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FARM-SIZE-SPECIFIC TECHNICAL EFFICIENCY: A STOCHASTIC FRONTIER ANALYSIS FOR RICE GROWERS IN BANGLADESH

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Abstract

The study was conducted during 2008-2009 to estimate the farm-size-specific technical efficiency of rice growers. The technical efficiency scores were estimated using stochastic production frontiers. The large farms received the highest yield (4772.83 kg) per hectare while marginal farms received the lowest yield (4610.53 kg). Gross return was found to be the highest for small farms and net return was the highest for marginal farms. The marginal farm experienced the highest benefit-cost ratio (BCR) followed by small, medium and large farm respectively. The 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 was significant technical inefficiency in the production of rice for marginal farms indicating that production could be increased by increasing efficiency with the existing technology for marginal farms. Farm management could help in increasing production in marginal farms. For other farms, increased managerial capacity was not enough for increasing production. New investment and advanced technology were needed to increase production in these farms. Farmers could increase 12 percent output with application of inputs and production technology at the aggregate level. The costs of fertiliser, manure, irrigation, insecticide and area and experience were important factors to increase production. Age, education and family size had negative impact on technical inefficiency whereas land had positive impact on technical inefficiency.

I. INTRODUCTION

Rice is the most important crop in Bangladesh. It contributes over 70 percent of the crop GDP and over 50 percent of the agricultural GDP which in turn accounts for about a third of national GDP. Past growth in gross crop revenue has been due almost entirely to the growth in rice production, raising concern whether past performance of the rice sector can be maintained. More than two-thirds of the growth in rice output was attributable to the conversion from local to modern varieties rather than to increase in varietal yields (Baffes and Gautam, 2001; Rahman et al., 2006). During 1990-2004, the annual growth rate in total rice

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production was estimated at 3.15 percent while rice area grew at 0.30 percent. Modern Variety (MV) rice output, area and yield grew at the rates of 5.76, 4.19 and 1.51 percent respectively during 1990-2004 (Rahman and Schmitz, 2007).

Decisions about development strategies in agriculture are in part guided by farm size-specific performances. These farm size-specific performances can be attained in two ways by maximising output with the given set of inputs under existing production technology or by minimising production cost to produce a maximum level of output. The former concept is known as technical efficiency which is used as a measure of a firm's ability to produce maximum output from a given set of inputs under certain production technology. It is a relative concept as the performance of each production unit is usually compared to a standard. This standard may be used on farm size-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 firm operates on its frontier production function.

The measurements of farm-size-specific technical efficiency got momentum with increased demand for rice in Bangladesh. Here any particular farm size group possesses particular level of resources. Therefore, farm-size-specific efficiency measurements are particularly important. Different farm groups operate different sizes of land, there are some sorts of economies and diseconomies of scales in the production of crops. Optimum land size must have some economies of scales prevailing in the production processes (Rahman et al. 2004).

Scarcity of resources has prompted policy makers to think for developing and exploring managerial skills of farmers. The development of managerial skills helps increase productivity and efficiency of farmers which in turn generate more profits in agricultural production. The managerial skills indirectly lessen pressure on the soil by avoiding use of excessive inputs. In the policy arena, there is a continuing debate 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. Efficient farms are more likely to generate higher incomes and thus stand a better chance of surviving and prospering (Rahman et al. 1999).

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

II. METHODOLOGY

Data:

The data were collected from 1360 farmers interviewing them directly using a pre-tested questionnaire from 14 districts across Bangladesh. The districts were Dinajpur, Rangpur, Bogra, Rajshahi, Natore, Naogaon, Mymensingh, Sherpur, Kishoregonj, Sylhet, Camilla, Chittagong, Jessore and Barisal. The motivation of data collection was to accomplish a FAO funded research project. The selection of the districts was purposive considering them as major rice growing districts that contributed to about 16 percent of total rice production (BBS, 2008). But the selection of farmers of different categories was performed using stratified random sampling technique. The study was involved in four categories of farm households. These were marginal farm owning less than 50 decimals, small farm owning up to 249 decimals, medium farm up to 750 decimals and large farm owning above 750 decimals of land. Of the 1360 farm households, 138 households were selected from large, 416 households from medium, 440 households from small and 366 from marginal households. Some trained field enumerators collected the data during the crop year 2008 to 2009.

Model Specification

In order to estimate the level of technical efficiency in a way consistent with the theory of production function a Cobb-Douglas type stochastic frontier production function was specified. The Cobb-Douglas form of production function has properties that justify its wide application in economic literature (Henderson and Quandt 1971). It is a homogeneous function that provides a scale factor enabling to measure the returns to scale and to interpret the elasticity coefficients with relative ease. The function is easy to estimate and manipulate mathematically. The Cobb-Douglas production function works under several restrictive assumptions. Firstly, it assumes that the elasticity coefficients are constant, implying constant shares for the inputs. Secondly, it assumes that elasticity of substitution among factors is unity. Moreover, the function 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 argued that if interest rests on efficiency measurements and not on analysis of general structure of the underlying production technology, the Cobb-Douglas specification provides an adequate representation of production technology. In addition, its simplicity and widespread use in agricultural economics outweigh its drawbacks (Rahman 2002; Coelli et al. 1998)

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

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

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 (years), X_{10} = Experience of farm operator (years), EDU = Education of farm operator (year of schooling).

V_i are assumed to be independently and identically distributed random errors, having N $(0,\sigma_v^2)$-distribution; and the U_i are non-negative one-sided random variables, 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

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

Where AGE represents age of farm operator; EXPERIENCE is the experience of the farm operator; FAMSZ represents family size; FARMSZ represents farm size; and the W_i are unobservable random variables, which are 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

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \quad \text{......................} \quad (3)$$

and

$$\gamma = \sigma_u^2 / \sigma^2 \quad \text{...} \quad (4)$$

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 the computer program, FRONTIER Version 4.1.

The model for the inefficiency effects can only be estimated when the inefficiency effects are stochastic and have a particular distributional specification. Hence, there is interest to test the null hypothesis 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 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 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

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

where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function under null and alternative hypotheses, H_0 and 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 ith farmer can be shown to be equal to

$$\begin{aligned} TE_i &= \exp(-U_i) \\ &= \exp\{-E(U_i/\varepsilon_i)\} \\ &= 1 - E(U_i/\varepsilon_i)\} \quad \text{................................(ignoring higher order)} \qquad (6) \end{aligned}$$

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 $\varepsilon_i = (V_i - U_i)$. Farm size-specific or observation-specific estimates of technical inefficiency U (subscripts can safely be omitted here), can be obtained by using the expectation of the inefficiency term conditional on the estimate of 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:

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

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

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

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

The mean technical efficiency can be defined by

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

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

The model has been estimated for four farm size groups for all rice crops. *Aus* is a short-duration crop which is cultivated in March-April and harvested in July-August, utilising the pre monsoon rainwater. *Aman,* grown during June-August to November-December, is the monsoon crop. It grows with the floodwater and is harvested after the flood recede. *Boro* growing from November-January to April-June is the dry season rice crop. With the development of groundwater irrigation, *Boro* modern varieties have expanded rapidly at the expense of *Aus* rice. Further, because of overlapping production cycles, area under profitable *Boro* has also been expanded at the expense of broadcast *Aman* rice (Baffes and Gautam 2001).

III. RESULTS AND DISCUSSION

Socio-economic Profile of Respondents:
A summary statistics on the farm-size-specific socioeconomic variables used in the stochastic frontier and inefficiency effect model is presented in Table 1. The table reveals that the average age of farmers is 46.45 years with significant variations among farm size groups (F = 5.57**). Education levels of farm operators significantly (F = 34.08**) varied among the farms. The highest schooling year (8.74 years) was for large farms and the lowest was for marginal farms (5.15 years). The average schooling year was 7.01 years at the aggregate level. The average experience was 25.24 years at the aggregate level and there were also significant variations of experiences of farmers among the farm groups (F = 4.46**). The distribution of land under rice cultivation was quite dissimilar among farms (F = 290.82**). The average rice area was found to be 220.74 decimals for all farms. The total land under households was the highest (826.01 decimals) for the large farms.

Table1: Farm size wise distribution of socio-economic variables

Farm category	Sample size (N)	Age	Education	Experience	Area under production	T. L. under HH
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**

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

Cost and Return of Rice Cultivation:

Table 2 summarises per hectare basis farm inputs used for rice production. For the convenience of analysis, some of the inputs were expressed in money values. The results showed that medium farms used relatively higher labour (168.49 man-days). The higher amount of seed (51.75 kg) was used by large farms with significant differences (F = 6.31**) among farm groups. Farmers in different farms used different amounts of fertiliser with significant variations (F = 6.09**). The farmers of small farm group used the highest amount of fertiliser (363.72 kg).

Table 2: Farm size wise per hectare uses of farm inputs

Farm size	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

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

The highest amount of manure was used by medium farm group (3423.05 kg), where the overall manure use was 3290.80 kg. There was no significant difference in ploughing, irrigation and insecticide cost.

Per hectare labour cost was similar among different farm size groups although the highest labour cost was in medium farms (Tk. 26811.34) and the lowest labour cost was in marginal farms (Tk. 24378.11). The large farm received relatively higher production (4772.83 kg) per hectare. The average production at the aggregate level was 4641.66 kg. There was a significant difference of production cost per hectare ($F = 5.4^{**}$) among farm-size groups. The highest production cost was observed in medium farms (Tk. 62118.06) and the lowest was in marginal farms (Tk.57513.52). The gross return was highest for small farms (74131.14 Tk.) and net return was highest for marginal farms (15588.45 Tk.). The marginal farms obtained the highest BCR (1.39) followed by small farms (1.34) and medium farms (1.26) respectively (Table 3).

Table 3: Farm size wise per hectare production, cost and benefit cost ratio (BCR)

Farm Size	Per hectare labour cost(Tk.)	Per hectare production (Kg)	Per hectare return (Kg)	Per hectare cost (Tk.)	Per hectare net return (Kg)	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^{**}

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

Table 4: Maximum Likelihood (ML) estimates for parameters of Cobb-Douglas stochastic frontier production functions and technical inefficiency effect model for farm size groups

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 Prod.	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 (FAMSZ)	-0.0265**	-0.0247*	0.0088	0.0101
	(0.0093)	(0.0104)	(0.0169)	(0.0197)
Land under HH (FARMSZ)	0.0001**	0.0003**	0.0002	-0.0004
	(0.00007)	(0.00013)	(0.0004)	(0.0005)
Variance Parameters:	0.0558** (0.0063)	0.0738** (0.0066)	0.0716** (0.0242)	0.1295** (0.0332)
σ^2	0.0103 (0.1491)	0.1542 (0.0974)	0.1176 (0.3816)	0.7992** (0.0730)
γ	2.991	-23.71	-28.73	-27.14
Log-likelihood Function:				

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

Cobb-Douglas Stochastic Production Frontier and Technical Efficiency Effect:

The estimation of the maximum likelihood estimates for parameters of the Cobb-Douglas stochastic production frontiers and technical inefficiency effect model for different farm-size gropes is presented in Table 4. 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 had positive and significant coefficients. For medium, small and marginal farms, fertiliser, irrigation cost, insecticide and land 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 upon the inefficiency effects for medium farms. The results showed that older farmers had smaller inefficiency than that of younger farmers. In other words, it can be said that the older farmers were technically more efficient than that of the younger farmers in medium farm-size group (Table 4). Coelli and Battese (1996) found the same finding while studying technical efficiency of Indian farmers. Education was found to have significantly negative impact on the inefficiency effect in medium farms which implied that educated farmers were technically more efficient than 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 where land had positive and significant impact on inefficiency effect for large and medium farms. Positive coefficient of the land indicated that inefficiency effect increased with the increase of farm size.

Frequency distribution of farm-specific technical efficiency estimates revealed that most of the farmers of large farms obtained outputs which were very close to the frontier output (efficiency is 80% to 100%) and there were about 71% of farmers of medium farms whose technical efficiency levels ranged from 90% to100% and 90% small farmers produced rice at 90%-100% efficiency level. For marginal farm, technical efficiency varied from 30% to 100% (Table 5).

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

Table 5: Frequency distribution of farm-size- specific technical efficiency estimates from Cobb- Douglas stochastic frontiers

Efficiency level	Farm-specific groups			
	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 No. of farms	138(100)	416(100)	440(100)	366(100)

Figures in the parentheses indicate percentages. Source: Own estimation

Table 6: Farm size wise technical efficiency coefficients

Efficiency Parameter	Farm size groups				
	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

Hypothesis tested

The coefficients of farm-specific variables on the technical inefficiency effect models have been tested with the generalised likelihood-ratio statistic, LR. 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). There had an interest to test the null hypothesis that the inefficiency effects are not present. In other words, the null hypothesis is that there are no technical inefficiency effects in the model. That is, H_0: $\gamma = \delta_0 = \delta_1 = ... \delta_5 = 0$.

Table 7: Test of hypothesis for coefficients of the explanatory variables for the technical inefficiency effect model.

Null Hypothesis	Log-likelihood value	Test Statistics LR	Critical value	Decision
H_0: $\gamma = \delta_0 = \delta_1 = ... \delta_5 = 0$				
Farm Size:				
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

Table 7 reveals that there were significant technical inefficiency effects in the production for marginal farms only, since null hypothesis was rejected. For large, medium and small farms the null hypothesis was accepted indicating that there were no technical inefficiency effects.

IV. CONCLUSIONS AND POLICY IMPLICATIONS

Medium farms used higher amount of labour, manure, spent higher expenditure for ploughing and per hectare cost whereas the large farms used higher amount of seed and spent higher expenditure for irrigation. Large farms received higher production whereas small farms received higher gross return. Marginal farms received higher net return and benefit cost ratio. The identified vital factors responsible for the increase of production were fertiliser, manure, insecticide cost, land under production, experience and irrigation cost. Small farms attained the highest technical efficiency followed by medium, large and marginal farms respectively. The efficiency attainments at the highest level (90% - 100%) were highly satisfactory for small farms, moderately satisfactory for medium farms and most satisfactory for large farms. But this was not at all satisfactory for marginal farms.

All farms used the same production technology. Production could not be increased by increasing efficiency with available technology except in marginal farms. Only marginal farms could increase total output by the efficient utilisations of existing resources and available technology. Only more advanced technology was to be applied for increasing the volume of *Aus*, *Aman* and *Boro* rice in small, medium and large farms.

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