Technical Efficiency of Agricultural Farms in Khulna, Bangladesh: Stochastic Frontier Approach

Mohammed Ziaul Haider, Ph.D (Corresponding Author)
Associate Professor, Economics Discipline, Khulna University, Khulna– 9208, Bangladesh
Tel: 88-017-3000-4131 E-mail: haidermz@yahoo.com OR haidermz@econ.ku.ac.bd

Md. Shakil Ahmed
Economics Discipline, Khulna University, Khulna– 9208, Bangladesh
Tel: 88-019-1103-8801 E-mail: shakil.econ@gmail.com

Anup Mallick
Economics Discipline, Khulna University, Khulna– 9208, Bangladesh
Tel: 88-019-1943-1113 E-mail: anup.exl@gmail.com

Received: October 10, 2010 Accepted: November 21, 2010 doi:10.5539/ijef.v3n3p248

Abstract

This paper uses the stochastic frontier approach to measure technical efficiency level of the agricultural farms of Khulna, Bangladesh. It considers three sub-sectors: rice cultivation, fish cultivation and livestock rearing. About 76%, 81%, and 73% variations in output are due to technical inefficiency for the farms of the three sub-sectors, respectively. The highest variation in output (due to inefficiency) is found in the fish cultivation sub-sector. The sample farms are operating at an inefficient level and the inefficiency level decreases over time for the sub-sectors. The farming experience of the farmers and the availability of the credits significantly and positively affect the efficiency level of the farms. This study finds the necessity of redefining and redesigning the credit instrument for maintaining sustainability in the long run. It is also found that all the three sub-sectors have a chance to increase their production level with the same set of technology.

Keywords: Agriculture, Credit, Stochastic Frontier, Technical Efficiency, Production

1. Introduction

Agriculture is the most important sector of Bangladesh which contributed about 21 percent of the total GDP in the year 2006-07 (GOB 2008). This sector has been playing a vital role in socio-economic advancement and sustainable economic development through gradual improvement of the rural economy, ensuring food security and alleviating poverty. About 48 percent of the total labor forces of the country are engaged in agriculture (BBS 2009). Though the contribution of the agriculture sector has decreased over time, it has an indirect contribution to the overall growth of GDP. The growth in the service sector, particularly the growth in wholesale and retail trade, hotel and restaurants, transport and communication sectors are strongly supported by the agriculture sector. To upgrade the agricultural sector, the Bangladesh government has taken various steps. Government promotes the cultivation of high yielding varieties, liberalizes the market of inputs and outputs through agricultural reform policy which increased the use of purchased inputs by reducing their prices (Wadud 2003).

To uphold the role of agriculture sector and rural areas in the overall socio-economic development of the country, the government has been pursuing distribution programs of agriculture and rural credit through State-owned Commercial Banks (SCBs). The banks are also engaged in micro credit activities for poverty alleviation. The target of credit disbursement through Bangladesh Krishi Bank, Rajshahi Krishi Unnayan Bank, Nationalized Commercial Banks, Bangladesh Rural Development Board and Bangladesh Samobay Bank had been set at Taka 83.09 billion for fiscal year 2007-08 and total disbursement was Taka 85.81 billion which was 103 percent of the target. During year 2006-07, disbursement stood at Taka 52.93 billion against the target of Taka 63.51 billion (GOB 2008). The need of credit for smooth operation of agricultural farms is widely recognized and the need is more for small and marginal farmers (Hakim 2004). He also argues that access of small and marginal farmers to micro credit can significantly help them to avoid sliding down the poverty ladder. Agricultural credit has a significant effect on standard of living (Sanoy and Safa 2005). They also emphasize on the reduction of the interest rate to make credit more effective and to increase the accessibility to the credit that may lead to more welfare to the beneficiaries. Masawe (1994) argued that agricultural credit stimulates agricultural production, particularly among small farmers. Adebayo and Adeola (2008) recommend for establishing financial institutions such as agricultural and community banks in the rural areas. The procedures for securing loans should be reviewed in order to make it simple for the farmers. The relevant government agencies should mobilize the rural farmers to form themselves into formidable groups so that they can derive maximum benefit of collective investment of group savings. Therefore, taking care of the marginal level farmers and providing them proper financial support in easy terms and conditions are important to alleviate poverty.

This study considers the stochastic frontier approach with the assumption that the actual production cannot exceed the maximum possible production with the given input quantities (Aigner et al. 1977 and Meeusen and van den Broeck 1977). For measuring the performance or production efficiency, Kumbhakar et al. (1991) and Battese and Coelli (1995) suggest to determine the factors responsible for inefficiency. The important task is to relate inefficiency to a number of factors and measure the extent to which they contribute to generate inefficiency.

The stochastic frontier approach is widely used in agricultural economics studies. In case of Bangladesh it is observed that land fragmentation generates production inefficiency in the agriculture sector (Wadud 2003). He also finds that the farms could increase their rice production by 9 to 39 percent if they could operate at a full technical, allocative and economic efficiency level with their existing technology. The effect of land fragmentation on Chain's agriculture is examined by Wan and Cheng (2001) and Fleisher and Liu (1992). They find that a new land tenure institution emphasizing consolidation significantly improves the production efficiency. The mean efficiency of Nigerian agriculture is 77 percent. It means that there is a scope of 23 percent improvement in efficiency (Idong 2007). He also observes that educational level, association membership of farmer and access to the credit create significant and positive influences on farmers' efficiency. Cramer and Wailes (1996), Cheng (1998) and Liu and Zhuang (2000) also support that the education level is positively correlated with the production efficiency in agriculture sector.

The stochastic frontier approach is widely used for measuring technical efficiency of manufacturing firms. Influence of firm supervision on firm efficiency in China is observed by Jefferson (1990). He studies over 120 iron and steel enterprises. The study result over 39 manufacturing firms in Bangladesh shows that technical efficiency declines over the period and the truncated normal distribution is preferable to the half normal distribution for the technical inefficiency effect (Baten et al. 2009). They use panel data of nine consecutive years. Kalirajan and Cao (1993) look at the effect of economic reform on Chinese enterprise performance and (Wu 1995) uses a time-varying production model to measure the production efficiency of iron and steel mills. This approach is also used to evaluate the effect of major reforms on enterprise performance by Movshuk (2004). The noted literatures clearly demonstrate that the stochastic frontier approach is an important and appropriate tool for measuring technical, allocative as well as economic performance of both agriculture and industrial sectors.

The aim of this paper is to measure the technical efficiency of the agricultural farms of Khulna, Bangladesh. It tries to answer three specific research questions:

1.1 Research Question 1. How the actual production level of Bangladesh agriculture is deviated from the maximum attainable production level?

This question mainly highlights the inefficiency level of agriculture sector of Bangladesh. The important factors of production are land, labor and capital. If all the factors are utilized properly and efficiently, then the production would be at a maximum level. Otherwise, there will be a gap between the maximum level of production and the actual level of production and this gap will represent inefficiency. The efficiency level of a farm is measured by the ratio of actual output to the maximum attainable output.

1.2 Research Question 2: Which sub-sector of agriculture is proficiently using the available resources to produce output?

This question is mainly associated with the comparison among the three sub-sectors of agriculture which are Crop cultivation, Fish cultivation and Livestock rearing on the basis of their technical efficiency levels. This question also measures how efficiently these sub-sectors are using their credit facility, land and the available labor.

1.3 Research Question 3: Which factors are highly associated with technical efficiency?

Some social and demographic factors are to some extent related with the production process. Sometimes, these factors influence the production process directly or indirectly. The educational qualifications of the farmers, their age, sex, family size and farming experience are the examples of such factors. Credit type, interest rate, installment process and fragmentation of land are some other factors influencing the production process. This study tries to identify the factors which are highly related with the technical efficiency.

2. Research Methodology

2.1 Study Area

Batiaghata Upazila of Khulna district is the study area of this study. Total area of this upazila is 248.33 square kilometers. Batiaghata is situated on the bank of the river Kazibachha, 10 kilometers south from Khulna city. Total population of the area is 0.13 million and the male-female ratio is 51:49. Main occupations of the people are agricultural farming (42.94%), fishing (1.64%), agricultural laborer (19.67%), wage laborer (6.35%), commerce (10.53%), transport (2.22%), construction (1.06%), service (4.85%) and others (10.74%).

Total cultivable land of the Upazila is 18.49 thousand hectares and fallow land is 60.70 hectares. Among the total cultivable land, single crop occupies 87.74%, double crop 11.27% and treble crop 0.99% land. Average distribution of cultivable land is 0.15 hectares per head.

2.2 Sampling Technique

A random sampling technique is used in this study to select samples. The people taking agricultural credit from Bangladesh Krishy Bank (Bangladesh Agricultural Bank), Batiaghata Branch are the main information source of this study. There are 1,000 farmers who are the clients of this bank. A total of 80 farmers are randomly selected from the population (1,000 farmers). Among the selected 80 farmers, 32 are associated with crop cultivation and fish cultivation and livestock rearing include 24 farmers each. The data of three consecutive years (2007, 2008 and 2009) are collected from the farmers and bank.

2.3 Analytical Framework

2.3.1 Technical Efficiency (TE) Measurement

The commonly used approach in measuring the TE is the stochastic frontier approach. It is proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977). The technical efficiency shows the farms' ability of maximizing output with a set of given input. The range of TE is 0 to 1. TE = 1 implies that the farm is producing on its production frontier and is said to be technically efficient. Hence, (1–TE) represents the gap between actual production and optimum attainable production that can be achieved by moving the firm towards the frontier through readjusting inputs (Chaves and Aliber 1993). This study considers the following stochastic production function:

$$\ln Y_{it} = \beta_0 + \sum \beta_{it} \ln X_{it} + V_{it} - U_{it} \text{-------------} (i)$$

Following Battese and Coelli (1995), the inefficiency distribution parameter can be written as:

$$U_i = \delta_0 + \delta_i Z_i + W \text{-------------} (ii)$$

$i = 1, 2, 3 \ldots\ldots\ldots n$

$t = 1, 2, 3 \ldots\ldots\ldots T$

Where Y_{it} denotes the output of the i^{th} farm in the t^{th} time period, X_{it} denotes input vector for the i^{th} farm in t^{th} time period, V_{it} denotes the random error which is caused by the misspecification of the model which is assumed to be independently and identically distributed, $N(0, \sigma_v^2)$, and U_{it} is the inefficiency component where the common assumption is that the error term is farm specific, non-negative truncation of the distribution $N(\mu_i, \sigma_v^2)$. The model incorporates a simple specification of the time-varying inefficiencies following Battese and Coelli (1992) as:

$$U_{it} = \{\exp[-\eta(t - T)]\} U_i \text{------------} (iii)$$

Here η is an unknown parameter to be estimated, which determines whether inefficiencies are time varying or not. If η is positive, $-\eta(t-T) = \eta(T-t)$ is positive for t<T. Therefore, $\exp[-\eta(t-T)] > 1$, which implies that the technical efficiency of the farms declines over time. The technical efficiency of the farms remains constant when η is zero and it increases when η is negative (Baten et al. 2009).

Z_{it} symbolizes the farm specific characteristics to describe the inefficiency, w represents the random variable and δ is a vector of parameters to be estimated.

The equations (i) and (ii) are linked with each other by U (one sided error term). Battese and Corra (1977) describe the variance term of U and V as $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma^2$ where σ^2 is the variance of output. Here γ lies between 0 and 1. It represents the level of inefficiency. γ=0 implies no technical inefficiency. Thus the TE of the i^{th}

farm in the t^{th} year can be obtained by the expected value of U_i conditional on the random variable μ_i (Battesse and Coelli 1988).

$$TE_{it} = \exp(-U_{it}) ------ (iv)$$

2.3.2 Hypothesis

The hypotheses of interest are:

H_{0a}: $\gamma = 0$, technical inefficiency is not present in the model.

H_{0b}: $\eta = 0$, the technical inefficiency effect do not vary significantly over time.

The corresponding alternate hypotheses are:

H_{1a}: $\gamma \neq 0$, technical inefficiency is present in the model.

H_{1b}: $\eta \neq 0$, technical inefficiency effect varies overtime.

2.3.3 Tools to be used

This study uses the Ordinary Least Square (OLS) and Maximum Likelihood Estimation (MLE) approaches to estimate the parameters of the stochastic production frontier. SPSS, Frontier 4.1 and MS Excel are used for editing and analyzing the data.

2.3.4 Variable Identification for Empirical Model

The literatures identify various socio-economic and demographic factors as the causes generating inefficiency of the farms. Year of schooling, membership of association, farm size, access to the credit of the farmers' have the positive effect on the efficiency of the farm as described by Idiong (2007). Some other literatures also give much importance on land use, credit availability, land tenure, and the house hold labors' educational qualification (Seyoum et al. 1998, Coelli and Battese 1996, Wilson et al. 1998, Kumbhakar 1994). Whereas, Ali and Choudhury (1990) focus on the cultivation technique, share tenancy and farm holding size as influential factors on farm efficiency. Other environmental and non-physical factors like information availability, experience, supervision might affect the efficiency of the farms (Parikh and Shah 1995, Kumbhakar 1994).

There is a positive and significant relationship of year of schooling with technical inefficiency in Bangladesh (Wadud 2003). He also observes that farmers with greater plot size, that is, less land fragmentation, are operating at higher level of efficiency. In summary, the literatures endorse that inefficiency in agriculture mainly depends on farmers' age, sex, farming experience, year of schooling, plot size, irrigation facility, use of modern technology, institutional training and access to credit. Following the literatures and considering the agricultural practices of Bangladesh, this study uses a set of variables, such as, land fragmentation, educational qualification and house hold size of the farmers, number of years of taking credit, experience and the farm size as the main sources of inefficiency in agriculture (Table 1).

This study calculates total output as the market price of yearly production. Land is measured in *acre*. For crop cultivation, summation of all cultivable lands which a farmer uses for cultivation in the respective years is considered as the land size. For fish cultivation, total land coverage of all ponds under fish cultivation is considered and for livestock rearing, the farm area is considered. The labor hour is considered as the variable for labor and agricultural credit is used as the proxy variable for capital.

3. Data Analysis and Results

Since, the agriculture sector of Bangladesh mainly consists of three sub sectors: crop cultivation, fish cultivation and livestock rearing, the efficiency levels across these three sub sectors are evaluated. In addition, this study also attempts to identify the sub sector where the agricultural credit acts on more efficiently. In the data analysis and interpreting the findings, following assumptions are included to remove theoretical barriers:

- Agricultural credit is given to the farmers who have their own farming land.
- Agricultural credit is the only source of capital in the production process.
- Perfect competition prevails in the factor market as well as in the product market.
- Nature influences crop and fish cultivation significantly.
- Irrigation facility is absent in the study area due to salinity in deep water.

Table 2-4 summarize the OLS and MLE estimates of the parameters of Cobb-Douglas production function. The OLS estimates for capital on production of all three sub sectors are statistically significant and positive. They are significantly different from zero at 1% level, which implies that any positive change in capital will increase the level of production. The estimates for labor are also statistically significant at 1% level and positive on fish and livestock production, though it is insignificant for crop sub sector. The estimation for land provides mix results. It is negative and significant for the crop sub sector, positive and significant for livestock sub sector and insignificant for fish sub sector (Table 2-4). The estimated value of σ is positive which indicates that the observed output differs from frontier output due to factors which are within the control of the farms (Baten et al. 2009). This also implies that OLS estimation technique is inadequate in representing the data. The intercept values of ML estimation are grater than the OLS estimate which implies that the estimate of frontier production function lies above the traditional average function.

The MLE analyses indicate that land has a positive and significant effect on the output for fish and livestock production. However, the analyses find a significant and negative influence of land on crop production. The division and fragmentation of land, lack of proper irrigation and salinity problem mostly explain such an unexpected result. The estimates of labor input on fish cultivation and livestock rearing are positive and statistically significant. However the estimate is insignificant for crop cultivation. Double cropping pattern per year is the dominating trend of the study area. Moreover, natural hurdles often constraint agricultural production in the study area. As a result, disguised and seasonal unemployment are common in the study area which partly explains the insignificant impact of labor input on crop production. Agricultural credit is playing the vital role in crop cultivation, which is statistically significant and positive. The estimate of credit on livestock rearing is also significant and positive, though it is insignificant for fish cultivation.

The estimated values of the parameters using MLE method represent that the crop cultivating and livestock rearing farms are operating at decreasing returns to scale, whereas, the fish cultivating farms are operating at the increasing returns to scale.

3.1 Test of Hypothesis

This study considers two hypotheses for checking the existence (γ) of technical inefficiency and its variation (η) over time shown in the table 5.

Since the hypothesis H_0: $\gamma = 0$ is rejected in each of the three sub sectors, it may be concluded that technical inefficiency effect is present in the models. The estimate of variance parameter (γ) is significantly different from zero, which indicates that the inefficiency effects are significant in determining the level of output variability in the farm. This result is consistent with Wadud (2003), Sharma et al. (1997) and Coelli and Battese (1996). The estimated values of γ imply that 76%, 81%, and 73% variation in output are due to technical inefficiency of the crop cultivation, fish cultivation and livestock rearing sub sectors, respectively. It also confirms the presence of one sided error components in the models.

The second null hypothesis H_0: $\eta = 0$ is significant in the model for crop cultivation and fish cultivation. It means that technical inefficiency effect varies significantly over time for the two sub-sectors. Insignificances of the H_0: $\eta = 0$ in the model for livestock rearing tell that the technical inefficiency effects do not vary overtime. Although η is not statistically significant for *livestock rearing, it* possesses a positive value, and η is positive and statistically significant for the other two sub-sectors, crop cultivation and fish cultivation. A positive value of η indicates that inefficiencies decrease over time in the agricultural sector of this region. The result is consistent with Baten et al. (2009).

3.2 Farm Level Technical Efficiency

Table 6 illustrates farm level technical efficiency of the study area. The measure of technical efficiency ranges from 0.00 to 1.00. For crop cultivation and livestock rearing farms it ranges from 0.41 to 0.95 whereas for fish cultivating farms it ranges from 0.10 to 0.95. The mean technical efficiencies indicate that crop cultivating farms are producing 69% of their potential output, whereas, fish cultivating farms are producing 29% and livestock rearing farms are producing 66% of their potential output. These results also imply that farms can improve their output level by 31%, 71% and 34%, respectively by the available set of inputs and technology.

The efficiency distribution shows that about 56% crop cultivating farms attain 61% to 70% efficiency level and only 6% farms attain 91% to 100% efficiency level. For livestock rearing farms the statistics is 34% attaining 61% to 70% efficiency level and only 1% farms attain 100% level of efficiency. A majority of fish cultivating farms (61%) attain a very poor efficiency level ranging from 10% to 20%. A comparatively higher level of efficiency for crop cultivating farms and livestock rearing farms indicate that only a small fraction of output can be attributed as wastage (Idiong 2006). However, a large amount of output is attributed as wastage for fish cultivating farms.

3.3 Results of Efficiency Model

Table 7 represents the OLS estimates of the determinants which are commonly associated with the efficiency level of the agricultural farms. This study considers the same factors for the three sub-sectors. The result finds positive coefficients for land fragmentation, schooling years, credit taking years and farm size on cropping sub sector.

However, only credit taking years are significant at 5% level and the others are significant at 10% level. It indicates that the efficiency will increase for an increase in farm size and credit takings. But efficiency will decrease with the increase of family size. The results for fish cultivation articulate that coefficients for family size, age of the farmers, farming experience, credit taking years and schooling years have the positive sign, although only the farming experience and credit taking years significantly affects the efficiency level. The results are almost similar to Idiong (2007) and Wadud (2003). Finally, for livestock rearing farms, except farm size all other coefficients have a positive sign. However, the farming experience and credit taking years have a significant effect on efficiency level of the livestock rearing farms. Land fragmentation posses a negative sign for fish cultivation sub sector which implies that for an increase in land fragmentation, efficiency level will decrease.

4. Conclusion

This paper analyses the technical efficiency and its source in the agricultural farms of Khulna, Bangladesh. Stochastic frontier approach including MLE and OLS estimation methods for data analysis has been used to measure the efficiency level. In the analyses, technical efficiency is measured as the function of various socio-economic factors.

This study has revealed that agricultural farms of this region are not fully technically efficient. The farms of all three sub sectors have the potentiality to increase output using the same level of technology. Therefore, appropriate policy measures might enhance the farm efficiency. It is also evident that the farming experience of the farmers and the availability of the credits significantly and positively affect the efficiency level of the farms. Therefore, the government and concerned others need to take proper steps to enhance the experience level of the farmers. A scope of proper training facilities may be provided to the farmers for upgrading their productive capacity. In addition, agricultural credit with easy terms and conditions should be available for the farmers.

Farmers need to be encouraged to improve their educational qualification, which will help them to be conscious about the use of modern technology and enhance the information as well as the resource mobility in the production process. It is needed to redefine and redesign the credit instrument for maintaining sustainability in the long run. Land tenure system might be reviewed and redesigned to reduce land fragmentation. Some factors are absent in this region, such as, co-operative farming, proper training facility, and irrigation facility. These factors need to be introduced as early as possible to accelerate the overall productive efficiency in the agricultural sector of Khulna, Bangladesh.

References

Adebayo, O. O., & Adeola, R. G. (2008). Sources and uses of agricultural credit by small scale farmers in surulere local government area of Oyo State. *Anthropologist*, 10(4), 313-314.

Aigner, D. J., Lovell, C. A. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, 6(1), 21-37.

Ali, M., & Choudhry, M. A. (1990). Inter-regional farm efficiency in Pakistan's Punjab: a frontier production function study. *Journal of Agricultural Economics*, 41, 62-74.

Baten, M. A., Kamil, A. A., & Fatama, K. (2009). Technical efficiency in stochastic frontier model: an application to the manufacturing industry in Bangladesh. *Australian Journal of Basic and Applied Sciences*, 3(2), 1160-1169.

Battese, G. E., & Coelli, T. J. (1988). Prediction of firm level technical efficiencies with a generalized frontier production function and panel data. *Journal of Econometrics*, 38, 387-399.

Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effect in a stochastic frontier production function for panel data. *Empirical Economics*, 20, 325-332.

BBS (2009). *Statistical Yearbook of Bangladesh 2008*. (28th ed.). Dhaka: Bangladesh Bureau of Statistics (BBS), Planning Division, Ministry of Planning, Government of the People's Republic of Bangladesh.

Chavas, J., & Aliber, M. (1993). An analysis of economic efficiency in agriculture: a nonparametric approach. *Journal of Agricultural and Resource Economics*, 8(1), 1-16.

Cheng, E. J. (1998). Household heads, non-economic factors & grain production in China in the 1990s. Working Paper #98/5, Center for Asian Studies, Chinese Economy Research Unit, University of Adelaide, Adelaide.

Coelli, T., & Battesse, G. (1996). Identification of factors which influence the technical inefficiency of Indian farms. *Australian Journal of Agricultural Economics*, 40, 103-128.

Farrell, M. J. (1957). The measurement of production efficiency. *Journal of the Royal Statistical Society*, 120A, 257-281.

Farrell, M. J., & Fieldhouse, M. (1962). Estimating efficient production under increasing returns to scale. *Journal of the Royal Statistical Society*, 125A, 252 - 267.

Fleisher, B. M., & Liu, Y. H. (1992). Economies of scale, plot size, human-capital, and productivity in Chinese agriculture. *Quarterly Review of Economics and Finance*, 32, 112-123.

GOB (2008). *Bangladesh Economic Review 2008*. Dhaka: Finance Division, Ministry of Finance, Government of The People's Republic of Bangladesh (GOB).

Hakim, M. A. (2004). Microcredit and agriculture: how to make it work. In *Asia Pacific Region Microcredit Summit Meeting of Councils (APRMS)*. Dhaka: APRMS.

Idiong, I. C. (2006). Evaluation of technical, allocative and economic efficiencies in rice production systems in cross river state, Nigeria. Dissertation, Michael Okpara University of Agriculture, Umudike.

Idiong, I. C. (2007). Estimation of farm level technical efficiency in smallscale swamp rice production in cross river state of Nigeria: a stochastic frontier approach. *World Journal of Agricultural Sciences*, 3(5), 653-658.

Jefferson, G. H. (1990). China's iron and steel industry sources of enterprise efficiency and the impact of reform. *Journal of Development Economics*, 33, 329-355.

Jondrow, J. C., Lovell, A. K., Materov, I. S., & Schmidt, P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function model. *Journal of Econometrics*, 19, 233-238.

Kehinde, A. L., & Awoyem, T. T. (2009). Analysis of economic efficiency in sawnwood production in Southwest Nigeria. *Journal of Human Ecology*, 26(3), 175-183.

Kumbhakar, S. C. (1994). Efficiency estimation in a profit maximising model using flexible production function. *Agricultural Economics*, 10, 143-152.

Kumbhakar, S., Ghosh, S., & McGuckin. T. (1991). A generalized production frontier approach for estimating determinants of inefficiency in US dairy farms. *Journal of Business and Economic Statistics*, 9, 279-286.

Liu, Z., & Zhuang, J. (2000). Determinants of technical efficiency in post-collective Chinese agriculture: evidence from farm-level data, *Journal of Comparative Economics*, 28, 545-564.

Masawe, J. L. (1994). Agricultural credit as an instrument of rural development in Tanzania: A case study on the credit programme for tractorization of small scale agriculture in morogoro region. *African Study Monographs*, 15(4), 211-226.

Meeusen, W., & Van den Broeck, J. (1977). Efficiency estimation from cobb-douglas production functions with composed error. *International Economic Review*, 18(2), 435-444.

Movshuk, O. (2004). Restructuring, productivity and technical efficiency in China's iron and steel industry, 1988-2000, *Journal of Asian Economics*, 15, 135-152.

Parikh, A., Ali, F., & Shah, M. K. (1995). Measurement of economic efficiency in Pakistan agriculture. *American Journal of Agricultural Economics*, 77, 675-685

Sanoy, A., & Safa, M. S. (2005). The effectiveness of agricultural credit on the standard of living of borrowers in Yemen: An extended linear expenditure system (ELES) approach. *The Agriculturist*, 3(1 & 2), 117-127.

Seyoum, E. T., Battese, G. E., & Fleming, E. M. (1998). Technical efficiency and productivity of maize producers in Eastern Ethiopia: A study of farmers within and outside the Sasakawa-Glabal 2000 project. *Agricultural Economics*, 19, 341-348.

Sharma, K. R., Leung, P.S., & Zaleski, H.M. (1997). Productive efficiency of the swine industry in Hawaii; Stochastic frontier vs Data envelopment analysis. *Journal of Productivity*, 8, 447-459.

Wadud, M. A. (2003). Technical, allocative, and economic efficiency in Bangladesh: A stochastic and DEA approach. *The Journal of Developing Areas*, 37(1), 109-126.

Wan, G. H., & Cheng, E. J. (2001). Effects of land fragmentation and returns to scale in the Chinese farming sector. *Applied Economics*, 33, 183-194.

Wu, Y. (1995). The productive efficiency of Chinese iron and steel firms. *Resources Policy*, 21(3), 215-222.

Table 1. List of Variables for Primary Data Collection

Variable	Symbol	Measurement unit
Total Output	Y	BDT/Year
Land	X_1	Acre
Labor	X_2	Hour
Agricultural Credit	X_3	BDT/Year
Land Fragmentation	Z_1	Number of plots
Year of Schooling	Z_2	Year of schooling
Household Size	Z_3	Number of Family Member
Length of credit taking period	Z_4	Year
Experience	Z_5	Farming Age (in Year)
Farm Size	Z_6	Acre

Source: Authors' Compilation.

Table 2. Regression Model of Crop Cultivation

	OLS			MLE		
Variables	*Coefficient*	*SE*	*t- ratio*	*Coefficient*	*SE*	*t- ratio*
Constant	9.13	0.63	14.56	10.82	0.59	18.38
Ln(Land)	-0.21**	0.09	-2.30	-0.35***	0.12	-2.80
Ln(Labor)	0.06	0.06	1.08	0.03	0.07	0.38
Ln(Credit)	0.20***	0.05	4.02	0.10***	0.04	2.67
Variance parameters						
σ^2				0.03	0.01	3.22
γ				0.76***	0.08	9.82
η				0.11***	0.04	3.01
LLF				60.73		

*N.B.: ***, **, and * denote 1%, 5%, and 10% significance level respectively.*
OLS: Ordinary Least Square; MLE: Maximum Likelihood Estimator;
LLF: Log Likelihood Function; SE: Standard Error.

Source: Authors' Compilation.

Table 3. Model of Fish Cultivation

	OLS			*MLE*		
Variables	*Coefficient*	*SE*	*t-Ratio*	*Coefficient*	*SE*	*t-Ratio*
Constant	-371.16	89.09	-4.17	-370.55	1.00	-372.19
Ln(Land)	0.04	0.17	0.24	0.89***	0.23	3.94
Ln(Labor)	44.86***	10.76	4.17	45.49***	0.58	78.48
Ln(Credit)	0.60**	0.20	2.98	0.20	0.43	0.46
Variance parameters						
σ^2				0.50	0.22	2.28
γ				0.81***	0.07	11.16
η				0.04	0.09	0.41
LLF				-53.84		

*N.B.: ***, **, and * denote 1%, 5%, and 10% significance level respectively.*
OLS: Ordinary Least Square; MLE: Maximum Likelihood Estimator;
LLF: Log Likelihood Function; SE: Standard Error.

Source: Authors' Compilation.

Table 4. Model of Livestock Rearing

	OLS			MLE		
Variables	*coefficient*	*SE*	*t-ratio*	*coefficient*	*SE*	*t-ratio*
Constant	3.53	1.35	2.61	6.45	3.78	1.70
Ln(Land)	0.24***	0.07	3.28	0.31***	0.11	2.85
Ln(Labor)	0.17***	0.06	2.90	0.12***	0.05	2.37
Ln(Credit)	0.68***	0.11	6.15	0.50*	0.30	1.68
Variance parameters						
σ^2				0.05	0.03	1.34
γ				0.73***	0.19	3.83
η				0.11	0.07	1.47
LLF				28.51		

*N.B.: ***, **, and * denote 1%, 5%, and 10% significance level respectively.*
OLS: Ordinary Least Square; MLE: Maximum Likelihood Estimator;
LLF: Log Likelihood Function; SE: Standard Error.

Source: Authors' Compilation.

Table 5. Hypothesis Testing

Sub sector	*Null Hypothesis*	*Calculated t-value*	*Critical value of "t"*	*Decision*
Crop Cultivation	$H_0: \gamma = 0$	9.82	2.61***	H_0 is rejected
	$H_0: \eta = 0$	3.01	2.61***	H_0 is rejected
Fish Cultivation	$H_0: \gamma = 0$	11.16	2.66***	H_0 is rejected
	$H_0: \eta = 0$	0.41	1.67*	H_0 is rejected
Livestock Rearing	$H_0: \gamma = 0$	3.83	2.66***	H_0 is rejected
	$H_0: \eta = 0$	1.47	1.04	H_0 is not rejected
*N.B.: ***, and * represent the significance level at 1%, and 10% respectively.*				

Source: Authors' Compilation.

Table 6. Farm Level Technical Efficiency

Technical Efficiency	Crop *Cultivation*		*Fish Cultivation*		Livestock Rearing	
	Frequency	*Relative frequency (%)*	*Frequency*	*Relative frequency (%)*	*Frequency*	*Relative frequency (%)*
0.00-0.10	0	0	0	0	0	0
0.10-0.20	0	0	44	61	0	0
0.21-0.30	0	0	8	11	0	0
0.31-0.40	0	0	2	3	0	0
0.41-0.50	2	2	3	4	7	10
0.51-0.60	7	8	0	0	18	25
0.61-0.70	54	56	10	14	23	32
0.71-0.80	22	23	2	3	14	19
0.81-0.90	5	5	0	0	9	12
0.91-1.00	6	6	3	4	1	2
Total	96	100	72	100	72	100
Descriptive Statistics	N: 96 Mean : 0.69 Maximum: 0.95 Minimum: 0.43 Standard Deviation: 0.097		N: 72 Mean: 0.29 Minimum: 0.10 Maximum: 0.95 Standard Deviation: 0.235		N: 72 Mean: 0.66 Minimum: 0.44 Maximum: 0.91 Standard Deviation: 0.119	

Source: Authors' Compilation.

Table 7. Factors Affecting TE of Agricultural Farms

Variables	Crop Cultivation		Fish Cultivation		Livestock Rearing	
	δ_0	δ_i	δ_0	δ_i	δ_0	δ_i
Land Fragmentation	0.71	0.04	0.34	-0.11	0	0
Family Size	0.84	-0.29*	0.1	0.28*	0.68	0.01
Age of the Farmer	0.74	-0.06	-0.16	0.44**	0.59	0.17
Farming Experience	0.72	-0.04	0.15	0.4**	0.54	0.38**
Schooling Years	0.66	0.21	0.15	0.2	0.64	0.08
Credit Taking Years	0.63	0.35**	0.01	0.51**	0.54	0.44**
Farm Size	0.59	0.28*	0.42	-0.33*	0.69	-0.009
*N.B.: ** and * represent 5% and 10% significance level, respectively.*						

Source: Authors' Compilation.