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ROLE OF SOCIO-ECONOMIC FACTORS TO DETERMINE TECHNICAL EFFICIENCY OF SHRIMP FARMERS OF BANGLADESH

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Abstract

This paper is an attempt to measure the technical efficiency of shrimp farmers in Bangladesh using a translog production frontier and inefficiency effect model. A sample of 185 farmers has been considered from the Paikgacha Upazila of Khulna district. The result shows high levels of technical inefficiency exists in shrimp cultivation. The mean efficiency is 71% which suggests that farmers could increase production by increasing technical inefficiency by 29%. The efficiency differences are significantly explained by farm size, education, share of non-farm income, training, distance from pond to water source, water quality etc.

Key words: Shrimp, technical efficiency, translog stochastic production frontier.

Introduction

Shrimp production plays very important role in the economy of Bangladesh in terms of export and employment. Over the last two and half decades, from 1983 to 2008, the volume of shrimp cultivated has increased more than 14 times. The area of shrimp has also expanded from 20,000 ha in 1980 to 150,000 ha in 2001 (Karim, 2005) and this expansion has also been spurred by the introduction of 2002-03 shrimp export cash incentives and the government encouragement to farmers to increase shrimp production (Deb and Bairagi, 2009). Shrimp farming has also created a substantial volume of employment in the coastal regions of Bangladesh through its forward and backward linkages (i.e. processing, marketing and exporting). It is estimated that there are over 600,000 people employed directly in shrimp aquaculture who support around 3.5 million dependents (USAID, 2006). But the problems of disease and environmental degradation have contributed to a decline in productivity, with many shrimp farmers experiencing negative profits, a decline in living conditions and economic losses. Disease outbreaks are results of unnecessary use of chemicals, lack of proper water exchange and degradation of water quality (Alam, 2007).

By nature, the expansion of shrimp farming is dependent on tidal flow of common property brackish water which flows from water source to the main canals, main canals to sub-canals and the supply of water at the farms behind the sub-canals is usually done by using the others farm

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land. Thus, problem of a head-enders and tail-enders arises. The water management is very easy for the head-enders and tail-ender farmers exchange water by using others' private land and in most cases, they face restricted access to water exchange. Due to restricted access, the water quality degrades that affects shrimp production (Mazid, 2003). As a consequence, the tail-enders lease out land to the head-enders, leave farming occupation and engage in other non-farming activities. Literature informs us, different factors; such as institutional, social and economic issues contribute to increase productivity and efficiency as well as economic well-being. According to that, shrimp production can be increased by improving the technical and allocative efficiency, using existing resources and new technology. TE is more important where use of farm-produced inputs (not purchased from the market) is highly prevalent (Singh, et. al, 2009).

Given the above stated situation, the main objective of this paper is to measure the level of technical efficiency of shrimp producers and its determinants in the south-west coastal areas of Bangladesh. The results are expected to provide information to the policy level how higher productivity could be gained by improving technical efficiency of shrimp farming in Bangladesh.

The paper is organized as follows; the next section presents methodological issues. The results are presented and discussed in the third section and the last section draws conclusion and some implications for policy.

Methodology

Literature posits different methodologies to measure technical efficiency. Farrell (1957) pointed out that the frontier production function is appropriate for such analysis as it meets the theoretical definition of a production function. After his seminal paper, there has been a growing interest in methodologies and their applications to efficiency measurement. Among all the literatures, the frontier production function approach by Aigner, et. al, (1977) can generally be considered an appropriate method where they defined the random term is separated into two independent components as: $Y_i = f(X_i, \beta) + V_i - U_i$; where Y_i = output for observation i, β = vector of parameters. V_i is the two-sided symmetric, normally distributed random error $\{V_i \sim N(0,\sigma_v^2)\}$ representing the usual statistical noise found in any relationship and $U_i \geq 0$ is a one-sided error representing technical inefficiency with a half normal distribution $\{U_i \sim |N(0, \sigma_u^2)|\}$. Aigner, et. al, (1977) derived the log-likelihood function for the model as:

$$L_nL(Y/\beta\lambda\sigma^2) = N \ln \sqrt{\frac{2}{\pi}} + N \ln \sigma^{-1} + \sum_{i=1}^{n} \ln [1-F(\varepsilon_i\lambda\sigma^{-1})] - (\frac{1}{2\sigma^2})\sum_{i=1}^{N}\varepsilon_1^2$$; in which ε_i = error term for observation i. The error term ε_i is made up of two independent components (V_i-U_i).

Later Jondrow et al., (1982), Bravo-Ureta and Rieger (1991) and others expressed the likelihood function in terms of the two variance parameters, $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\lambda = \sigma_u/\sigma_v$. They interpreted λ to be an indicator of the relative variability of the two sources of the random error that distinguishes firms from one another. Here $\lambda = \sigma_u/\sigma_v$, is the ratio of the standard deviation of the non-negative error term U_i to the standard deviation of the two-sided symmetric error term V_i. If λ approaches 0 then it implies σ_v very large or σ_u is close to zero. Similarly, when σ_v is close to zero, λ becomes large and the one-sided error becomes the dominant source of random variation in the model (Rahman, 2002).

The next step is to estimate the farm-specific technical efficiency for the individual observation. The farm-specific technical efficiency relative to the stochastic production frontier as the ratio of observed output to the frontier or expected output. That is: exp. $(-U_i) = \frac{Y_i}{f(X_i)e^v}$;

The value of U_i is practically unobservable and the farm-specific technical efficiency is usually obtained by finding out the conditional expectation of U_i given ε_i.

Based on the above mentioned literature, a stochastic Cobb-Douglas production frontier model may be written as: $\text{In } Y = b_0 + \sum_{i=1}^{k} b_i \text{ In } X_i + V_i - U_i$; where $b_0 = \ln a$.

Though the Cobb-Douglas production function is the most widely used form for fitting agricultural production data, but it imposes certain limitations, such as: constant elasticity regardless of the input level; and the elasticity of substitution among inputs is unity whereas the translog production function does not impose these restrictions and it is a flexible functional form. However, the translog production function is more difficult to mathematically manipulate and it can suffer from degrees of freedom and multicollinearity problems (Coelli, et. al, 1998). The translog function has been used in stochastic production frontier studies by Wilson, et. al, (2001), Awudu and Eberlin (2001), Awudu and Huffman (2000), Rahman and Rahman (2005). The translog frontier production model could be defined as:

$$\text{In } Y_i = \beta_o + \sum_{j=1}^{n} \beta_j \ln X_{ji} + \sum_{j=1}^{n} \sum_{k=1}^{p} \beta_j \ln X_{ji} \ln X_{ki} + V_i - U_i$$

Where Y_i represents the output on i-th farm; β_o represents intercept term; β_j is the effect due to the X input in the i-th farm; β_{jk} is the interaction effect of the inputs X_j, and X_k, in the i-th farm; In this study, Y = output (kg) and X_is are area, labor, lime, fry, fertilizer and feed. The technical inefficiency model is defined by:

$Ui = \delta0 + \delta_1$ age $+ \delta_2$ education$+ \delta_3$ training $+ \delta_4$ non farm income $+ \delta_5$ (non farm income)^2 $+ \delta_6$ family labor$+ \delta_7$ ownership $+ \delta_8$ water quality$+ \delta_9$ distance $+ \delta_{10}$ farm size $+ \delta_{11}$ (farm size)^2 $+ \delta_{11}$ local $+ w_i$

It is important to mention that the inefficiency effect model can only be estimated if inefficiency effects are stochastic and have particular distributional specification. Therefore, testing null hypothesis is important based on inefficiency effects are not present; H_0: $\gamma = \delta_0 = . . . = \delta_{10} = 0$; the inefficiency effects are not stochastic, H_0:γ=0; and the coefficients of the variables in the model for the inefficiency effects are zero, H_0: $\delta_1 = \delta_2 = \delta_3 = \ldots\ldots\ldots = \delta_{10} = 0$. Coelli (1995) suggested that the one-sided generalized likelihood-ratio test should be performed when ML estimation is involved because this test has the correct size (Rahman, 2002). The generalized likelihood-ratio test is a one sided test since γ cannot take negative values. The test statistic is calculated as: $LR = -2\{\ln[L(H_0) \div L(H1)]\}$; where L ($H_0$) and L ($H_1$) are the values of the likelihood function under the specifications of the null and alternative hypotheses, respectively.

Data and descriptive statistics

As a data set, 185 shrimp farmers were interviewed using a structured interview schedule from Paikgacha Upazilla. Multistage random sampling technique was followed on the basis of distance from the water source (head and tail enders) and farm size (small, medium and large). Farmers whose fields are adjacent to the canal are considered as head enders and if distance is ≥ 5 meter then, they are considered as tail enders. While selecting samples from head and tail-enders, farm size was also considered proportionately like as small, medium and large. In Bangladesh, farms with ≤1 hectare are considered as small; ≤ 2.5 hectares, medium and above 2.5 hectares, large. From them, 65 farmers were head ender and the rest 120 were tail-enders of which, 74 farmers were small, 59 were medium and 52 farmers were large. Data was collected in 2008.

The descriptive statistics of all variables has been presented in Table 1 and in the inefficiency model (Table 2), W_is are unobservable random variables, which are assumed to be independently distributed with a positive half-normal distribution. The parameters of stochastic frontier and translog production function models are estimated by the method of maximum likelihood, using the computer program, FRONTIER Version 4.1.

Table 1. Descriptive statistics (mean and standard deviation) of the variables

Inputs and output variables (per hectare)						
Output (Kg.)	Land (Area of one pond, hec.)	Labor (Man-days)	Lime (Kg)	Fingerlings (No.)	Fertilizer (Kg.)	Feed (Kg.)
184.9 (61.08)	4.38 (9.64)	115.2 (41.59)	44.77 (23.39)	12848 (3047)	10.98 (29.51)	49.55 (31.23)

Technical inefficiency estimators					
Age of household head	Education (Number of school years)	NFI (Share of non-farm income)	No. of adult family labor	Distance (meter) from canal to pond	Farm size (hectare)
39.39 (12.73)	8.56 (3.92)	.452 (.274)	2.56 (1.088)	206.5 (364.7)	5.73 (10.35)

Training, ownership and water quality are dummy variables where 1 for trained farmer, owner operator and good quality water respectively, local is also a dummy variable where 1 is if farmers are living in farming community (within 10 km from the pond).

Results and discussion

Before analyzing the inefficiency effects, hypothesis was tested on the choice of functional form (Cobb–Douglas versus translog) and it was found that translog production function is a better representation of the production structure (Table 3). Therefore, this study focuses on the results of the translog production function. Table 2 shows results of the stochastic frontier model from the two different functional forms. Gamma (γ) measures the level of the inefficiency in the variance parameter which ranges between 0 and 1. For the translog model, it is estimated at 0.564, this can be interpreted as: 56 percent of random variation in shrimp production is explained by inefficiency.

Table 2. Maximum likelihood (ml) estimates for parameters of Cobb-Douglas and translog stochastic production frontier functions and technical inefficiency effect

Variables	Parameters	Cobb- Douglas Model		Translog model	
		Coefficient	Std. error	Coefficient	Std. error
Intercept	β_0	4.9300**	0.0036	3.19802**	0.9861
ln Land	β_1	0.3926**	0.1035	0.4153**	0.0049
ln Labor	β_2	0.2614**	0.0015	0.2964**	0.0114
ln Lime	β_3	0.0121**	0.0001	0.0108	0.0438
ln Fry	β_4	0.1884**	0.0677	0.2047**	0.8650
ln Fertilizer	β_5	0.0170	0.0090	0.0165	0.1064
ln Feed	β_6	0.0081	0.0242	0.0093	0.9074
½ ln Land^2	B_{11}			0.0339	0.0295
½ ln Labor^2	B_{22}			0.0026**	0.0040
½ ln Lime^2	B_{33}			-0.2259	0.9789
½ ln Fry^2	B_{44}			0.5319	1.6392
½ ln Fertilizer^2	B_{55}			0.0056	0.0263
½ ln Feed^2	B_{66}			-0.0052	0.0109
ln Land X ln Labor	B_{12}			0.7968	0.8143
ln Land X ln Lime	B_{13}			0.0064	0.0058
ln Land X ln Fry	B_{14}			-0.2423	0.9535
ln Land X ln Fertilizer	B_{15}			-0.0025	0.0148
ln Land X ln Feed	B_{16}			0.0325	0.3637
ln Labor X ln Lime	B_{23}			2.546**	1.014
ln Labor X ln Fry	B_{24}			0.0077	0.0695
ln Labor Xln Fertilizer	B_{25}			1.7031*	0.9058
ln Labor X ln Feed	B_{26}			0.0186	0.0223
ln Lime X ln Fry	B_{34}			-0.0064	0.0158
ln Lime X ln Fertilizer	B_{35}			-1.5351	1.4113
ln Lime X ln Feed	B_{36}			-0.0174	0.0407
ln Fry X ln Fertilizer	B_{45}			0.0042	0.0268
ln Fry X ln Feed	B_{46}			0.3422	0.8836
ln Fertilizer X ln Feed	B_{56}			-0.5012	0.4918
Technical Inefficiency Factors					
Intercept	δ_0	-0.0261	0.6549	-0.0478	0.2308
Age	δ_1	0.0418	0.0704	0.0001	0.0086
Education	δ_2	0.0391**	0.0040	0.0074**	0.0018
Training	δ_3	-1.382**	0.1970	-0.0005**	0.0175
Non-farm income	δ_4	-0.003**	0.0007	-0.0022**	0.0196
(Non-farm income)^2	δ_5	0.0001**	0.0000	0.0001**	0.0000
Family labor	δ_6	-0.0004	0.0000	-0.6032*	0.3473
Ownership	δ_7	-0.0003*	0.0001	-0.0004**	0.0001
Water quality	δ_8	0.0104**	0.0031	0.0104**	.00426
Distance	δ_9	0.0049**	0.0010	0.0123**	0.0022
Farm size	Δ_{10}	-0.0001**	0.0000	-0.0010**	0.0002
(Farm size)^2	Δ_{11}	0.0091*	0.0038	0.0074*	0.0031
Local dummy	Δ_{12}	-0.103	0.2905	-0.1090*	0.0050
Variance parameters	σ^2	0.0159**	0.0022	0.0110**	0.0436
	γ	0.5999**	0.0652	0.5639**	0.0389

The mean technical efficiency (TE) is computed and it is 71 percent for both models. Hypotheses have also been tested by using likelihood-ratio (LR) test statistic. The null hypothesis, there is no inefficiency is rejected at the 1% level of significance and establishes the presence of inefficiency effects and they are stochastic. In addition, the null hypothesis that the inefficiency effects are not present in the model (Ho: =γ= 0), is also rejected at the same level of significance. Thus, a significant part of the variability in production among farms has been explained by the existing differences in the level of technical inefficiency.

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Technical efficiency has been computed for each farm. Figure 1 shows a histogram of predicted technical efficiencies. The minimum estimated efficiency is 26.45 percent, and the mean is 71.01 percent with a standard deviation of 18.04 percent. This suggests that, on an average, about 29 percent of shrimp yield is lost because of inefficiency and in the short run; there is a scope for increasing shrimp production by 29 percent by improving socio-economic factors.

Table 3. Hypothesis tests

Null Hypothesis	LR test statistic (χ^2)	d.f.	*p*-value (Prob>χ^2)	Decision
Choice of functional form: Cobb–Douglas versus translog model (H_0: $\beta_{jk} = 0$ for all jk)	62.13	21	0.030	reject
No inefficiencies present in the model (H_0: $\mu = \gamma = 0$)	87.12	3	0.000	reject
No inefficiency effects	51.05	12	0.000	Reject

Table 2 shows that farm size increases farmers' efficiency, but the coefficient of (farm size)^2 confirms that very large farm size negatively affects the efficiency. So, how much land farmers are able to manage efficiently. Hoque (1988) found that farm size between 7 and 12 acres is the most efficient for Bangladesh agriculture. In the same line, five piece-wise regressions for five ranges of farm size have been considered and the results are presented in Table 4. Result shows that farm size and technical efficiency are

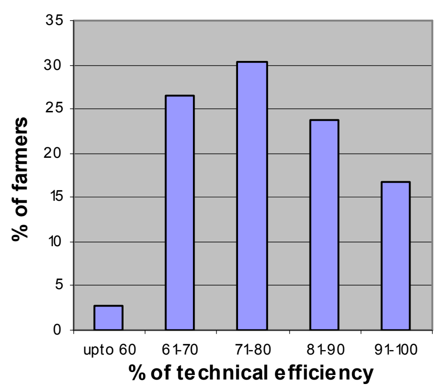

Figure 1. Frequency distribution of technical efficiency from translog model

positively related for less than 3 hectares and the regression coefficients are significant. This implies that technical efficiency increases with less than 3 hectares of land. On the other hand, the relationship is negative and significant for 3- <5.5 hectares. Table 5 also shows that average farm size for most efficient producers is 4.32 hectares.

Though, the relationship is negative after 3 hectares of size, it sounds that optimum farm size may be found around 5 hectares. When all the farms are considered together, the relationship is positive but insignificant. Thus, piece-wise regressions give better indication about the relationship between farm size and technical efficiency. It has also been found that rich people are taking land in terms of lease from the absentee land owners and from those who cannot produce shrimp due to conflict with neighbors. Increasing the amount of land is a matter of reputation for them. There is competition among rich farmers, to be the owner of the highest amount of land rather than to maximise productivity or efficiency. Therefore, very large farmers are rarely capable to manage their farm.

Non-farm income is a very critical issue in farming. Increased non farm income may reduce financial constraints, particularly for resource-poor households by enabling them to apply inputs in time; thereby increase productivity as well as efficiency. It is clear from figure 2 that with the increase of non farm income share, small farmers' efficiency increases but medium and large farmers´ efficiency decreases. As small farmers' land-man ratio is very less compared to other categories (Table 6), it seems, if some additional labors engage in non farm sector, production would be same. So, in that sense, farmers having more land should be attentive in farming. Since large farmers have a shortage of labor, additional small farm labors could be hired.

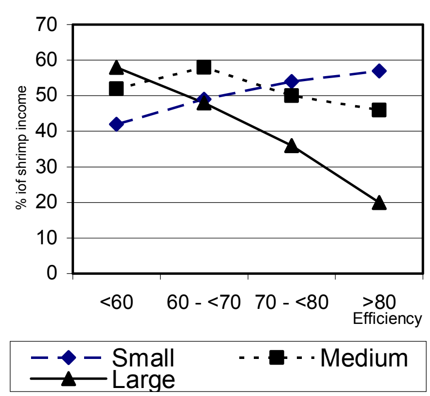

Figure 2. Percentage of shrimp income to total income for different farmers

Table 4. Socio-economic characteristics on the basis of different levels of technical efficiency

Level of TE	Different socio economic characteristics					
	Mean Education (years)	Training (yes)	Proportion of shrimp income	Proportion of Family labor	Owner operato r (%)	Average farm size (hac)
< 60	11	38.2	0.38	0.44	38	11.32
60-< 70	7	70.5	0.57	0.42	53	4.26
70- < 80	8	58.8	0.77	0.53	58	6.94
80- < 90	8	79.6	0.79	0.53	73	3.55
90-100	8	85.7	0.76	0.54	100	4.32

Source: Authors' calculation based on field survey data, 2008.

Table 5. Regression results: Farm size is independent and TE is dependent variable

Farm size (hectare)	Reg. coeff. (std. error)	R^2
<1 ha.	0.53** (0.24)	0.68
1- < 3	0.29* (0.23)	0.53
3- <5.5	-0.13 (0.08)	0.43
>5.5 ha.	-0.04 (0.15)	0.28
All farms	0.008 (0.02)	0.23

Source: Authors' calculation
Figures in the parentheses indicate standard error

Table 6. Average land-man ratio of different farmers

Types of farmers	Small	Medium	Large
Land man ratio (ha.)	0.108	0.355	4.442

Source: Authors calculation based on field survey data, 2008.

The positive coefficient of education reveals that efficiency decreases with the increase of farmers´ level of education. In the context of Bangladeshi culture and values, agricultural activities are reserved for the illiterate people; higher educated persons don't want to be farmers. When farmers are more educated, they start to ignore farming responsibilities. Table 4 shows that efficiency decreases after secondary level of education which could be explained by the education system of Bangladesh. After secondary level of education, education becomes specialized and there remain very little scope to learn about farming. So, education system should be farming oriented and social values needs to be changed. Various studies have found a positive connection (like Ali and Flinn, 1989), while several others have reported no statistically significant relationship between these two variables (Bravo-ureta and Evenson 1994; Kalirajan 1984), and Haller (1972) found a negative relationship for education on agricultural productivity (Phillips, 1987). Coefficient of training is negative which means that trained farmers are more efficient than non-trained farmers. So, it could be said that improvement in farmer's managerial ability is a key factor for sustainable operation, which can be improved by providing adequate training.

Conclusion and policy implications

In this study, the translog specification was found more appropriate than the Cobb-Douglas for the data being analyzed. The result shows 29 percent technical inefficiency exists which can be attained by the efficient use of existing inputs; without any additional cost to the farmers. Such detailed information has important implications for formulating agricultural policy.

Based upon the analytical result, this study suggests that around 5 hectares could be an optimum farm size for shrimp farming which is not a small amount in Bangladesh perspective. The present study bears an important message that there is ample opportunity to redistribute land from those having more than 5 hectares to those having less. For increasing efficiency, large landholdings could be discouraged through policy instruments. For instance, progressive rate of land tax could be charged for farmers having more land. This measure will have some monitoring and enforcement costs, but may also raise substantial revenues that can be used to finance technological improvements that would reduce natural resource degradation normally induced by shrimp cultivation.

As distance from pond to canal negatively affects farmer's efficiency, the study recommends that narrow sub canals could be constructed for the tail end farmers; the proposal should be carefully examined focusing on the costs; and effects on the efficiency and production of farmers. Farmers could also be socially organized for collective water management. If farmers get timely supply of water, they will be able to produce shrimp along with one season rice and fresh water fish.

Poor performance of farmers in shrimp farming with increased non-farm income indirectly implies that farming is becoming a secondary occupation and is incapable of providing sufficient returns from farming activities. Off farm income could be helpful for farming because it provides liquidity for agricultural expenditures and long-term investments; but if farmers operate farming as secondary occupation, then off-farm income reduces efficiency. However, the risk of disease epidemic in shrimp pushes small and medium farmers to engage in non farm income-earning activities. This study recommends that large farmers should be attentive in farming and they could hire additional labors from small farms.

Shrimp farming is relatively new occupation for the farmers and they have little formal knowledge on framing technology. Therefore, this study recommends training for shrimp farmers. After completion of secondary level of education, the members of farm family become eligible to receive training. To encourage training, monetary incentives could be introduced for the trainees.

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