Agris on-line Papers in Economics and Informatics

Volume III Number 2, 2011

A Stochastic Production Investigation of Fish Farms in Ghana

E. E. Onumah[1] and H. D. Acquah[2]

[1] Department of Agricultural Economics and Agribusiness, University of Ghana.
[2] Department of Agricultural Economics and Extension, University of Cape Coast, Ghana.

Abstract

This paper considers the stochastic production frontier approach to analyse the technical efficiency and its determinants of fish farms in Ghana using a cross-section data of 150 farms. It considers the explicit effects of family and hired labour on production by setting the log-value of the zero-observation of these two sources of labour to zero with dummy variables. Results demonstrate that expected elasticities of mean output with respect to all input variables are positive and significant. Findings also show that family and hired labour used for fish farming in Ghana may be equally productive. Fish farms in Ghana are revealed to be characterised by technology with increasing return to scale. The combined effects of operational and farm specific factors are found to influence efficiency. The study further reveals that inclusion of interaction between some exogenous variables in the inefficiency model is significant in explaining the variation in efficiency. Results also suggest that small pond operators are more efficient than farms with large ponds. Mean technical efficiency is estimated to be 78 percent.

Key words

Technical efficiency, stochastic frontier, elasticity, return to scale.

Introduction

The contribution of the fisheries sector to the economic development of Ghana is enormous. The sector provides income, employment and serves as a major supply of protein intake in the country. Consumption of fish ranges from 20 to 30 kg per capita with an average per capita consumption of 27.2 kg per annum, making Ghana one of the highest fish-consuming countries in Africa. The two main sources of fish in the country (traditional marine and inland fisheries) contribute about 435,000MT per annum which is about 400,000MT less of what the country demands (Attah-Mills et al., 2004). It is estimated that Ghana spends about $125 million dollars a year to import fish products to supplement domestic production. This is not only inadequate but also a drain on the nation’s scarce foreign exchange.

Due to these problems, the government considers fish farming as a major means of efficiently increasing fish production to bridge the gap between domestic demand and supply and to produce surpluses for export. In view of this point, banks were directed to enhance finance for pond construction at subsidised interest rate in the 1980s. This motivated both male and female individual farmers, farm families and union or cooperative groups to consider fish farming either as a full-time occupation or as a part-time business. This attracted a number of farmers into the industry which resulted in the increase use of agricultural lands for fish farms. Moreover, since the inception of the industry, the fish farming activity has not seen any major technological improvement to boost production due to inadequate resources (MacPherson et al., 1990). Based on these challenges, efficiency study is paramount to raise productivity by improving output without increasing the resource base or developing new technologies.

A variety of frontier techniques have been considered for technical efficiency studies across the globe in many countries. Whilst the two-stage approach (Pitt and Lee, 1981) outperforms the earlier approaches of Aigner et al. (1977), Kumbhakar et al. (1991); Huang and Liu (1994); and Battese and Coelli (1995) criticise this technique on the ground that the specification of the second-stage model violates the assumption of the identically distributed technical inefficiency effects in the stochastic frontier and propose a single-stage modelling method in which parameters in the frontier and inefficiency models are estimated simultaneously. Application of this methodology in the fisheries and fish farming sector is outlined by Kirkley et al. (1995); Iinuma et al. (1999); Dey et al. (2000); and Chiang et al. (2004).

However, most of these studies fail to account for interactive effects of the exogenous variables on efficiency. Moreover, in order to avoid the problem of zero observation in the estimation of frontier production function, majority of the technical efficiency studies implicitly assume equal productivity and aggregate family and hired labour to assess their effect on production. Although some studies separately consider family and hired labour variables in the frontier model (Heshmati and Mulugeta, 1996), their study is confined to farmers who use positive values of these two sources of labour and discard cases with zero observations. Discarding parts of the observations appears to be unappealing since the available data do not seems to be fully utilised. Thus, some authors treat the zero-observation case by using values of one or an arbitrarily small number greater than zero for the key input concern. This procedure may result in serious bias estimators of the production function as notes by Battese (1997).

Against this background, the present study applies the single-stage modelling stochastic frontier approach to examine technical efficiency and its determinants of fish farms in Ghana and extends the scope of the analysis to explore the issues of interactive effects of some exogenous variables on efficiency of production using a modified model of Huang and Liu (1994) and Battese and Coelli (1995). In addition, the study adopts a model by Battese and Broca (1997) to examine output elasticity with respect to the various inputs used to assess how changes in such input resources could boost productivity. Further, guided by Battese et al. (1996) and Battese (1997), the study examines explicitly the effect of family and hired labour on production by setting the log-value of the zero-observation of these two sources of labour to be zero with dummy variables. This procedure ensures that efficient estimators are obtained using the full data set without introducing any bias. The rest of the paper is divided into three sections. Section 2 discusses the materials and methods. Results and discussion are presented in section 3, whilst conclusion and policy recommendation are outlined in section 4.

Material and methods

The stochastic frontier technique

The two main methodologies for the estimation of technical efficiency include: the Data Envelopment Analysis (DEA) which involves mathematical programming and the Stochastic Frontier Analysis (SFA) which uses econometric methods. This study adopts the stochastic frontier approach as it is preferred because of the inherent stochasticity involved (Aigner et al., 1977; and Meeusen and Van den Broeck, 1977). The SFA specifies output variability by a non-negative random error term (u) to generate a measure of technical inefficiency as considered also by advocates of the deterministic approach (Afriat, 1972) and a symmetric random error (v) to account for effects of exogenous shocks beyond the control of the analysed units which embodies variation in weather conditions, diseases, poaching etc, measurement errors and any other statistical noise

Assuming a transcendental logarithmic production function, this study specifies the stochastic frontier model as:

$$\mathbf{ln}Y_i = \beta_0 + \psi_1 DFL_i + \psi_2 DHL_i + \sum_{j=1}^{6}\beta_j \,\mathbf{ln}X_{ji} + 0.5\sum_{j=1}^{6}\sum_{k=1}^{6}\beta_{jk}\,\mathbf{ln}X_{ji}\mathbf{ln}X_{ki} + (\boldsymbol{v_i} - \boldsymbol{u_i}) \quad (1)$$

where i and ln are the ith farmer and logarithm to base e, respectively.

(Y) Output, is expressed as quantity of fish harvested in kilograms;

(DFL) is a dummy variable equal to one if the number of family labour used is positive, zero otherwise;

(DHL) is a dummy variable equal to one if the number of hired labour used is positive, zero otherwise (X_1) $FLabour$ denotes the number of family labour used (measured in man-days[19]). *Ln* (X_{1i}) in model (1) is expressed as *Ln* [max(*FLabour*$_i$,1-*DFL*$_i$)]

(X_2) *HLabour* represents the number of hired labour used (measured in man-days)

Ln (X_{2i}) in model (1) is expressed as *Ln* [max (*HLabour*$_i$, 1-*DHL*$_i$]

(X_3) Feed, represents cost of feed in Ghana Cedi (GHC);

(X_4) Seed, indicates quantity of fingerlings (fry), measured in kilograms;

(X_5) Land, is the total area of pond(s) operated, measured in hectares;

(X_6) Other cost, denotes cost of intermediate inputs in GHC. It includes: cost of chemicals, fertilizer, fuel, electricity, farm rent, maintenance cost, depreciation cost.

(v) Represents a stochastic error term (e.g. measurement errors, extreme weather, industrial action, poaching and other noise errors such as misspecification problems);

(u) Denotes a non-negative random variable associated with farm-specific factors which contribute to farms not achieving maximum efficiency.

The expressions:

Ln [max(*FLabour*$_i$,1-*DFL*$_i$)] and

Ln [max (*HLabour*$_i$, 1-*DHL*$_i$]

account for zero usage of family and hired labour respectively by some farmers, whilst *DFL* and *DHL* account for intercept change. The estimator for the responsiveness of fish farm output to use of hired and family labour could be bias without inclusion of *DFL* and *DHL* (Battese, 1997). This study assumes that the elasticities of output associated with other variables are the same for farmers who did not use either hired or family labour and those who did.

The stochastic error term (v) is commonly assumed to be independently, identically and normally distributed with zero mean and constant variance, $\sigma_v^2, [v_i \sim N(0, \sigma_v^2)]$. Different distributions namely: half-normal, truncated, exponential and gamma distributions have been assumed with varied specifications for the inefficiency error term (u) in the literature. However, this study considers a model by Battese and Coelli (1995) which assumes that u1 is distributed as a truncation of the normal distribution with mean μi and a constant variance20,
$[u_i \sim N(\sigma_u^2)]$ such that the mean is defined as:

$$\mu_i = Z_i \delta \quad (2)$$

where Z_i is a *(Px1)* vector of explanatory variables associated with the technical inefficiency effects which could include socioeconomic and farm management characteristics. δ is a *(1xP)* vector of unknown parameters to be estimated. Huang and Liu (1994) also purport the non-neutral stochastic frontier model defined as:

$$\mu_i = Z_i \delta + Z_i^* \delta^* \quad (3)$$

where Z_i^* is a vector of values of interactions between farm specific factors and input variables and δ^* is a vector of unknown parameters. Their model implies that a shift in the frontier for different farms depend on the level of the input variables, whilst elasticities of the mean output for different farms are functions of the particular farm specific variables involved in the vector of explanatory variables. When the coefficients in the vector $\delta^*$are zero, this model reduces to model (2) of Battese and Coelli (1995). However, this study adopts a modification of the models by Huang and Liu (1994) and Battese and Coelli (1995) and specifies μ_i as:

$$\mu_i = \varphi_0 + \sum_{m=1}^{7} \delta_m Z_{mi} + \sum_{n=1}^{3} \omega_n I_{ni} + \pi L_i \quad (4)$$

where,

[19] Man-days are computed according to the rule that one adult male, one adult female and one child (< 18 years) working for one day (8 hours) equal 1 man day; 0.75 man days; and 0.50 man days respectively. Battese et al. (1996) and Coelli and Battese (1996) also employ the use of these ratios.

[20] Caudill and Ford (1993) parameterise the variance of the pre-truncated distribution of the inefficiency term u_i as a function of exogenous variables in an attempt to address the problem of heteroskedasticity. However, earlier check by the study for heteroskedasticity in the residual using Breusch-Pagan test is revealed to be negative.

(Z_1) Gender dummy; has the value of 1, if farm decision maker is a male or 0, for a female;

(Z_2) Cultural system dummy; has the value of 1, if monoculture is practiced or 0, if poly-culture is the adopted practice;

(Z_3) Age; represents the age of the primary decision maker;

(Z_4) Education; represents the maximum level of formal schooling[21] for a member of the household;

(Z_5) Pond type dummy; has the value of 1, if the farm uses earthen pond or 0, if concrete pond is used

(Z_6) Eastern region dummy; has the value of 1, if farm is located in Eastern region or 0, if otherwise.

(Z_7) Ashanti region dummy; has the value of 1, if farm is located in Ashanti region or 0, if otherwise. Greater Accra region is considered as the base. Region-specific dummy variables are included to capture regional influence on technical efficiency of production.

(l_1) AgeExp; represents the interaction of age and experience of primary decision maker;

(l_2) AgeEv; represents the interaction of age of primary decision maker and extension visit;

(l_3) EduFAE; represents the interaction of maximum level of formal schooling and formal fish farming education for a member of the household;

(L) Land input; is total pond area and it is used as a proxy to capture size effect.

φ_0, δ, s, ω,s and π are unknown parameters to be estimated. μ is the pre-truncated mean of u and it is parameterized as a function of Z in order to relate Z to the distribution of the inefficiency (u).

[21] Ranking of level of formal schooling in Ghana is outlined as: None ⇒ 0; Primary level ⇒ 1; Junior Secondary/Middle School level ⇒ 2; Senior Secondary level ⇒ 3; Technical School level ⇒ 4; Polytechnic level ⇒ 5; University (bachelor) level ⇒ 5; and University (graduate or above) level ⇒ 7.

Elasticities

The estimated coefficients in the translog stochastic frontier production function (1) do not have straight forward interpretation. Considering this function, the output elasticities with respect to the inputs are functions of the first-order and the second-order coefficients together with the level of inputs. Further, since the input variable land in this study is a factor involved in both the stochastic frontier model (1) and the inefficiency model (4), the output elasticity with respect to this input variable is a function of the value of the input in both the frontier and the inefficiency models. This study follows Battese and Broca (1997) to derive the elasticities of mean output with respect to the different inputs. The sum total of the output elasticities is the estimated scale elasticity (ε). When, $(\varepsilon) > 1 \Rightarrow$ increasing return to scale (IRS), $(\varepsilon) < 1 \Rightarrow$ decreasing return to scale (DRS), and $(\varepsilon) = 1 \Rightarrow$ constant return to scale (CRS).

The maximum likelihood estimates of the parameters involved in the frontier and inefficiency models are obtained using the Ox version 4.10 (windows) (C) J. A. Doornik, specifically, the SFAMB package (Brümmer, 2003). The technical efficiency of the ith farm, denoted by TE_i is defined as the ratio of the mean of production for the ith farmer, given the value of the inputs, X_i, and its technical inefficiency effect, u_i, to the corresponding mean of production if there were no inefficiency of production (Battese and Coelli, 1988). This is expressed as:

$$TE_i = \frac{E(Y_i|X_i,u_i)}{E(Y_i|X_i,u_i=0)} = \exp(-u_i) \qquad (5)$$

The measure of TE_i has a value between one and zero, where one indicates a fully efficient farm and zero implies a fully inefficient farm. The estimation of the parameters are obtained in terms of the parameterisation: $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/\sigma^2 = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$, where for 0<$\gamma$<1, output variability is characterised by the presence of both technical inefficiency and stochastic errors (Battese and Corra, 1977).

Hypotheses test

A number of hypotheses are tested to examine the adequacy of the specified models, presence of inefficiency and relevance of variables in explaining inefficiency etc. (Table II). These tests are investigated using the generalised likelihood-ratio statistic (LR) which is given by: $LR = -2[ln\{L(H_0)\} - ln\{L(H_1)\}]$, where $L(H_0)$ and $L(H_1)$ are values of likelihood function under the null (H_0) and alternative (H_1) hypotheses, respectively. LR has approximately a Chi-square (or mixed Chi-square) distribution if the given null hypothesis is true with a degree of freedom equal to the number of parameters assumed to be zero in (H_0). Coelli (1995) proposes that all critical values can be obtained from appropriate Chi-square distribution. However, if the test of hypothesis involves γ=0, then the asymptotic distribution necessitates mixed Chi-square distribution (Kodde and Palm, 1986).

Data and sampling technique

The study is conducted in three regions of Ghana namely: Greater Accra, Ashanti and Eastern regions. Consideration of these regions for the study is based on concentration of fish farms. A total of five sub-districts from each region were randomly selected. Consequently, the selected sub-districts represent the average condition of the respective regions fairly well. Ten fish farms from each sub-district were chosen for detailed data collection. The overall sample for analysis is 150 farms from the three regions. During the data collection, a well structured questionnaire designed to obtain relevant socioeconomic characteristics, farming practices, output, inputs and price data is employed. Summary statistics of data collected through the survey are provided in Table I.

Results and discussion

Hypotheses test

The first hypothesis that the coefficients of the second-order variables in the translog model are zero, meaning that the Cobb-Douglas frontier is an adequate representation for the data is strongly rejected (Table II). This indicates that the specification for the translog stochastic frontier production function is more suitable to derive conclusions in the data. Both the test for the absence of inefficiency effects and that inefficiency effects are not stochastic in the second and third hypotheses, respectively are strongly rejected. Hence, the traditional average (OLS) function is not an adequate representation for the data. The fourth hypothesis that the intercept and the coefficients associated with farm-specific variables in the technical inefficiency model are zero (that the technical inefficiency effects have a traditional half-normal distribution with mean zero) is strongly rejected. The fifth hypothesis that all coefficients, except the constant term of the inefficiency model are zero (hence the technical inefficiency effects have the same truncated-normal distribution with mean equal to δ_0) is also rejected. This reveals that the combined effects of factors involved in the technical inefficiency model are important in explaining the variation in production of fish farms in Ghana, although individual effects of some variables may not be significant. Given the specification of model (4), the sixth hypothesis that model (2) is an adequate representation of the data i.e. $\omega_1 = \omega_2 = \omega_3 = \pi = 0$, is rejected. This implies that inclusion of the interactions between age and experience of the primary decision maker; age and extension visit to farms; formal schooling and formal fish farming education for a member of the household; and total pond area in the inefficiency model are significant in explaining variation in efficiency.

Frontier model estimates

This study discusses the parameter estimates of the stochastic production frontier model (1) in terms of output elasticities evaluated at the mean values with respect to the various inputs (Table III). The expected elasticities of mean output with respect to all the input variables are positive and significant. Land is found to have the highest elasticity of 0.42, indicating that a 1% increase of pond size will increase production by 0.42%. This means that family labour, hired labour, land, feed, seed and other cost have reasserting influence on fish farming in Ghana. The computed return to scale is revealed to be 1.12 (0.082) and it is statistically different from 1. The return to scale, defined as the percentage change in output from 1% change of all input factors is more than one implying that fish farms in Ghana are characterised by technology with increasing return to scale. This means that if the industry increases all factor inputs by 1%, fish farm output in the study area would increase by 1.12%. Output elasticities with respect to family and hired labour are both significant but not statistically different from each other ($\alpha = 0.05$).

Variable	Minimum	Mean	Maximum	Standard deviation
Output	138	7929	73446	10666
DFL	0	0.91	1	0.29
DHL	0	0.52	1	0.50
Family labour	0	281.60	960	166.54
Hired labour	0	187.20	1620	249.66
Feed	159.42	3493.10	39554	5267.60
Seed	29	471.51	4356	691.02
Land	0.04	0.75	7	1.10
Other cost	141.98	2277.90	36233	4194
Gender	0	0.91	1	0.29
Cultural system	0	0.08	1	0.27
Age	28	49.84	71	9.32
Pond type	0	0.93	1	0.25
Education	0	4.24	7	1.29
Eastern region	0	0.33	1	0.47
Ashanti region	0	0.33	1	0.47
AgeExp[a]	58	382.92	1475	260.62
AgeEv[b]	0	9.53	60	18.71
EduFAE[c]	0	0.46	7	1.43
Land	0.04	0.75	7	1.10

a ≡ interaction between age and experience of primary decision maker, b ≡ interaction between formal schooling and formal aquaculture education, c ≡ interaction between age of primary decision maker and extension visit.

Table 1: Summary of variables in the frontier and inefficiency models.

Null hypothesis	Test statistics (λ)	Critical value $\left(\lambda^2_{0.001}\right)$	Decision
1. $H_0 : \beta_{ij} = 0$	178.60	46.80	Reject H_0
2. $H_0 : \gamma = \varphi_0 = \delta_i = \omega_i = \pi = 0$	102.68a	33.82	Reject H_0
3. $H_0 : \gamma = 0$	17.06a	9.50	Reject H_0
4. $H_0 : \varphi_0 = \delta_i = \omega_i = \pi = 0$	85.54	32.91	Reject H_0
5. $H_0 : \delta_i = \omega_i = \pi = 0$	68.32	31.26	Reject H_0
6. $H_0 : \omega_1 = \omega_2 = \omega_3 = \pi = 0$	30.42	18.47	Reject H_0
Other hypotheses test			

7. $H_0 : \psi_1 = \psi_2 = 0$	21.96	13.82	Reject H_0
8. $H_0 : \pi = 0$	32.85	10.83	Reject H_0
9. $H_0 : \delta_6 = \delta_7 = 0$	0.28	5.99b	Accept H_0

a ≡ test of one sided error from the Ox output. b ≡ critical value at 0.05 level The correct critical values for the hypotheses involving γ are obtained from Kodde & Palm (1986).

Table 2: Hypothesis test for model specification and statistical assumption.

Elasticities with respect to					
Family labour	Hired labour	Feed	Seed	Landa	Other cost
0.07*	0.09	0.13*	0.17	0.42	0.24
(0.03)	(0.02)	(0.05)	(0.04)	(0.15)	(0.06)

* ≡ statistically significant at level of 0.05, all other estimates are significant at level of 0.01. Values in brackets are standard errors. a ≡ since the coefficient of land in the inefficiency model is positive, there is a negative contribution of the elasticity of technical efficiency in obtaining the elasticity of mean output for land.

Table 3: Elasticities of mean output.

This revelation may indicate that the two types of labour are equally productive. The intercept coefficient for family labour (DFL) and hired labour (DHL) are both estimated to be significantly negative. This implies that there could be bias estimators of the parameters in the frontier production function without inclusion of these dummies as confirmed by the rejection of the seventh null hypothesis ($H_0: \psi_1 = \psi_2 = 0$).

Inefficiency model estimates

The estimates of the inefficiency model are presented Table IV. The estimated gender dummy coefficient is significantly negative, indicating that farm decision makers who are males operate more efficiently than their female counterparts. Fish farming involves fairly continuous labour input for gruelling work and coupled with division of labour that assigns domestic role to women in Ghana as notes by Assibey-Mensah (1998), which allows little time to be spent on fish farms impedes efficiency of production. The coefficient of the cultural system dummy is revealed to be negative implying that fish farms involved in monoculture tend to be more technically efficient than farms growing several types of fish. However, the relationship is weak.

The coefficient of age is estimated to be positive and significant, indicating that older farmers are technically less efficient than the younger ones who are progressive and willing to implement new production systems. Further analysis reveals that estimated coefficient for older farmers who have greater number of years of experience in fish farming (AgeExp) demonstrate a significant positive effect on technical efficiency of production. Although many years of experience may infer adhering to old methods of production which may be technically less efficient, it is demonstrated by the current studies that the source of technical knowledge gained by the older farmers over the period in the business may be due to years of contacts with advisory services through extension personnel. This revelation is confirmed by the coefficient of the interaction between age and extension visit (AgeEv) which is estimated to be significantly negative. Many studies have shown that contact with advisory service is a positive factor in increasing agricultural productivity.

Battese et al. (1996) report a positive relationship between maximum years of formal schooling for a member of household and technical efficiency. In this study, the coefficient of education is estimated to be positive and significant, indicating that households with high level of formal schooling are less technically efficient. Fish farming requires proper technical know-how for higher productivity (Roy et al., 2002). Thus, when interaction of household with formal schooling and formal aquaculture education (EduFAE) is modelled to assess their effect on efficiency, the study demonstrates a positive impact. This means that formal education which enlightens farmers about the technical aspect of fish farming is more important in Ghana to enhance efficiency in the industry.

The coefficient of pond type dummy is also estimated to be significantly negative, implying that farmers who adopt the use of earthen pond for their operations tend to be less inefficient than concrete

Variables	Parameters	Coefficients	Standard error
Constant	φ_0	-0.542	0.626
Gender	δ_1	-0.321***	0.104
Cultural system	δ_2	-0.063	0.213
Age	δ_3	0.031**	0.013
Education	δ_4	0.097***	0.030
Pond type	δ_5	-0.124***	0.048
Eastern region	δ_6	0.014	0.044
Ashanti region	δ_7	0.018	0.038
AgeExpa	ω_1	-0.014**	0.005
AgeEvb	ω_2	-0.013**	0.006
EduFAEc	ω_3	-0.065**	0.033
Land	π	0.132**	0.053

*, **, *** ≡ statistically significant at levels of 0.10, 0.05, and 0.01, respectively. a ≡ interaction between age and experience of primary decision maker, b ≡ interaction between age of primary decision maker and extension visit, c ≡ interaction between formal schooling and formal aquaculture education.

Table 4: Inefficiency model estimates.

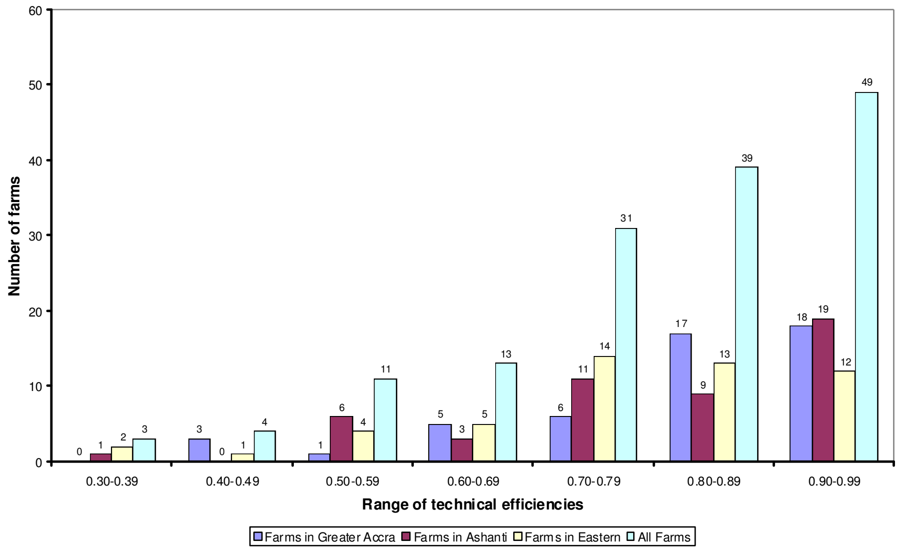

Figure 1: Frequency distribution of technical efficiencies.

pond users. In addition to supplementary feed, fish farmers in Ghana rely on production of fish food through natural process by fertilization. Earthen ponds may provide a good better for growth of live food. Pilley (1990) notes that most live food are rich in essential nutrients needed by fish for growth.

A varied relationship between farm size and technical efficiency in the developing countries using the frontier production function has been established (Lundvall & Battese, 2000). The coefficient of land in this study is estimated to be significantly positive, implying that larger farms suffer from an oversize problem, resulting in larger measures of technical inefficiency (at the mean) than comparably smaller farms. This finding is consistent with Chiang et al. (2004) who observe in Taiwan that smaller farms that produce 20-50 MT per hectare of milkfish operate close to the efficient frontier compared to big producers (> 50 MT per hectare). However, a contrary observation is revealed by Iinuma et al. (1999) in carp pond culture in Peninsula Malaysia, and Dey et al. (2000) in grow-out pond operations in the Philippines.

The coefficients of Eastern region and Ashanti region dummies are both positive but insignificant. This implies that location of farm according to regions may not influence technical efficiency of production in the study area. This is confirmed by the acceptance of the null hypothesis that there is $H_0: \delta_6 = \delta_1 = 0$ no regional effect. This finding may reveal that differences in the quality of inputs used, level of advisory services and support from government aquaculture offices etc. within the respective regions do not influence technical efficiency of production.

Technical efficiency

Figure 1 reports the distribution of the technical efficiencies of farms in the study area. The overall level of efficiency ranges from 34.3% to 98.4%. The frontier is built up by 49 farms (32.7%) found to be operating at efficiency levels of 90% or above. Only 7 farms (4.7%) belong to the least efficient category (30-49%). Majority of the farms (62.7%) operate with technical efficiency index between 0.50 and 0.89. When the study classifies location of farms by regions, no substantial variation in terms of mean technical efficiency is observed as confirmed by the acceptance of the null hypothesis $\delta_6 = \delta_1 = 0$ that there is no regional effect on technical efficiency of production. The predicted overall mean technical efficiency is estimated to be 0.78. This indicates that on the average, fish farms produce 78% of the potential (stochastic) frontier output, given the present state of technology and input level. However, 22% of technical potential output is not realised. Therefore, the possibility of increasing fish farm production in Ghana by an average of 22% can be achieved in the short run by adopting the practices of the best fish farm.

Conclusion and recommendation

This study adopts the single-stage modelling stochastic frontier approach to examine technical efficiency and its determinants of fish farms in Ghana. The study specifically examines the explicit effect of hired and family labour on production by setting the log-value of the zero-observation of these two sources of labour to be zero with dummies. It extends the conventional technical efficiency estimation technique to explore the issues of interactive effects of some farm specific variables on efficiency of production. The study finds that output elasticities with respect to all the inputs (family labour, hired labour, land, feed, seed and other cost) are significant and have the expected positive signs. Results also reveal that although elasticity of output with respect to hired labour is slightly higher than the value obtained for family labour, the two sources of labour used for fish farming in Ghana may be equally productive. The estimate of return to scale is more than one implying that fish farms in Ghana are characterised by technology with increasing return to scale. The combined effects of operational and farm specific factors are found to influence efficiency. Further, the study reveals that inclusion of interaction between some exogenous factors, and input variables in the inefficiency model are significant in explaining the variation in efficiency. Specifically, it is demonstrated that fish farms in the study area suffer from oversize problems whilst extension advice plays a major role in efficiency of production. Mean technical efficiency is estimated to be 78%, indicating that the realised output could be increased by about 22% without any additional resources.

Based on these findings, the study provides evidence to improve fish farm production through increase in technical efficiency. Allocation of resources to improve the level of formal fish education and extension services will play an important role in this respect. Formation of fish farm association should be encouraged to enhance coordination between young and old farmers. It will also be important to advice large farms on how to take advantage of economics of scale to improve efficiency. This study is pertinent since the Ghanaian economy appears to offer several challenges to increasing output directly, thus gains from improving efficient behaviour appear to be a viable option to increase output from the fish farms.

Corresponding author:
Edward E. Onumah
Department of Agricultural Economics and Agribusiness
University of Ghana, Post Office Box LG 68, Legon – Ghana.
Tel. 00233-542835782
Email: eonumah@ug.edu.gh

References

[1] Afriat, S. N. (1972): Efficiency estimation of the production function. International Economic Review, Vol. 13, pp. 568–598.

[2] Aigner, D. J., Lovell C. A. K., Schmidt, P. (1977): Formulation and estimation of stochastic frontier production function models. Journal of Econometrics, Vol. 6, pp. 21-37.

[3] Assibey-Mensah, G.O. (1998): Ghana's women-in-development program: problems, issues, and prescription. Journal of Black Studies, Vol. 29, No. 2, pp. 277-295.

[4] Atta-Mills, J., Alder, J., Sumaila, U.R. (2004): The decline of a regional fishing nation: the case of Ghana and West Africa. Natural Resources Forum, Vol. 28, pp. 13-21.

[5] Battese, G.E. (1997): A note on the estimation of Cobb-Douglas production functions when some explanatory variables have zero values. Journal of Agricultural Economics, Vol. 48, No. 2, pp. 250–252.

[6] Battese, G:E., Coelli, T.J. (1988): Prediction of firm-level technical efficiencies with a generalised frontier production function and panel data. Journal of Econometrics, Vol. 38, pp. 387–399.

[7] Battese, G.E., Corra, G.S. (1977): Estimation of a production frontier model: with application to the pastoral zone of Eastern Australia. Australian Journal of Agricultural Economics, Vol. 21, pp. 169–179.

[8] , G.E., Malik, S.J., Gill, M.A. (1996): An investigation of technical inefficiency of production of wheat farmers in four districts of Pakistan. Journal of Agricultural Economics, Vol. 47, No. 1, pp. 37–49.

[9] Battese, G.E., Broca, S.S. (1997): Functional forms of stochastic frontier production functions and models for technical inefficiency effects: a comparative study for wheat farmers in Pakistan. Journal of Productivity Analysis, Vol. 8, pp. 395–414.

[10] Battese, G.E., Coelli, T.J. (1995): A model for technical efficiency effects in a stochastic frontier production function for panel data. Empirical Economics, Vol. 20, pp. 325–332.

[11] Brümmer, B. (2003): Stochastic frontier analysis using SFAMB for Ox. Department of Agricultural Economics and Rural Development, Georg-August University, Göttingen.

[12] Caudill, S.B., Ford, J.M. (1993): Biases in Frontier Estimation Due to Heteroscedasticity. Economics Letters, Vol. 41, pp. 17–20.

[13] Chiang, F.S., Sun, C.H., Yu, J.M. (2004): Technical efficiency analysis of milkfish (Chanos chanos) production in Taiwain: an application of stochastic frontier production function. Aquaculture, Vol. 230, pp. 99–116.

[14] Coelli, T.J. (1995): Estimators and hypothesis tests for a stochastic frontier function: a monte carlo analysis. Journal of Productivity Analysis, Vol. 6, pp. 47–268.

[15] Coelli, T.J., Battese, G.E. (1996): Identification of factors which influence the technical inefficiency of Indian farmers. Australian Journal of Agricultural Economics, Vol. 40, pp. 103–128.

[16] Dey, M., Paraguas, M.F.J., Bimbao, G.B., Regaspi, P.B. (2000): Technical efficiency of grow-out pond operations in the Philippines. Aquaculture Economics and Management, Vol. 4, No. 1&2, pp. 33–47.

[17] Heshmati, A., Mulugeta, Y. (1996): Technical efficiency of Ugandan matoke farms. Applied Economics letters, Vol. 3, pp. 491–494.

[18] Huang, C.J., Liu, J.T. (1994): A non-neutral stochastic frontier production function. Journal of Productivity Analysis, Vol. 5, pp. 171–180.

[19] Iinuma, M., Sharma, K.R., Leung, P. (1999): Technical efficiency of the carp pond culture in Peninsula Malaysia: an application of stochastic production frontier analysis with technical efficiency model. Aquaculture, Vol. 175, pp. 199–213.

[20] Kirkley, J., Squires, D., Strand, I. (1995): Assessing technical efficiency in commercial fisheries: the mid-Atlantic sea scallop fishery. American Journal of Agricultural Economics, Vol. 77, pp. 686–697.

[21] Kodde, D.A., Palm, F.C. (1986): Wald criteria for jointly testing equality and inequality restrictions. Econometrica, Vol. 54, pp. 1243–1248

[22] Kumbhakar, S., Ghosh, S.C., McGuckin, J.T. (1991): A generalised production frontier approach for estimating determinants of inefficiency in U.S. dairy farms. Journal of Business and Economic Statistics, Vol. 9, pp. 279–286.

[23] Lundvall, K., Battese, G.E. (2000): Farm size, age and efficiency: evidence from Kenyan manufacturing firms. The Journal of Development Studies, Vol. 36, No. 3, pp. 146–163.

[24] MacPherson, N.J., Wijkstrom, U.N., Kapetsky, J.M., Vincke, M.M.J., Agyenim-Boateng, C.E., Pedini, M. (1990): A synthesis report on technical assistance and investment framework for aquaculture and culture-based fisheries in Ghana. Food and Agriculture Organization (FAO) project report on aquaculture. Microfiche no: 314891. TCP/GHA/0051.

[25] Meeusen, W., Van den Broeck, J. (1977): Efficiency estimation from Cobb-Douglas production functions with composed errors. International Economic Review, Vol. 18, pp. 435–444.

[26] Pillay, T.V.R. (1990): Aquaculture principles and practices. Fishing News Book. University Press, Cambridge, UK.

[27] Pitt, M.M., Lee, L.F. (1981): The measurement and sources of technical inefficiency in the Indonesian weaving industry. Journal of Development Economics, Vol. 9, pp. 43–64.

[28] Roy, A.K., Sahoo, K.N., Saradhi, K.P., Saha, G.S. (2002): Farm Size and Aquaculture Productivity Relationship. Asian Fisheries Science, Vol. 15, pp. 129–134.