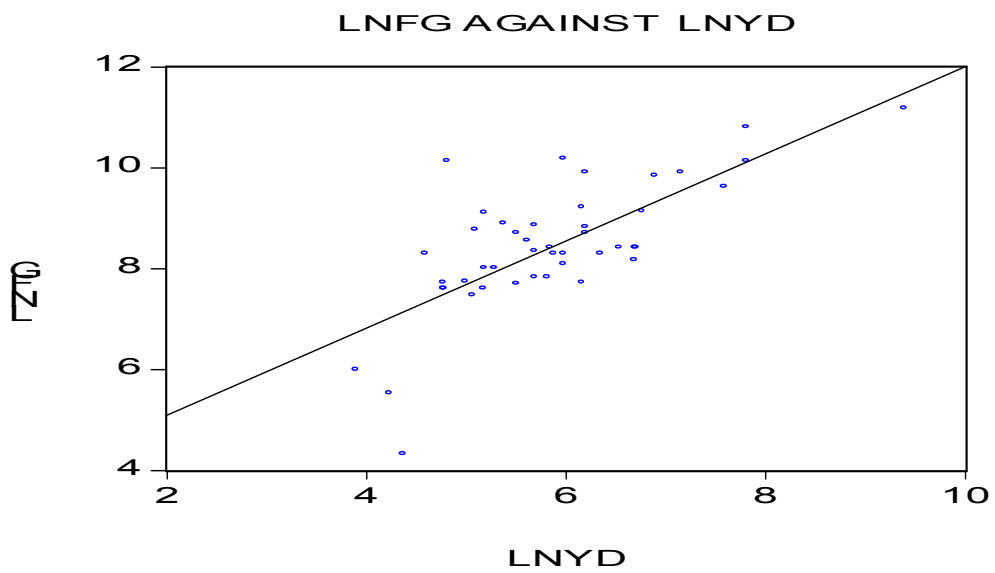
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545 Figure 6: Graph of LnFT against LnYD

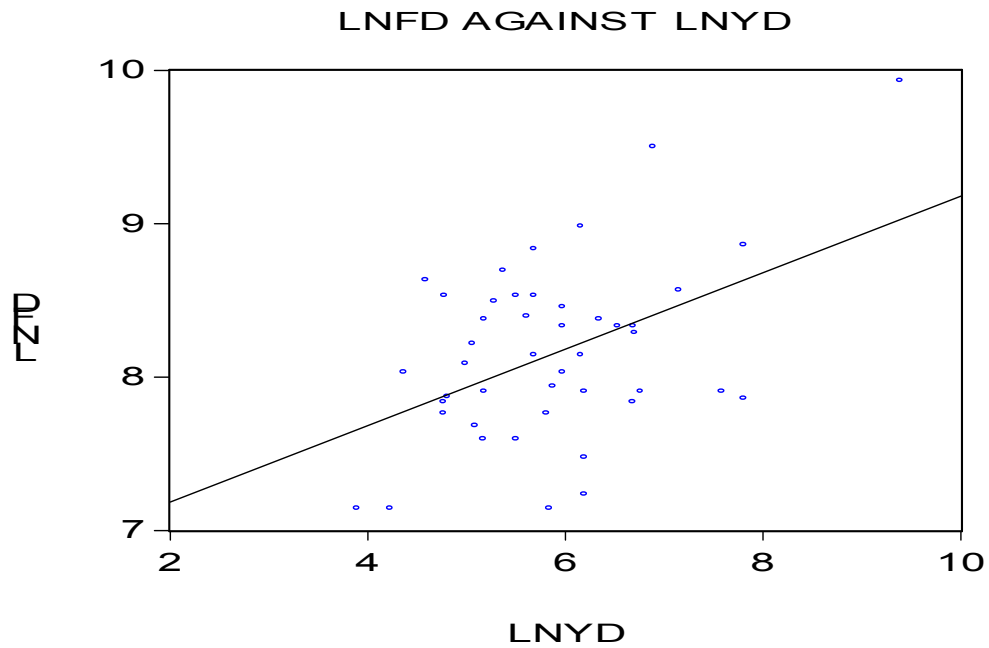
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 548 *Figure 7: Graph of $\ln LB$ against $\ln YD$*
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 553 *Figure 8: Graph of $\ln FG$ against $\ln YD$*
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557 Figure 9: Graph of **LnFD** against LNYD
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