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A STOCHASTIC FRONTIER COST FUNCTION ANALYSIS ON THE WHEAT FARMERS IN BANGLADESH

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ABSTRACT

The main objectives of the study are to estimate the farm specific economic efficiency of wheat production and to identify and measure the impacts of different factors associated with economic efficiency of wheat farmers. The study employed farm level cross sectional data from three major wheat growing areas of Bangladesh. Economic efficiency of wheat farmers was found to vary across locations and among farm categories. Cost of seed and urea, land rent and date of sowing were found to contribute significantly in the economic efficiency of wheat farmers. The average economic efficiency of wheat production in Bangladesh is 76 percent. This indicates a good potential for increasing wheat output by 24 percent with the existing technology and levels of inputs while considering amount and cost of inputs. Education and training of the farmers were found to have significant effect on yield and economic efficiency of wheat production.

I. INTRODUCTION

Wheat is one of the main cereal crops in Bangladesh as well as in the world. The average wheat yield of top five Asian wheat growing countries including Bangladesh was 1.82 t/ha against top five developed countries' average yield of 3.72 t/ha in 1980 (Hanson *et al.,* 1982). Wheat yields in developing countries lag behind those of developed countries, which was about 1.9 t/ha. This gap suggests opportunities for continued progress in future years. The possibility of increasing yield per unit area depends on the increase of acreage of high yielding variety (HYV), and by minimizing potential yield gap of HYVs. The yield gap is also high between farm level actual yield and potential yield. Wheat is one of the important cereal crops with respect to both acreage and production and currently it ranks second among the cereals in Bangladesh. The annual production of wheat in Bangladesh is about 0.74 million tons which is cultivated in 0.48 million hectares of land with an average yield of 1.54 t/ha (BBS, 2007). This yield is very low compared to the yield obtained by the popular varieties in the research stations as well as in the farmers' field demonstrations.

It is believed that farmers' performance is lower than their potential capacity due to underutilization of the most recently developed production technologies. The socioeconomic constraints to higher production of wheat are of vital importance. The socioeconomic constraints may explain why farmers are not utilizing the practices and inputs identified as capable of raising yields. Therefore, planners and policy makers need information on the relative importance of various yield constraints so that they can allocate and redistribute the available resources for various researchable issues in order to augment productivity.

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Generally, adoption of modern technology and production practices vary across farms. Variation in different items of production package is mainly responsible for such kind of yield gap. Amount and quality of different inputs used and other management vary from one farmer to another. Thus the potential yield level at farmers' field is not achieved in many cases. The management practices and input use are likely to be influenced by various socio-agroeconomic factors such as farmers' age, education, occupation, experience in farming, resource base, family size, access to information, physical infrastructure, cost of inputs and outputs, etc. These factors influence farmers to adopt any technology fully or partially. It is possible to attain a higher yield of different crops by adopting modern practices and thus the yield gaps can be minimized in this way. Profitability is certainly an important consideration in the farmers' selection of crops and in the adoption of new technologies. The returns from the crops and the productivity of inputs or resources determine the ability of farmers to acquire and sustain a certain type and quantity of resources which in turn will be used for further increase of productivity. The efficient use of resources is an important indicator of increased production in agriculture. Efficient use of inputs can help farmers to get higher production from a given amount of resources.

Like other food grains, wheat output could be increased by efficient utilization of inputs such as land, labour and capital; and organizing the management of production effectively. Input intensification has already reached the point where a further increase in input may not be profitable. Efficient utilization of present level of inputs may be advised for higher productivity. As there is a limited scope for further increase of wheat area, production can be increased by increasing the efficiency of wheat farmers using existing technology. Several studies in other countries have shown that there is significant potential for raising agricultural output or profitability by improving productive efficiency using existing resources (Rahman, 2002). These studies have also indicated that there may be significant efficiency differentials across regions and among farms as well. Understanding the determinants of economic efficiency of wheat production is very important for both farmers and policymakers to increase the productivity and profitability of wheat production.

Efficiency is an important issue of productivity growth in the agriculture based economy of developing countries. The estimation of efficiency with the help of production function has been a popular area of applied econometrics. Recent works in duality theory, which has linked production and cost functions, has made this topic more attractive. However, definition of a production function is given in terms of the maximum output attainable at given level of the inputs and that of a cost function gives the minimum cost of producing a given level of output at same set of input cost. Modeling production and cost frontiers and their empirical estimation for studying productive efficiency of wheat farmers in Bangladesh could be benefited to a great extent from such studies. Estimates on the extent of efficiency may help improve productivity through input reallocation or cost minimization. The study is, therefore, designed to estimate the farm specific economic efficiency of wheat production in the study areas and to identify and measure different factors associated with economic efficiency of wheat farmers.

In order to fulfill the research objectives of the study, the following hypotheses will be tested:

There is a significant economic inefficiency effect in wheat production in Bangladesh and socioeconomic factors have significant effect on economic inefficiency of wheat production in Bangladesh.

II. DATA AND METHODOLOGY

Source of Data

A multistage sampling procedure was followed to select wheat growing areas. In the first stage three wheat growing districts i.e. Dinajpur, Rajshahi and Jamalpur were chosen purposively considering the intensity of wheat area coverage among different districts. In the second stage, one upazila from each district and one union from each upazila were selected randomly. Finally, three mouzas namely Char Palisha Madhyapara of Melandah Upazila under Jamalpur district, Bhatgaon of Kaharol Upazila under Dinajpur district and Bhograil of Paba Upazila under Rajshahi district were selected randomly for this study.

To collect primary data a sampling frame of wheat growing farmers in the selected mouzas were prepared with the help of village leaders and record book of union council. These farmers were stratified into small (0.2 ha to < 1.0 ha), medium (1.0 ha to < 2.0 ha) and large (2.0 ha and above) as per classification of farm category followed in different farming systems and crop based studies in Bangladesh (Islam, 1995; Karim, 1996; Hasan *et al.*, 2002; Uddin and Hasan, 2003). For determining the sample size Fisher's measure of skewness formula was applied (Fisher, 1958) and an optimum number samples from different stratum were determined (Cochran, 1999). Thus a total of 293 samples [Dinajpur-101 (large-33, medium-29 and small 39); Jamalpur-89 (large-8, medium-25 and small-56) and Rajshahi-103 (large-19, medium-32 and small-52)] were chosen. Total number of farmers according to farm category was large 60, medium 86 and small 147. A pre-designed and pre-tested questionnaire was applied to collect data during November 2003 to June 2004.

Empirical Cobb-Douglas frontier cost function model

The empirical Cobb-Douglas frontier cost function with double log form can be written by normalizing with labour wage rate as:

$$Ln(C_i / W_{1i}) = \alpha_0 + \alpha_1 Ln(Q_i) + \sum_{j=2}^{13} \alpha_j Ln(W_{ji} / W_{1i}) + \sum_{k=1}^{6} \mu_k D_{ki} + v_i + u_i \quad (1)$$

Where,

C_i = Cost of production of the i^{th} farm (Tk.)

Q_i = Output of the i^{th} farm (Kg)

W_{1i} = Labour wage rate of the i^{th} farm (Tk./man-day)

W_{2i} = Cost of animal power of the i^{th} farm (Tk./pair-day)

W_{3i} = Cost of seed of the i^{th} farm (Tk./kg)

W_{4i} = Cost of urea of the i^{th} farm (Tk./kg)

W_{5i} = Cost of TSP of the i^{th} farm (Tk./kg)

W_{6i} = Cost of DAP of the i^{th} farm (Tk./kg)

W_{7i} = Cost of MP of the i^{th} farm (Tk./kg)

W_{8i} = Cost of gypsum of the i^{th} farm (Tk./kg)
W_{9i} = Cost of farm yard manure (FYM) of the i^{th} farm (Tk./kg)
W_{10i} = Cost of mechanical power of the i^{th} farm (Tk./ha)
W_{11i} = Weedicides cost of the i^{th} farm (Tk./ha)
W_{12i} = Land rent of the i^{th} farm (Tk./ha)
W_{13i} = Irrigation charge of the i^{th} farm (Tk./ha)
D_{1i} = Dummy for land type of the i^{th} farm (1= Medium high land, 0 = otherwise)
D_{2i} = Dummy for soil type of the i^{th} farm (1= Loamy soil, 0 = otherwise)
D_{3i} = Dummy for sowing date of the i^{th} farm (1= optimum sowing, 0 = otherwise)
D_{4i} = Dummy for variety of the i^{th} farm (1= Kanchan, 0 = Otherwise)
D_{5i} = Dummy for seed source of the i^{th} farm (1= Self preserved, 0 = otherwise)
D_{6i} = Dummy for location of the i^{th} farm (1= Rajshahi, 0 = otherwise)
v and u are assumed to have normal and half normal distribution, respectively.
α 's, μ 's are parameters to be estimated.

Cost or economic inefficiency effect model

To examine the role of relevant farm specific variables in efficiency, the cost or economic inefficiency effect model can be written as below:

$$u_i = \delta_0 + \delta_1 z_{1i} + \delta_2 z_{2i} + \delta_3 z_{3i} + \delta_4 z_{4i} + \delta_5 z_{5i} + \delta_6 z_{6i} + \delta_7 z_{7i} + W_i \quad (2)$$

Where, u_i refers to the total economic or cost inefficiency of the i-th farm operator
z_{1i} = Ln farm size of the i^{th} farmer (ha)
z_{2i} = Age of the i^{th} farmer (years)
z_{3i} = Education level of the i^{th} farmer (year of schooling)
z_{4i} = Experience in wheat farming of the i^{th} farmer (years)
z_{5i} = Household size of the i^{th} farmer (persons/household)
z_{6i} = Dummy for extension contact of the i^{th} farmer (1= yes, 0 = otherwise)
z_{7i} = Dummy for wheat training of the i^{th} farmer (1 = yes, 0 = otherwise)
δ 's are unknown parameters to be estimated
W_is were unobservable random variables or classical disturbance term, which are assumed to be independently distributed, obtained by truncation of the normal distribution with mean zero and unknown variance, σ^2, such that u_i is non negative.

The α, μ and δ coefficients are unknown parameters to be estimated, together with the variance parameters which are expressed in terms of

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \quad (3)$$

and

$$\gamma = \sigma_u^2 / \sigma^2 \quad (4)$$

γ is the ratio of variance of farm specific technical efficiency to the total variance of output and has a value between zero and one.

The estimates for all parameters of the cost frontier (1) and inefficiency model (2) were estimated in a single stage by the maximum likelihood (ML) method using the econometric computer software package FRONTIER 4.1 (Coelli, 1996).

The economic efficiencies were estimated with the help of derived normalized cost frontier described in equations (1) and (2) by maximum likelihood estimate (MLE) method using a computer software, FRONTIER 4.1 (Coelli, 1996). Asides from estimates of coefficients in the model, the output of the FRONTIER 4.1 programme also provides other variance parameters such as sigma square (σ^2), gamma (γ) and log likelihood function. To generate farm specific economic efficiency indices for wheat production in the study areas, the stochastic frontier cost function with production cost as dependent variable was estimated in which all input costs were normalized by labour wage rate.

Hypotheses testing

The model for inefficiency effects mentioned in equation (2) can only be estimated if the inefficiency effects are stochastic and have a particular distributional specification. Hence, there is interest in testing the null hypotheses that

(i) The inefficiency effects are not present,

H_0: $\gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = 0$; and

(ii) The inefficiency effects are not stochastic,

H_0 : $\gamma = 0$ and

(iii) The coefficients of the variables in the model for the inefficiency effects are zero,

H_0: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = 0$

These null hypotheses were tested using generalized likelihood ratio statistic, λ, defined by:

$$\lambda = -2Ln[L(H_0)/L(H_1)]$$
$$= -2[Ln\{L(H_0)\} - Ln\{L(H_1)\}]$$

Where,

$L(H_0)$ and $L(H_1)$ are the values of the likelihood function for the specification of the null and alternative hypotheses, H_0 and H_1, respectively.

III. RESULTS AND DISCUSSION

ML Estimates of Farm-Specific Stochastic Frontier Cost Function Model

The ML estimates of the coefficients of stochastic Cobb-Douglas cost frontier and economic inefficiency effect model showing the minimal cost performance are presented in Table 1. The empirical results indicated that the coefficients of output, cost of seed, cost of urea and per hectare land rent were positive and significant implying that an increase in the magnitudes of these variables would result in the corresponding increase of cost of producing wheat. The coefficients of cost of TSP, cost of MP, per hectare mechanical, weedicides and irrigation cost, dummy for soil type and location were found to be positive but insignificant.

On the other hand, the coefficients of cost of FYM and dummy for sowing date were negative and significant which meant that an increase in the magnitudes of FYM and optimum sowing would result in the corresponding decrease of cost of producing wheat. The coefficients of cost of animal power, cost of DAP, cost of gypsum, dummy for land type, dummy for variety and dummy for seed source were found negative but insignificant. As the cost frontier was normalized by labour wage rate, it was excluded from the model.

Table 1. ML estimates for parameters of Cobb-Douglas stochastic normalized cost frontier model for wheat

Independent variables	Parameters	Co-efficient	Standard error	t-ratio
Stochastic frontier:				
Constant	α_0	4.46	0.816	5.47
Ln Output (kg)	α_1	0.509**	0.051	10.06
Ln Animal power cost (Tk/pair-day)	α_2	-0.020	0.063	-0.32
Ln Cost of seed (Tk/kg)	α_3	0.135*	0.067	2.02
Ln Cost of urea (Tk/kg)	α_4	0.540*	0.244	2.21
Ln Cost of TSP (Tk/kg)	α_5	0.143	0.114	1.25
Ln Cost of DAP (Tk/kg)	α_6	-0.027	0.090	-0.30
Ln Cost of MP (Tk/kg)	α_7	0.007	0.025	0.29
Ln Cost of gypsum (Tk/kg)	α_8	-0.016	0.174	-0.09
Ln Cost of FYM (Tk/kg)	α_9	-1.11*	0.449	-2.48
Ln Mechanical cost (Tk/ha)	α_{10}	0.005	0.018	0.30
Ln Weedicides cost (Tk/ha)	α_{11}	0.001	0.0011	1.04
Ln Land rent (Tk/ha)	α_{12}	0.142**	0.052	2.73
Ln Irrigation cost (Tk/ha)	α_{13}	0.009	0.006	1.59
Dummy for land type (1=MHL, 0=otherwise)	μ_1	-0.020	0.012	-1.61
Dummy for soil type (1=Loamy, 0=otherwise)	μ_2	0.009	0.012	1.07
Dummy for sowing date (1=Optimum, 0=otherwise)	μ_3	-0.012*	0.006	-1.96
Dummy for variety (1=*Kanchan*, 0=otherwise)	μ_4	-0.137	0.129	-1.06
Dummy for seed source (1=Own, 0=otherwise)	μ_5	-0.020	0.011	-1.85
Dummy for location (1=Rajshahi, 0=otherwise)	μ_6	0.008	0.025	0.30
Inefficiency effect model:				
Constant	δ_0	0.155	0.078	2.74
Ln Operated land (ha)	δ_1	0.003	0.015	0.21
Farmers age (years)	δ_2	-0.0008	0.0011	-0.78
Farmers education (year of schooling)	δ_3	-0.005*	0.002	-2.18
Farming experience (years)	δ_4	0.0034	0.0018	1.92
Household size (person/hh)	δ_5	-0.003	0.006	-0.51
Dummy for extension contact (1=Yes, 0=otherwise)	δ_6	0.029	0.023	1.28
Dummy for training (1=Yes, 0=otherwise)	δ_7	-0.022	0.024	0.91
Variance parameters:				
Sigma squared	σ^2	0.811**	0.0011	7.91
Gamma	γ	0.999**	0.000093	106.76
Log likelihood function		308.99		

** and * indicate significant at 1% and 5% level of probability, respectively.

ML Estimates of Location-Specific Stochastic Frontier Cost Function Model

The empirical results from location specific estimates showed that at Dinajpur, the coefficients of output, cost of seed and per hectare land rent were positive and significant implying that an increase in the magnitudes of these variables would result in the corresponding increase of cost of producing wheat (Table 2). The coefficients of cost of animal power, cost of gypsum and dummy for variety were also positive but insignificant. On the other hand, the coefficient of cost of urea, cost of DAP, cost of MP, per hectare mechanical cost, dummy for soil type and seed source were negative and significant implying that an increase in the use of these variables and increased use of loamy soil and own seed would result in the decrease of cost of producing wheat for the farmers at Dinajpur. The coefficients of cost of TSP, cost of FYM, per hectare irrigation cost, dummy for land type and sowing date were negative but insignificant.

The coefficients of output, cost of urea, cost of TSP, cost of DAP and dummy for seed source were positive and significant implying that an increase in the magnitude of these variables and own seed would result in the corresponding increase of cost of producing wheat for the farmers at Jamalpur. The coefficients of cost of animal power, cost of gypsum and per hectare land rent were positive but insignificant. On the other hand, the coefficient of cost of MP, cost of FYM, per hectare mechanical cost and dummy for sowing date were negative and significant which implying that an increase in the magnitude of these variables would result in the decrease of cost of producing wheat for the farmers at Jamalpur. The coefficients of cost of seed, per hectare irrigation cost, dummy for land type, soil type and variety were found to be negative but insignificant.

The coefficients of output and per hectare mechanical cost were positive and significant implying that an increase in the level of these variables would result in the corresponding increase of cost of producing wheat for the farmers at Rajshahi. The coefficients of cost of seed, cost of TSP, cost of DAP, cost of MP, cost of gypsum, per hectare land rent, dummy for land type and variety were found to be positive but insignificant.

On the other hand, the coefficient of cost of urea, cost of FYM and dummy for sowing date were negative and significant which implying that an increase in the magnitude of these variables and optimum sowing would result in the decrease of cost of producing wheat for farmers at Rajshahi. The coefficients of cost of animal power, per hectare irrigation cost, dummy for soil type and seed source were found to be negative but insignificant.

Table 2. ML estimates for parameters of location specific Cobb-Douglas stochastic normalized cost frontier model.

Independent variables	Para-meters	Location		
		Dinajpur	Jamalpur	Rajshahi
Stochastic frontier:				
Constant	α_0	6.23 (0.913)	-11.98 (1.10)	-10.13 (1.11)
Ln Output (kg)	α_1	0.804* (0.393)	0.847** (0.138)	0.931** (0.236)
Ln Animal power cost (Tk/pair-day)	α_2	0.389 (0.814)	0.103 (0.114)	-0.551 (1.21)
Ln Cost of seed (Tk/kg)	α_3	0.234** (0.061)	-0.177 (0.100)	0.300 (1.01)
Ln Cost of urea (Tk/kg)	α_4	-0.281** (0.097)	0.572** (0.122)	-0.261* (0.110)
Ln Cost of TSP (Tk/kg)	α_5	-0.032 (0.176)	0.582** (0.143)	0.728 (0.993)
Ln Cost of DAP (Tk/kg)	α_6	-0.470** (0.12)	0.107** (0.019)	0.088 (0.199)
Ln Cost of MP (Tk/kg)	α_7	-0.275** (0.155)	-0.081** (0.025)	0.009 (0.049)
Ln Cost of gypsum (Tk/kg)	α_8	0.290 (0.269)	0.043 (0.092)	0.715 (0.964)
Ln Cost of FYM (Tk/kg)	α_9	-0.310 (0.98)	-0.435** (0.011)	-0.477* (0.239)
Ln Mechanical cost (Tk/ha)	α_{10}	-0.024** (0.002)	-0.024** (0.005)	0.023* (0.011)
Ln Land rent (Tk/ha)	α_{11}	0.190* (0.079)	0.085 (0.061)	0.011 (0.124)
Ln Irrigation cost (Tk/ha)	α_{12}	-0.003 (0.011)	-0.006 (0.007)	-0.009 (0.009)
Dummy for land type (1=MHL, 0=otherwise)	μ_1	-0.006 (0.020)	-0.022 (0.023)	0.010 (0.022)
Dummy for soil type (1=Loamy, 0=otherwise)	μ_2	-0.087** (0.029)	-0.016 (0.022)	-0.043 (0.067)
Dummy for sowing date (1=Optimum, 0=otherwise)	μ_3	-0.0002 (0.0002)	-0.005** (0.001)	-0.0006* (0.0003)
Dummy for variety (1=*Kanchan*, 0=otherwise)	μ_4	0.400 (0.233)	-0.367 (0.232)	0.162 (0.277)
Dummy for seed source (1=Own, otherwise-0)	μ_5	-0.632** (0.068)	0.144* (0.074)	-0.011 (0.073)
Inefficiency effect model:				
Constant	δ_0	-0.68 (0.625)	2.31 (0.633)	0.021 (0.109)
Ln Operated land (ha)	δ_1	-0.251 (0.036)	0.037 (0.020)	-0.075 (0.133)
Farmers age (years)	δ_2	0.052** (0.012)	-0.113** (0.024)	-0.025 (0.027)
Farmers education (year of schooling)	δ_3	-0.043** (0.012)	-0.009* (0.004)	-0.029* (0.014)
Farming exp. (years)	δ_4	0.004 (0.084)	-0.156* (0.074)	-0.236 (0.265)
Household size (person/hh)	δ_5	-0.273 (0.95)	0.245 (0.508)	-0.008 (0.112)
Dummy for extension contact (1=Yes, 0=otherwise)	δ_6	0.0003 (0.0004)	0.0001 (0.0004)	0.0001 (0.0003)
Dummy for training (1=Yes, 0=otherwise)	δ_7	0.0001 (0.00021)	0.0007 (0.0016)	-0.0005* (0.0003)
Variance parameters:				
Sigma squared	σ^2	0.980** (0.0015)	0.482** (0.001)	0.608** (0.201)
Gamma	γ	0.999** (0.0038)	0.999** (0.0006)	0.583** (0.217)
Log likelihood function		121.90	134.08	111.90

** and * indicate significant at 1% and 5% level of probability, respectively.

ML Estimates of Farm-Size Specific Stochastic Frontier Cost Function Model

The empirical results from farm size-specific estimates showed that for the large farms, the coefficients of output, cost of seed, cost of FYM and dummy for variety were positive and significant which implying that an increase in the magnitudes of these variables would result in the corresponding increase of cost of producing wheat (Table 3). The coefficients of cost of DAP, per hectare irrigation cost, dummy for sowing date, seed source and location were found to be positive but insignificant. On the other hand, the coefficient of cost of urea and cost of TSP were negative and significant implying that an increase in the use of urea and TSP would result in the decrease of cost of producing wheat for the large farmers. The coefficients of cost of animal power, cost of MP, cost of gypsum, per hectare mechanical, weedicides and land rent, and dummy for land type and soil type were found to be negative but insignificant for the large farmers.

The coefficients of output, cost of FYM, cost of weedicides and land rent, and dummy for seed source were positive and significant which implying that an increase in the magnitude of these variables would result in the corresponding increase of cost of producing wheat for the medium farms. The coefficients of cost of animal power, cost of gypsum, per hectare irrigation cost, and dummy for land type, soil type, sowing date and variety were found to be positive but insignificant. On the other hand, the coefficient of cost of urea and per hectare mechanical cost were negative and significant implying that an increase in the magnitude of these variables would result in the decrease of cost of producing wheat for the medium farmers. The coefficients of cost of seed, cost of TSP, cost of DAP, cost of MP and dummy for location were found to be negative but insignificant.

For the small farm category, the coefficients of output and per hectare land rent were positive and significant implying that an increase in the magnitude of output and land rent would result in the corresponding increase of cost of producing wheat. The coefficients of cost of seed, cost of urea, cost of TSP, cost of gypsum, cost of weedicides, dummy for land type and location were found to be positive but insignificant.

Table 3. ML estimates for parameters of farm size-specific Cobb-Douglas stochastic normalized cost frontier model

Independent variables	Para-meters	Farm category		
		Large	Medium	Small
Stochastic frontier:				
Constant	α_0	3.18 (0.998)	15.14 (0.991)	-9.00 (3.06)
Ln Output (kg)	α_1	0.590** (0.291)	0.358** (0.168)	0.619** (0.293)
Ln Animal power cost (Tk/pair-day)	α_2	-0.974 (0.999)	0.487 (1.05)	-0.853 (1.07)
Ln Cost of seed (Tk/kg)	α_3	0.331** (0.145)	-0.635 (0.472)	0.531 (0.325)
Ln Cost of urea (Tk/kg)	α_4	-0.640* (0.196)	-0.721** (0.321)	0.507 (0.867)
Ln Cost of TSP (Tk/kg)	α_5	-0.568** (0.249)	-0.004 (0.411)	0.396 (0.386)
Ln Cost of DAP (Tk/kg)	α_6	0.145 (0.996)	-0.316 (0.450)	-0.222* (0.110)
Ln Cost of MP (Tk/kg)	α_7	-0.004 (0.261)	-0.226 (0.319)	-0.305** (0.117)
Ln Cost of gypsum (Tk/kg)	α_8	-0.456 (0.993)	0.382 (0.325)	0.381 (0.382)
Ln Cost of FYM (Tk/kg)	α_9	0.656** (0.145)	0.677** (0.311)	-0.187* (0.091)
Ln Mechanical cost (Tk/ha)	α_{10}	-0.025 (0.023)	-0.029** (0.004)	-0.021** (0.005)
Ln Weedicides cost (Tk/ha)	α_{11}	-0.002 (0.069)	0.024** (0.006)	0.017 (0.025)
Ln Land rent (Tk/ha)	α_{12}	-0.080 (0.965)	0.806* (0.334)	0.163** (0.045)
Ln Irrigation cost (Tk/ha)	α_{13}	0.108 (0.460)	0.014 (0.008)	-0.018 (0.010)
Dummy for land type (1=MHL, 0=otherwise)	μ_1	-0.079 (0.047)	0.041 (0.035)	0.023 (0.022)
Dummy for soil type (1=Loamy, 0=otherwise)	μ_2	-0.192 (0.332)	0.101 (0.075)	-0.086 (0.077)
Dummy for sowing date (1=Optimum, 0=otherwise)	μ_3	0.0003 (0.0009)	0.0003 (0.0002)	-0.0005** (0.0001)
Dummy for variety (1=*Kanchan*, 0=otherwise)	μ_4	0.242* (0.222)	0.0001 (0.083)	-0.182 (0.241)
Dummy for seed source (1=Own, 0=otherwise)	μ_5	0.305 (0.952)	0.476* (0.212)	-0.264 (0.397)
Dummy for location (1=Rajshahi, 0=otherwise)	μ_6	0.018 (0.025)	-0.008 (0.019)	0.026 (0.021)
Inefficiency effect model:				
Constant	δ_0	0.005 (0.999)	0.476 (0.651)	0.372 (0.544)
Ln Operated land (ha)	δ_1	-0.026 (0.272)	0.015 (0.037)	0.071 (0.043)
Farmers age (years)	δ_2	0.006 (0.156)	-0.064 (0.035)	0.074* (0.034)
Farmers education (yr.of schooling)	δ_3	-0.041* (0.021)	-0.095* (0.047)	-0.080* (0.039)
Farming exp. (years)	δ_4	0.002 (0.998)	0.190 (0.953)	0.149 (0.942)
Household size (person/hh)	δ_5	-0.0004* (0.0002)	0.001** (0.0004)	0.0001(0.0003)
Dummy for extension contact (1=Yes, 0=otherwise)	δ_6	-0.0002 (0.0007)	0.0003 (0.0008)	0.0005 (0.003)
Dummy for training (1=Yes, 0=otherwise)	δ_7	0.000059 (0.00066)	-0.00025* (0.00012)	-0.00047 (0.00026)
Variance parameters:				
Sigma squared	σ^2	0.109 (0.011)	0.936** (0.001)	0.638** (0.793)
Gamma	γ	0.995 (0.938)	0.971** (0.212)	0.993** (0.107)
Log likelihood function		81.26	93.82	178.27

** and * indicate significant at 1% and 5% level of probability, respectively.

On the other hand, the coefficient of cost of DAP, cost of MP, cost of FYM, per hectare mechanical cost and dummy for sowing date were negative and significant implying that an increase in the magnitude of these variables would decrease the cost of producing wheat for small farms. The coefficients of cost of animal power, per hectare irrigation cost and dummy for soil type, variety and seed source were found to be negative but insignificant.

Economic Efficiency and Its Distribution

Using the cost function and normalized input costs, locations specific and farm size specific economic efficiency was estimated (Table 4). It was observed that the mean economic efficiency was 0.76 with a range from 0.40 to 0.98. This implied that, on an average, the wheat producers were producing wheat about 76 percent of the potential (stochastic) cost frontier levels, given the levels of their inputs and the technology currently being used. This also indicated that there existed an average level of economic inefficiency of 24 percent i.e. 24 percent cost of production could be reduced keeping the output constant.

Table 4. Farm specific economic efficiency of wheat producers

Region/ Location	Farm category	No. of farms	Economic efficiency			
			Mean	Maximum	Minimum	Standard deviation
Dinajpur	Large	33	0.78	0.92	0.58	0.09
	Medium	29	0.72	0.98	0.50	0.11
	Small	39	0.73	0.90	0.43	0.09
	All	101	0.74	0.98	0.43	0.10
Jamalpur	Large	8	0.82	0.89	0.72	0.07
	Medium	25	0.77	0.93	0.61	0.07
	Small	56	0.82	0.97	0.60	0.06
	All	89	0.81	0.87	0.60	0.07
Rajshahi	Large	19	0.75	0.85	0.58	0.07
	Medium	32	0.76	0.93	0.55	0.09
	Small	52	0.73	0.92	0.40	0.11
	All	103	0.74	0.93	0.40	0.10
All	Large	60	0.77	0.92	0.58	0.09
	Medium	86	0.75	0.98	0.50	0.09
	Small	147	0.76	0.97	0.40	0.10
	All	293	0.76	0.98	0.40	0.09

Source: Hasan (2006)

The economic efficiencies were almost the same for different farm categories (mean economic efficiency level was 77% for large, 75% for medium and 76% for small farmers). The variation in economic efficiency was observed higher with the small (ranged from 40 to 97%) and medium farmers (ranged from 50 to 98%) than the large farmers (ranged from 58 to 92%). On the other hand, mean level of economic efficiency was lower at Dinajpur and Rajshahi (74% each) as compared to Jamalpur (81%). The variation in economic efficiency was observed higher at Dinalpur (ranged from 43 to 98%) whereas it was 60 to 87 percent at

Jamalpur and 40 to 93 percent at Rajshahi. The higher variation in economic efficiency implied that economic efficiency was somewhat unstable for the small farmers as well as for the farmers at Dinajpur in wheat production.

Considering different locations, the farmers at Jamalpur were found to be economically more efficient in wheat production compared to other two locations. Sixty percent of the farmers at Jamalpur achieved economic efficiency level of more than 80 percent (Table 5). On the other hand, 29 percent of the farmers at Dinajpur and 33 percent of the farmers at Rajshahi achieved economic efficiency level of more than 80 percent. On the contrary, more of the farmers at Dinajpur (26%) achieved economic efficiency level of less than 70 percent followed by Rajshshi (19%) and Jamalpur (6%). Ten percent farmers at Rajshahi and 8 percent farmers at Dinajpur had economic efficiency below 60 percent against none at Jamalpur with similar efficiency.

Table 5. Frequency distribution of economic efficiency of wheat producers

Region/Location	Farm category	Number of farmer under different economic efficiency level (%)					
		≤ 60	61-70	71-80	81-90	91-100	All
Dinajpur	Large	1 (3)	4 (12)	15 (45)	9 (27)	4 (12)	33 (100)
	Medium	5 (17)	6 (21)	11 (38)	6 (21)	1 (3)	29 (100)
	Small	2 (6)	8 (21)	20 (51)	8 (21)	1 (3)	39 (100)
	All	8 (8)	18 (18)	46 (46)	23 (23)	6 (6)	101 (100)
Jamalpur	Large	-	-	3 (38)	5 (62)	-	8 (100)
	Medium	-	3 (12)	11 (44)	10 (40)	1 (4)	25 (100)
	Small	-	2 (4)	17 (30)	31 (55)	6 (11)	56 (100)
	All	-	5 (6)	31 (35)	46 (52)	7 (8)	89 (100)
Rajshahi	Large	1(5)	3 (16)	11(58)	4 (21)	-	19 (100)
	Medium	3 (9)	2 (6)	13 (41)	12 (38)	2 (6)	32 (100)
	Small	6 (12)	15 (29)	15 (29)	12 (23)	4 (6)	52 (100)
	All	10 (10)	20 (19)	39 (38)	28 (27)	6 (6)	103 (100)
All	Large	2 (3)	7 (12)	29 (48)	18 (30)	4 (7)	60 (100)
	Medium	8 (9)	11 (13)	35 (41)	28 (33)	4 (5)	86 (100)
	Small	8 (5)	25 (17)	52 (35)	51 (35)	11 (7)	147 (100)
	All	18 (6)	43 (15)	116 (40)	97 (33)	19 (6)	293 (100)

Figures in the parentheses indicate percent of total
Source: Hasan (2006)

When different farm categories were taken into consideration, it was observed that 42 percent of the small farmers obtained economic efficiency level of more than 80 percent compared to medium and large farmers' 38 and 37 percent, respectively (Table 5). This indicated better performance of the small farmers. On the contrary, 22 percent each of the small and medium farmers and 15 percent of the large farmers achieved economic efficiency level of less than 70 percent indicated that economic efficiency was somewhat unstable for small farmers.

Farm Specific Indices of Economic Efficiencies

The frequency distribution of economic efficiency indices of wheat producers are shown in Table 6. The average economic efficiency was 0.76 indicated that 24.0 percent cost saving is possible keeping the output constant. On the other hand, only 4.1 percent of the farmers were able to achieve economic efficiency level (frontier minimum cost) greater than 90 percent. There were a large number of farmers (23.9%) whose economic efficiency was less than 70 percent and thus their 30 percent cost saving was possible.

Table 6. Frequency distribution of farm specific economic efficiency estimates of wheat producers

Efficiency levels (%)	Economic efficiency	
	No.[a]	%[b]
≤ 60	21	7.2
61 – 70	49	16.7
71 – 80	121	41.3
81 – 90	90	30.7
91 – 100	12	4.1
Total	293	100
Mean	0.76	
Maximum	0.98	
Minimum	0.40	
Standard deviation	0.09	

[a] Number of farms, [b] Percentage of total farms
Source: Hasan (2006)

Factors Affecting Farm-Specific Economic Inefficiency

The ML estimates of the coefficients of stochastic Cobb-Douglas cost frontier and economic inefficiency models (farm-specific, location specific and farm-size specific) showed the minimal cost performance. The estimates of farm specific variables in those models which were responsible for economic inefficiency are discussed in the following sections.

***Farm size*:** The coefficient of farm size was positive but insignificant in the economic inefficiency model for wheat production (Table 1). The coefficient of farm size was negative for Dinajpur and Rajshahi; and positive for Jamalpur but all of them were insignificant in the location-specific economic inefficiency model (Table 2). On the other hand, the coefficient of farm size for large farms was negative and that for small and medium farms was positive in the farm size-specific economic inefficiency model for wheat production (Table 3) but all were insignificant. Rahman (2004) observed that economic inefficiency decreases with the increase of land holding when studying aman rice producers in Bangladesh. Kaiser (1988) and Bravo-Ureta and Pinheiro (1997) also found positive and statistically strong relationship between farm size and economic efficiency. On the contrary, Parikh *et al.* (1995) and Rahman (2002) found that economic inefficiency increases with the increase in farm size when studying Pakistan agriculture and rice crops of Bangladesh, respectively.

***Farmers' age*:** The coefficient of farmers' age was negative but insignificant in the economic inefficiency model for wheat production (Table 1). The coefficients of farmers' age were positive and significant for Dinajpur, negative and significant for Jamalpur and negative but insignificant for Rajshahi in the location-specific economic inefficiency model for wheat production (Table 2). This implied that economic inefficiency increases with the increase in farmers' age at Dinajpur but economic inefficiency decreases with the increase in farmers' age at Jamalpur. The coefficients of farmers' age were positive for large farms and negative for medium farms but both were insignificant. On the other hand, the coefficient for the small farms was positive and significant in the farm size-specific economic inefficiency model for wheat production (Table 3). The significant coefficient for the small farms indicated that economic inefficiency will increase with the increase in farmers' age. This result was consistent with the findings of Bravo-Ureta and Evenson (1994), Coelli and Battese (1996) and Bravo-Ureta and Pinheiro (1997). Furthermore, younger farmers were likely to have some formal education, and therefore, might be more successful in gathering information and understanding new practices, which in turn would improve their economic efficiency through higher levels of technical and/or allocative efficiency. On the contrary, Rashid (2002) found negative but insignificant relationship between farmers' age and economic inefficiency while studying shrimp farming in Bangladesh.

Farmers' education: The coefficient of farmers' education was negative and significant in the economic inefficiency model for wheat production (Table 1) which implied that economic inefficiency decreases with the increase in farmers' education. That is, farmers with higher education were economically more efficient than farmers with lower education. The coefficient of farmers' education was negative and significant for all the three locations in the location-specific economic inefficiency model (Table 2) which implied that economic inefficiency decreases with the increase in farmers' education in all the three locations. The coefficient of farmers' education was negative and significant for all the three farm categories too in the farm size-specific economic inefficiency model (Table 3) which also implied that economic inefficiency decreases with the increase in farmers' education for all farm categories. This finding was in conformity with the findings of Rashid (2002) and Rahman (2004) but contradictory with the finding *of* Rahman (2002). Bravo-Ureta and Pinheiro (1997) did not find any association between economic efficiency and education.

Farming experience: The coefficient of farming experience was positive but insignificant in the economic inefficiency model for wheat production (Table 1). The coefficient of farming experience was positive and insignificant for Dinajpur, negative and significant for Jamalpur and negative but insignificant for Rajshahi in the location-specific economic inefficiency model (Table 2) which implied that economic inefficiency decreases with the increase in wheat farming experience at Jamalpur. It may be mentioned here that the average farming experience was half for the farmers at Jamalpur than the farmers of Dinajpur and Rajshahi. The coefficient of farming experience was positive for all the three farm categories in the farm size-specific economic inefficiency model for wheat production (Table 3) but all were insignificant. Rahman (2004) found negative relationship between experience and economic efficiency but Rahman (2002) observed positive correlation between experience and economic efficiency while studying rice farming in Bangladesh.

Household size: The coefficient of household size was negative but insignificant in the economic inefficiency effect model for wheat production (Table 1). The coefficients of household size were negative for Dinajpur and Rajshahi and positive for Jamalpur but all were insignificant in the location-specific economic inefficiency model for wheat production (Table 2). The coefficients of household size were negative and significant for large farms, positive and significant for medium farms and positive but insignificant for small farms in the farm size-specific economic inefficiency model (Table 3) which implied that economic inefficiency decreases with the increase in household size for the large farms but economic inefficiency increases with the increase in household size for the medium farms. Pinheiro (1992) observed negative impact of household size on economic efficiency while studying small farms in the Dominican Republic.

Extension contact: The coefficient of extension contact dummy was positive but insignificant in the economic inefficiency model for wheat production (Table 1). Though extension contact should have a positive effect on economic efficiency by providing up-to date information regarding modern technology than that of non-contact farmers, in this particular case no significant role was found. This may be due to very poor contacts between extension personnel and farmers in the study areas. The coefficients of dummy for extension contact were positive for all the three locations but all were insignificant in the location-specific economic inefficiency effects model (Table 2). The coefficients of dummy for extension contact were negative for large farmers but positive for both medium and small farms in the farm size-specific economic inefficiency model for wheat production (Table 3) but all were insignificant. The positive and significant impact of extension contact and economic efficiency were observed in many studies (Parikh *et al.*, 1995; Bravo-Ureta and Pinheiro, 1997; Rahman, 2002, Rahman, 2004) but the present finding is not in conformity with them.

Training on wheat: The coefficient of training dummy was negative but insignificant in the economic inefficiency model for wheat production (Table 1). This implied that economic inefficiency decreased with the farmers who received training on wheat. The coefficients of training dummy were positive and insignificant for Dinajpur and Jamalpur but negative and significant for Rajshahi in the location-specific economic inefficiency effects model (Table 2) indicated that economic inefficiency decreases with the farmers had training on wheat at Rajshahi. The coefficients of wheat training dummy was positive for large farmers but negative for medium and small farmers in the farm size-specific economic inefficiency model (Table 3). The negative and significant coefficient for medium farms implied that economic inefficiency decreases with the increase in training on wheat for the medium farms. It is expected that training on wheat should have a positive effect on economic efficiency by providing up-to date information regarding modem technology than that of non-trained farmers, in this particular case we did not find strong relationship may be due to very small number of farmers had training on wheat.

Hypothesis Testing for Economic Inefficiency Effect

The coefficients of farm specific variables on the economic inefficiency effects model were tested using generalized likelihood-ratio statistic. Table 7 shows the generalized likelihood ratio statistic to identify the presence of economic inefficiency effects in the production of wheat in Bangladesh. It was observed that there were significant economic inefficiency effects in the production of wheat in all farm size groups and in all locations except Rajshahi since the null hypothesis was rejected for all farm categories, Dinajpur and Jamalpur locations. This means there was no economic inefficiency effect in Rajshahi but economic inefficiency effects were found to be significant in Dinajpur and Jamalpur.

Table 7. Tests of hypotheses for coefficients of the explanatory variables for the economic inefficiency effects in the stochastic frontier cost functions

Null Hypothesis	Log likelihood	Test Statistic (λ)	Critical $\chi^2_{V, 0.95}$ value	Decision
H₀: $\gamma = \delta_0 = \delta_1 = \delta_2 = ...\delta_7 = 0$				
Farm specific:				
Large	87.808	28.472	Mixed $\chi^2_{9, 0.95}$ = 16.274	H_o Rejected
Medium	101.725	21.192	Mixed $\chi^2_{9, 0.95}$ = 16.274	H_o Rejected
Small	167.098	17.558	Mixed $\chi^2_{9, 0.95}$ = 16.274	H_o Rejected
Location specific:				
Dinajpur	119.310	17.748	Mixed $\chi^2_{9, 0.95}$ = 16.274	H_o Rejected
Jamalpur	130.276	18.546	Mixed $\chi^2_{9, 0.95}$ = 16.274	H_o Rejected
Rajshahi	112.371	5.252	Mixed $\chi^2_{9, 0.95}$ = 16.274	H_o Accepted
All	321.369	32.152	Mixed $\chi^2_{9, 0.95}$ = 16.274	H_o Rejected
H₀: $\gamma = 0$				
Farm specific:				
Large	77.097	7.050	Mixed $\chi^2_{1, 0.95}$ = 2.706	H_o Rejected
Medium	96.629	4.600	Mixed $\chi^2_{1, 0.95}$ = 2.706	H_o Rejected
Small	158.347	3.820	Mixed $\chi^2_{1, 0.95}$ = 2.706	H_o Rejected
Location specific:				
Dinajpur	115.436	2.914	Mixed $\chi^2_{1, 0.95}$ = 2.706	H_o Rejected
Jamalpur	126.135	2.864	Mixed $\chi^2_{1, 0.95}$ = 2.706	H_o Rejected
Rajshahi	109.778	2.768	Mixed $\chi^2_{1, 0.95}$ = 2.706	H_o Rejected
All	310.376	10.166	Mixed $\chi^2_{1, 0.95}$ = 2.706	H_o Rejected
H₀: $\delta_1 = \delta_2 = ... = \delta_7 = 0$				
Farm specific:				
Large	87.808	21.422	$\chi^2_{7, 0.95}$ = 14.067	H_o Rejected
Medium	101.725	14.192	$\chi^2_{7, 0.95}$ = 14.067	H_o Rejected
Small	167.098	17.502	$\chi^2_{7, 0.95}$ = 14.067	H_o Rejected
Location specific:				
Dinajpur	119.310	17.748	$\chi^2_{7, 0.95}$ = 14.067	H_o Rejected
Jamalpur	130.276	18.282	$\chi^2_{7, 0.95}$ = 14.067	H_o Rejected
Rajshahi	112.371	15.186	$\chi^2_{7, 0.95}$ = 14.067	H_o Rejected
All	321.369	21.986	$\chi^2_{7, 0.95}$ = 14.067	H_o Rejected

Note: Mixed χ^2 critical values are taken from Kodde and Palm (1986).

The hypothesis was also rejected for all farms (pooled data) implying that economic inefficiency effects were found to be significant for wheat farmers in general. The null hypothesis that the inefficiency effects were not stochastic was rejected for all the three locations and for all the three farm categories. This hypothesis was also rejected for all farms (pooled data) implying that economic inefficiency effects were stochastic in wheat production. The null hypothesis involving the parameters of the inefficiency function other than intercept was also rejected for all the three farm categories, for all the three locations and all farms (pooled data). This indicated the significant contribution of the combined effects of farm specific factors on economic inefficiencies of all farm categories and locations in wheat production.

IV. CONCLUSION AND POLICY IMPLICATIONS

The average economic efficiency of the wheat farmers is about 76 percent. This indicated that about 24 percent economic inefficiency existed among the farmers as well as a potential for decreasing 24 percent cost of production through the improvement of efficiency.

Optimum sowing and seeds from BADC/research institutions played a positive role in increasing yield and efficiency of wheat. Farmers are applying seeds at higher rate than recommendation due to the lack of good quality seed. Supply of quality seeds to the farmers should be ensured by strengthening seed production and distribution system both in public and private sectors. On the other hand, effort should be given to overcome the problem of late sowing. The principal cause of late sowing is late release of lands occupied by preceding T.aman rice. To overcome this situation short duration early maturing T.aman rice variety should be developed and popularized. The turn around period after T.aman rice harvest should also be minimized to facilitate wheat sowing at optimum time. Short duration heat tolerant wheat variety can also overcome the problem of delayed sowing. Therefore, continuous effort should be made for variety development considering diverse issues and climatic factors.

Extension contact has a positive impact in increasing production of wheat and efficiency of wheat farmers. Hence, farm level extension service should be strengthened so that farmers' consciousness regarding improved production and management practices is ensured. Education and training on wheat of the farm operators was found to have significant effect on yield and efficiency of wheat production in the farm specific, location specific and farm size specific stochastic frontier cost function models. Economic efficiency increases (or inefficiency decreases) with the increase in education and training on wheat of farm operators. Thus, it is a priority issue to invest in public education to explore and develop human resources of farms. Formal training on wheat technology will also be an effective technique to improve farmers' efficiency.

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