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A Stochastic Frontier Approach to Model Technical Efficiency of Rice Farmers in Bangladesh: An Empirical Analysis

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Abstract

A study was conducted in the year 2008-2009 to estimate the farm-size-specific productivity and technical efficiency of all rice crops. Farm-size- specific technical efficiency scores were estimated using stochastic production frontiers. There were wide of variations of productivity among farms, where large farms exhibited the highest productivity. Gross return was the highest for small farms and net return was the highest for marginal farms. The lowest net return or the highest cost of production was accrued from both the highest wage rate and highest amount of labour used in medium farms. The marginal farms experienced the highest benefit-cost ratio (BCR) followed by small and medium farms. Average technical efficiency for large, medium, small, marginal and all farms were respectively 0.88, 0.92, 0.94, 0.75 and 0.88. There were significant technical inefficiency effects in the production of rice for marginal farms only. In this case, production cannot be increased by increasing efficiency with the existing technology except in marginal farms. The application of efficient management system would be able to increase production in the marginal farms. For other farms, increased managerial capacity is not enough for increased production, rather new investment and advanced technology are needed to increase production in these farms. On an average, farmers could increase 12 percent output with existing inputs and production technology. Fertiliser, manure, irrigation cost, insecticide cost, area under production and experience were important factors to increase production. In the technical inefficiency effect, age, education and family size had positive impact on efficiency effect, whereas land under household had negative impact on efficiency effect.

Keywords: **Stochastic production frontier, technical efficiency, farm-category- specific technical efficiency**

1. Introduction

Decisions about development strategies in agriculture are in part guided by farm level performance. The farm level performance can be attained in two alternate ways: by maximising output with the given set of inputs under existing production technology or by minimising production cost to produce a prescribed level of output. The former concept is known as technical efficiency. Technical efficiency is used as a measure of a farm's ability to produce maximum output from a given set of inputs under certain production technology. It is a relative concept in so far as the performance of each production unit is usually compared to a standard. The standard may be used on farm-specific estimates of best practice techniques (Herdt and Mandac, 1981) but more usually by relating farm output to population parameters based on production function analysis (Timmer, 1971). A technically efficient farm operates on its frontier production function. Given the relationship of inputs in a particular production function, the farm is technically efficient if it produces on its outer-bound production function to obtain the maximum possible output, which is feasible under the current technology. Putting it differently, a farm is considered to be technically efficient if it operates at a point on an isoquant rather than interior to the isoquant. The measurements of farm-size-specific technical efficiency get momentum to meet the increasing demands of rice in Bangladesh. Since different farm size groups possess different resources, farm-size-specific efficiency measurements are particularly important for the developing countries like Bangladesh. Different farm groups operate different sizes of land; there are some economies and diseconomies of scales in the production of crops. Optimum land size must have some economies of scales prevailing in the production process. Our keen interest was to know which farm group is more efficient in the rice production in Bangladesh.

The measurement of the productive efficiency of a farm relative to other farms or to the "best practice" in an industry has long been of interest to agricultural economists. Efficiency measurement has received considerable attention by both theoretical and applied economists. From a theoretical point of view, there has been a spirited exchange about the relative importance of various components of farm efficiency (Leibenstein, 1966; Leibenstein, 1977; Comanor and Leibenstein, 1969; Stigler, 1976). From an applied perspective, measuring efficiency is important because this is the first step in a process that might lead to substantial resource savings. These resource savings have important implications for both policy formulation and farm management (Bravo-Ureta and Rieger, 1991). In the policy arena, there is a continuing controversy regarding the connection between farm size, efficiency and the structure of agricultural production. For individual farms, gains in efficiency are particularly important in periods of financial stress. The efficient farms are likely to generate higher incomes and thus stand a better chance of surviving and prospering.

The objectives of this paper, therefore are: (i) to develop a specification and estimation for a stochastic frontier model to estimate farm-size-specific technical efficiency; (ii) to identify the factors causing variations in technical inefficiency effects (or technical efficiencies) among the sample farmers; (iii) to implicate certain development policy.

2. Materials and Methods

This study is based on primary data collected from 1360 farmers through direct interview method using pre-tested questionnaires in 14 different districts of Bangladesh. The selection of the districts was purposive considering them as major rice growing districts which contributed about 16 percent of total rice production in Bangladesh (BBS, 2008). The selection of farmers of different categories was performed using stratified random sampling technique. This study involved four categories of farm households. These are marginal farms (farm size less than 50 decimals); small farms (farm size 50-249 decimals); medium farm (farm size 250-750 decimals); and large farms (above 750 decimals of land). Of the 1360 farm households, 138 farmers were arbitrarily selected and interviewed from large farms, 416 farmers from medium farms, 440 from small farms and 366 from marginal farms. Data were collected by trained field enumerators during the year 2008 to 2009.

In order to estimate the level of technical efficiency in a way consistent with the theory of production function, we specified a Cobb-Douglas type stochastic frontier production function. The Cobb-Douglas form of production function has some well known properties that justify its wide application in economic literature (Henderson and Quandt, 1971). It is a homogeneous function that provides a scale factor enabling one to measure the returns to scale and to interpret the elasticity coefficients with relative ease. It is also easy to estimate and mathematically manipulate.

The Cobb-Douglas production function makes several restrictive assumptions. It is assumed that the elasticity coefficients are constant, implying constant shares for the inputs. The elasticity of substitution among factors is unity in the Cobb-Douglas form. Moreover, this being linear in logarithm, the output is zero if any of the inputs is zero, and the output expansion path is assumed to pass through the origin. It is also argued that if interest rests on efficiency measurements and not on an analysis of the general structure of the underlying production technology, the Cobb-Douglas specification provides an adequate representation of the production technology. In addition, its simplicity and widespread use in agricultural economics outweigh its drawbacks. It is less affected by multicollinearity problem and less suffered from degrees of freedom.

The explicit Cobb-Douglas stochastic frontier production function is given below:

$$\ln Y_i = \ln\beta_0 + \sum_{i=1}^{10} \beta_i \ln X_i + \beta_{11} EDU + V_i - U_i \quad \ldots\ldots\ldots(1)$$

Where, Y = Output (kg), X_1 = Area under rice crops (decimal), X_2 = Human labour (man-days), X_3 = Seed (kg), X_4 = Fertiliser (kg), X_5 = Manure (kg), X_6 = Ploughing cost (Tk), X_7 = Irrigation cost (real value, Tk), X_8 = Insecticide cost (Tk), X_9 = Age of farm operator, X_{10} = Experience of farm operator, EDU = Education of farm operator (year of schooling). V is assumed to be independently and identically distributed random error, having $N(0, \sigma_v^2)$ distribution; and the U is non-negative one-sided random variable, called technical inefficiency effects, associated with the technical inefficiency of production of the farmers involved. It is assumed that the inefficiency effects are independently distributed with a half normal distribution $(U \sim |N(0, \sigma_u^2)|)$.

The model for the technical inefficiency effects in the stochastic frontier of equation (1) is defined by

$$U_i = \delta_0 + \delta_1 AGE_i + \delta_2 EDU_i + \delta_3 EXPERIENCE_i + \delta_4 FAMSZ_i + \delta_5 FARMSZ_i + W_i \quad \ldots\ldots\ldots(2)$$

where, AGE represents age of farm operator, EXPERIENCE is the experience of the farm operator, FAMSZ is family size, FARMSZ is farm size and the W_i are unobservable random variables assumed to be independently distributed with a positive half normal distribution.

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

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

and

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

where, the γ-parameter has value between zero and one. The parameters of the stochastic frontier production function model are estimated by the method of maximum likelihood, using computer program-FRONTIER Version 4.1.

A model for the inefficiency effects (2) can only be estimated if the inefficiency effects are stochastic and have a particular distributional specification. Hence, there is interest to test the null hypotheses that the inefficiency effects are not present, H_0: $\gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = 0$. This null hypothesis of interest was tested using the generalised likelihood ratio test and t-test. The generalised likelihood-ratio test is a one-sided test since γ can not take negative values. The generalised likelihood ratio test requires the estimation of the model under both the null and alternative hypotheses. Under the null hypothesis, H_0: $\gamma = 0$, the model is equivalent to the traditional average response function, without the technical inefficiency effect, U_i. The test statistic is calculated as:

$LR = -2\{\ln[L(H_0)/L(H_1)]\} = -2\{\ln[L(H_0)] - \ln[L(H_1)]\}$ ……(5)

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

The technical efficiency of a farmer at a given period of time is defined as the ratio of the observed output to the frontier output, which could be produced by a fully efficient farm, in which the inefficiency effect is zero. Given the specifications of the stochastic frontier model (1) - (2), the technical efficiency of the i^{th} farmer can be shown to be equal to:

$$TE_i = \exp(-U_i) = \exp\{-E(U_i/\varepsilon_i)\} = 1 - E(U_i/\varepsilon_i)\} \quad \text{……..(6)}$$

Thus, the technical efficiency of a farmer is between zero and one and is inversely related to the inefficiency effect. The farm specific efficiencies are predicted using the predictor that is based on the conditional expectation of U_i given composed error $\varepsilon_i = (V_i\text{-}U_i)$. Farm-specific or observation specific estimates of technical inefficiency, U (subscripts can safely be omitted here), can be obtained using the expectation of the inefficiency term conditional on the estimate of the entire composed error term, as suggested by Jondrow *et al*. (1982) and Kalirajan and Flinn (1983). One can use either the expected value or the mode of this conditional distribution as an estimate of U:

$$E(U/\varepsilon) = \sigma_*[\frac{f\left(\varepsilon\lambda/\sigma\right)}{1 - F\left(\varepsilon\lambda/\sigma\right)} - \left(\frac{\varepsilon\lambda}{\sigma}\right)] \quad \text{……..(7)}$$

Where, f and F are, the standard normal density and distribution functions respectively, evaluated at

$$\varepsilon\lambda/\sigma, \quad \sigma_*^2 = \sigma_u^2\,\sigma_v^2/\sigma^2, \quad \lambda = \sigma_u/\sigma_v$$
$$and \quad \sigma^2 = \sigma_u^2 + \sigma_v^2.$$

The mean technical efficiency or the mathematical expectation of the farm-specific technical efficiencies can be calculated for given distributional assumptions for the technical inefficiency effects. The mean technical efficiency can be defined as:

$$\text{Mean T.E.} = E[\exp\{-E(U_i/\varepsilon_i)\}] = E[1 - E(U_i/\varepsilon_i)\} \quad \text{………..(8)}$$

With the help of FRONTIER (Version 4.1c), the parameters of the stochastic frontier production function (1) are estimated, together with farm-specific technical efficiencies and mean technical efficiency for the farms.

The model has been estimated for four farm size groups. *Aus* is a short-duration direct seeded crop which is sown in March-April and harvested in July-August, utilising the pre monsoon rainwater. *Aman* is sown during June-August to November-December and *Boro* is grown during November-January to April-June.

3. Results and Discussion

A summary statistics on selected farm-size-specific or socioeconomic variables used in stochastic frontier and inefficiency effect model defined by the equations 1 and 2 are presented in Table 1. All variables are expressed in per farm basis. Table 1 reveals that medium aged farmers are engaged in farming practices and average age of farmers is 46.45 years with significant variations among farm groups ($F=5.57^{**}$). Older (49.57 years) farmers were found to work on activities in large farms. Education levels of farm operators significantly ($F=34.08^{**}$) varied among farms and the highest education level of farmer (8.74 years) was observed in large farm and the lowest education level was observed in marginal farm (5.15 years) with the average education level being 7.01 years at the aggregate level. The highest experience large farms had of 27.80 years with an average of 25.24 years at the aggregate level. There were also significant variations of experiences of farmers among the farm groups ($F=4.46^{**}$). The distribution of cultivable land under rice production was quite dissimilar among farms ($F=290.82^{**}$) and large farmers owned the largest area under rice cultivation (625.40 decimals) with an average rice area of 220.74 decimals for all farms. The total land under households was also the highest (826.01decimals) for the large farmers and total land per household varied significantly ($F=474.17^{**}$) among the farms (Table 1).

Table 2 summarises the inputs used for the production of rice in different farms. For convenience of the analysis, some of the inputs are expressed in money values. The results show that medium farmers used relatively higher amount of labour (168.49 man-days) per hectare and there is no significant differences of labour use among the farms (F=2.42). The higher amount of seed (51.75kg) was used by large farm with significant differences ($F=6.31^{**}$) among farm groups. Farmers in different farms used different amounts of fertilisers with significant variations ($F=6.09^{**}$) and farmers of small farm group used the highest amount (363.72kg), whereas farmers at the aggregate level used 350.18kg of fertiliser. Manure use was found to be insignificantly different in different farms (F=2.36kg) and the highest amount of manure was used by medium farm group (3423.05kg), whereas the overall manure use was 3290.80kg. There was no significant difference in ploughing cost among different farms (F=0.19). There was no significant difference (F=1.68) in irrigation and insecticide costs (F=0.507) among the farms. The highest irrigation cost was (Tk.2775.24) in large farm and the highest insecticide cost (Tk 1019.52) was in marginal farm.

Table 3 summarises labour and rice production costs, gross returns, net returns and benefit cost ratio (BCR) in different farms. Per hectare labour cost were similar among farm groups, although the highest labour cost was found in medium farms (Tk.26811.34) and the lowest was observed in marginal farms (Tk.24378.11). The large farm exhibited relatively higher production (4772.83kg) per hectare, whereas the average production at the aggregate level was 4641.66kg. There was significant difference in production costs per hectare ($F=5.4^{**}$) among the farms. There was significant difference ($F=4.26^{**}$) among farms for BCR. The highest production cost was in medium farms (Tk.62118.06) and the lowest was observed in marginal farms (Tk.57513.52). Gross return was highest for small farms (Tk.74131.14) and net return was the highest for marginal farms (Tk.15588.45). The marginal farm showed the maximum BCR (1.39) followed by small (1.34) and medium farms (1.26).

Table 1. Farm category wise distribution of different socio-economic variables

Farm Category	Sample Size (N)	Age (Year)	Education (Year of Schooling)	Experience (Year)	Area under Production (decimal)	Total Land under household (decimal)
Large	138	49.57 (13.68)	8.74 (3.49)	27.80 (14.67)	625.40 (453.01)	826.01 (450.35)
Medium	416	47.25 (12.24)	7.86 (3.84)	26.04 (11.98)	263.10 (168.05)	393.10 (179.67)
Small	440	45.81 (11.59)	7.21 (5.45)	23.81 (12.20)	151.40 (95.77)	230.09 (106.68)
Marginal	366	45.14 (11.66)	5.15 (3.94)	25.07 (12.46)	102.40 (100.98)	140.22 (108.18)
Total	1360	46.45 (12.10)	7.01 (4.58)	25.24 (12.52)	220.74 (239.88)	316.24 (275.80)
F-value		5.57^{**}	34.08^{**}	4.46^{**}	290.82^{**}	474.17^{**}

NB: ** and * indicate significance at 0.01 and 0.05 probability level, respectively. Figures in the parentheses indicate standard deviation.

Table 2. Farm category wise uses of different farm inputs per hectare

Farm Category	Sample size	Labour (man-days)	Seed (kg)	Fertiliser (kg)	Manure (kg)	Ploughing cost (Tk.)	Irrigation cost (Tk.)	Insecticide cost (Tk.)
Large	138	163.84 (55.11)	51.75 (18.14)	355.50 (133.26)	3389.86 (2806.22)	4214.43 (2020.75)	2775.24 (2352.47)	1003.57 (333.49)
Medium	416	168.49 (59.10)	49.76 (17.17)	356.99 (133.56)	3423.05 (2647.09)	4242.78 (1882.69)	2501.85 (2279.84)	1014.84 (312.02)
Small	440	162.99 (58.83)	48.65 (17.84)	363.72 (139.27)	3394.55 (2628.73)	4145.30 (1925.05)	2729.01 (2393.79)	994.18 (320.22)
Marginal	366	157.25 (57.06)	45.39 (16.48)	324.14 (146.06)	2978.41 (2558.90)	4174.41 (2022.40)	2413.27 (2349.05)	1019.52 (319.45)
Total	1360	163.22 (58.45)	48.43 (17.41)	350.18 (139.61)	3290.80 (2638.30)	4189.97 (1947.12)	2579.25 (2344.91)	1008.27 (318.73)
F-value		2.416	6.307**	6.091**	2.358	0.194	1.684	0.507

NB: Figures in the parentheses indicate standard deviations. ** and * indicate significance at 0.01 and 0.05 probability level, respectively.

Table 3. Farm category wise production, cost and benefit cost ratio (BCR) per hectare

Farm Category	Labour Cost (Tk)	Production (Kg)	Return (Tk)	Production Cost (Tk)	Net Return (Tk)	BCR
Large	25669.47 (11276.74)	4772.83 (1727.49)	73146.07 (24869.94)	61546.20 (14908.86)	11599.86 (27325.74)	1.24 (0.47)
Medium	26811.34 (12750.19)	4635.41 (1601.48)	73484.99 (25083.65)	62118.06 (16490.09)	11366.94 (29269.33)	1.26 (0.54)
Small	25429.61 (12379.60)	4632.34 (1496.85)	74131.14 (24552.07)	60277.57 (16852.41)	13853.57 (30031.67)	1.34 (0.61)
Marginal	24378.11 (12440.71)	4610.53 (1552.37)	73101.97 (24247.73)	57513.52 (16743.88)	15588.45 (28743.07)	1.39 (0.64)
All	25593.62 (12425.72)	4641.66 (1567.51)	73556.57 (24643.60)	60225.42 (16605.44)	13331.16 (29207.25)	1.32 (0.58)
F-value	2.54	0.38	0.14	5.40**	1.57	4.26**

NB: Figures in the parentheses indicate standard deviations. ** indicates significance at 0.01 probability level.

Table 4 shows the simultaneous estimation of the maximum likelihood estimates for parameters of the Cobb-Douglas stochastic production frontiers and technical inefficiency effect model for different farms. If we estimate the technical efficiency effects frontier by FRONTIER 4.1 package (Coelli, 1996), we can simultaneously estimate the stochastic frontier and technical inefficiency effect model in a single step. Kumbhakar, Ghosh and Mcguckin (1991), Reifschneider and Stevension (1991), Huang and Lui (1994) and Battese and Coelli (1995) specified stochastic frontiers and models for the technical inefficiency effects and simultaneously estimated all the parameters involved. This one-stage approach is less objectionable from a statistical point of view and is expected to lead to more efficient inference with respect to the parameters involved. For large farms, fertiliser, manure, irrigation cost, land under production and experience variables had positive and significant coefficients. For medium, small and marginal farms, fertiliser, irrigation cost, insecticide and land under production had positive and significant coefficients. Manure had positive and significant effect on rice production for medium and small farms.

In the technical inefficiency effect models, age and education had negative and significant effect on the inefficiency effects for medium farms, whereas age had also expected (negative) signs for large and marginal farms. This implied that the older farmers had lesser inefficiency than that of younger farmers. In other words, the older farmers were technically more efficient than that of younger farmers in medium farms. Coelli and Battese (1996) found similar results while studying technical efficiency of Indian farmers. Education had significantly negative impact on the inefficiency effect in medium farms which implied that educated farmers were technically more efficient than that of less educated or uneducated farmers. Education had also expected sign for small and marginal farms. Experience had expected sign for large, medium and marginal farms. Family size had negative and significant impact, whereas land under household had positive and significant impact on inefficiency effect for large and medium farms. Positive coefficient of land under household indicated that inefficiency effect increased with the increase in farm size of household for both the farm groups.

Table 5 shows frequency distribution of farm-specific technical efficiency estimates for large, medium, small and marginal farms from Cobb-Douglas stochastic frontiers. The results reveal that maximum large farms were obtained outputs which were very close to the maximum output estimated through frontier (efficiency is 80 to 100%) and there were about 71% medium farms whose technical efficiency levels ranged from 90-100%, whereas 90% small farmers produced rice at 90-100% efficiency level. For marginal farms, technical efficiency varied from 30 to 100%.

The average technical efficiency scores for large, medium, small, marginal farm and all farms were respectively 0.88, 0.92, 0.94, 0.75 and 0.88. The maximum efficiency scores attained for large, medium, small, marginal farms and all farms were respectively 0.99, 0.98, 0.98, 0.95 and 0.98, whereas the minimum efficiency scores for the above farms were respectively 0.62, 0.57, 0.70, 0.34 and 0.34 (Table 6).

3.1. Hypothesis

The coefficients of farm-specific variables on the technical inefficiency effect models were tested using generalised likelihood-ratio statistic, L R. Coelli (1995) suggested that one-sided generalised likelihood-ratio test should be performed when ML estimation is involved because this test has the correct size (i.e., probability of Type I error). We have an interest to test the null hypothesis that the inefficiency effects are not present. In other words, the null hypothesis is that where there are no technical inefficiency effects in the model. That is,

H_0: $\gamma = \delta_0 = \delta_1 = ... = \delta_5 = 0$.

Table 7 reveals that there are significant technical inefficiency effects in the production for marginal farm only, since null hypothesis is rejected. For large, medium and small farms the null hypothesis is accepted.

Table 4. Maximum Likelihood (ML) estimates of Cobb-Douglas production frontiers and technical inefficiency effect model

Variables	Farm Size			
	Large	Medium	Small	Marginal
Stochastic Frontier :				
Intercept	1.263	3.144**	1.689**	4.482**
	(0.4896)	(0.4421)	(0.3069)	(0.5593)
Human Labour	-0.0542	-0.0512	-0.1241	-0.0590
	(0.0639)	(0.0354)	(0.0323)	(0.0350)
Seed	0.0279	0.0131	-0.0055	-0.0184
	(0.0544)	(0.0361)	(0.0344)	(0.0366)
Fertiliser	0.1998**	0.1511**	0.1027**	0.1082**
	(0.0499)	(0.0284)	(0.0239)	(0.0216)
Manure	0.0259**	0.0168**	0.0118**	0.0038
	(0.0062)	(0.0042)	(0.0046)	(0.0051)
Ploughing cost	-0.0411	-0.0064	0.0159	-0.0019
	(0.0553)	(0.0146)	(0.0117)	(0.0149)
Irrigation cost	0.0303**	0.0355**	0.0332**	0.0506**
	(0.0063)	(0.0042)	(0.0046)	(0.0052)
Insecticide cost	0.02169	0.1376**	0.1633**	0.1061*
	(0.0650)	(0.0449)	(0.0046)	(0.0450)
Land under Production	0.7294**	0.8028**	0.8516**	0.7828**
	(0.1266)	(0.0675)	(0.0615)	(0.0674)
Age	0.1797	-0.01905	0.1711	-0.3933
	(0.1397)	(0.1141)	(0.0884)	(0.1575)
Experience	0.0282**	0.0429	-0.0145	0.0213
	(0.0066)	(0.0439)	(0.0383)	(0.0665)
Education	0.0108	-0.0111	0.0035	0.0009
	(0.0174)	(0.0062)	(0.0035)	(0.0063)
Inefficiency Model:				
Intercept	-0.0245	0.6711	-0.5765	1.0372
	(0.2722)	(0.3130)	(0.3829)	(0.3218)
Age	-0.0010	-0.0143*	0.0068	-0.0168
	(0.0048)	(0.0064)	(0.0055)	(0.0098)
Education	0.0236	-0.0313*	-0.0073	-0.0153
	(0.0149)	(0.0129)	(0.0166)	(0.0145)
Experience	-0.0023	-0.00.29	0.0047	-0.0052
	(0.0044)	(0.0042)	(0.0047)	(0.0093)
Family size	-0.0265**	-0.0247*	0.0088	0.0101
	(0.0093)	(0.0104)	(0.0169)	(0.0197)
Land under HH	0.0001**	0.0003**	0.0002	-0.0004
	(0.00007)	(0.00013)	(0.0004)	(0.0005)
Variance Parameters:				
σ^2	0.0558**	0.0738**	0.0716**	0.1295**
	(0.0063)	(0.0066)	(0.0242)	(0.0332)
γ	0.0103	0.1542	0.1176	0.7992**
	(0.1491)	(0.0974)	(0.3816)	(0.0730)
Log-likelihood Function:	2.991	-23.71	-28.73	-27.14

NB: Figures in the parentheses indicate standard errors. ** and * indicate significance at 0.01 and 0.05 probability level respectively.

Table 5. Frequency distribution of farm-category- specific technical efficiency estimates using stochastic frontiers

Efficiency Level	Farm Category			
	Large	Medium	Small	Marginal
30-40	-	-	-	4 (1.1)
40-50	-	-	-	17 (4.6)
50-60	-	1 (0.2)	-	39 (10.7)
60-70	2 (1.4)	5 (1.2)	-	51 (13.9)
70-80	22 (15.9)	26 (6.3)	15 (3.4)	79 (21.6)
80-90	55 (39.9)	90 (21.6)	28 (6.4)	135 (36.9)
90-100	59 (42.8)	294 (70.7)	397 (90.2)	41 (11.2)
Total	138 (100)	416 (100)	440 (100)	366 (100)

NB: Figures in the parentheses indicate percentages. Source: Own estimation

Table 6. Farm category wise technical efficiency coefficients

Efficiency Parameter	Farm Category				
	Large	Medium	Small	Marginal	All
Maximum	0.99	0.98	0.98	0.95	0.99
Minimum	0.62	0.57	0.70	0.34	0.34
Mean	0.88	0.92	0.94	0.75	0.88

Table 7. Test of hypothesis for the technical inefficiency effects in Cobb-Douglas stochastic frontier production functions

Null Hypothesis	Log-likelihood value	Test Statistics LR	Critical value	Decision
H_0: $\gamma = \delta_0 = \delta_1 = ... = \delta_5 = 0$				
Farm Category:				
Large	2.99	8.99	12.02	Accepted
Medium	-23.71	9.87	12.02	Accepted
Small	-28.72	7.35	12.02	Accepted
Marginal	-27.14	17.13	12.02	Rejected

Source: Own Estimation

4. Conclusions and Recommendations

There were wide variations of productivity among different categories of farms, where large farm exhibited the highest productivity; medium farms the second highest productivity and marginal farms the lowest per hectare. The gross return was the highest for small farms and net return was the highest for marginal farms. The lowest net return or the highest cost of production for medium farms was accrued from both the highest wage rate and the highest amount of labour used in this farm. The marginal farms experienced the highest benefit-cost ratio (BCR) followed by small and medium farms, respectively.

The vital factors responsible for the increased production were fertiliser, manure, insecticide cost, land and experience. Production was positively influenced by demographic variations also. Older farmers had smaller inefficiencies than that of younger farmers. Technical efficiency increased with the increase in age of farmers. Farmers with the highest education had higher technical efficiency. Farm size has negative relations with efficiency. There were significant inefficiency effects for marginal farms only.

With the existing production technology and input use, production can not be increased by increasing efficiency level, except for marginal farms. Advanced technology is needed to increase production. Higher yielding new variety development and improved input management practices are inevitable for increased production.

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