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Estimating Technical Efficiency of IRRI Rice Production in the Northern Parts of Bangladesh

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Abstract

Using stochastic frontier function, this paper estimates the technical efficiencies of the IRRI (International Rice Research Institute) rice production in three village farms of the northern part (Natore) of Bangladesh and determines the significant factors underlying their technical efficiency. The paper finds that the mean technical efficiency for IRRI rice cultivation is 85.2 percent. The farm level technical efficiency ranges between 16.5 percent and 94.5 percent. Twenty five percent of the farms for IRRI cultivation have technical efficiencies above 70 percent. Secondary school education (SS), years of cultivation experience, and use of fertilizers are positively and significantly related to technical efficiency.

JEL classification numbers: C13, C24
Keywords: Technical efficiency, IRRI cultivation, Bangladesh

1 Introduction

Throughout history rice has been the main stable food for the people of Bengal. Bangladesh (a par of Bengal) has been a deficit country in food production since it was born in 1971. The deficit was attributed to the increasing growth rate of population and irregular (flood and draught) weather conditions.

The government of Bangladesh laid great emphasis on increasing food production and decreasing population growth. Consequently, Bangladesh is making good progress toward self-sufficiency in food production. The progress toward self-sufficiency has been almost entirely due to the high yielding variety of rice, called IRRI rice. Bangladesh is now heavily dependent and engaged in the IRRI rice cultivation. The traditional paddy, called Aman, relied heavily on rainfall, and has almost been totally replaced by IRRI (or BRRI)

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rice acre for two reasons. (i) The natural rain fall is uncertain (ii) Productivity of Aman paddy is very low.

BRRI rich is now cultivated in three seasons a year in most of the high-land areas of Bangladesh including the villages under the study of this paper. The cultivation is heavily dependent on irrigated water, fertilizers, paste, and insecticides. The higher productivity depends on adequate supply of irrigated water, timely application of fertilizers, pest control, and insecticides. All of these require involvement of running capital on the part of farmers.

Since the high-yielding rice cultivation is dependent on modern technology, knowledge and skill of farmers also play an important role in using the amount and timing of fertilizers, insecticides, and pest control.

The study of farm level mean technical efficiencies of the farmers' BIRI cultivation in Bangladesh is important for several reasons.

First, the survey of literature indicates that there is no efficiency (inefficiency) study for IRRI rice production in Bangladesh for estimating farm level technical efficiencies.

Second, IRRI farmers in Bangladesh, engaged in IRRI production, need to know the status of technical efficiencies for their cultivation.

So, this study focuses on estimating the technical efficiencies of IRRI cultivation of three village farms in the northern part (district: Natore) of Bangladesh. The paper also examines the factors that are significant farm level technical efficiencies.

The paper is organized as: A brief survey of literature is provided in Section 2. Data and methodology are described in Section 3. Empirical results are provided in Section 4. Conclusion is given in Section 5.

2 Survey of Literature

Since this is a *farm* level study, not a *firm* level, this paper focuses on the survey of farm level literature studies only. The literature on the financial and manufactured firms' technical efficiencies is wide. There are, however, only a few studies on estimating the technical efficiencies of agricultural farms. They are as follows:

Battese and Coelli (1992) estimated the technical efficiencies of paddy farmers in India with panel data. He found that the technical inefficiencies of Indian farmers of paddy production were not time invariant.

Kumbhakar, Ghosh, and McGuckin (1991) investigated farm level technical and allocative efficiency of U.S. dairy farms. His study found that levels of farmers' education were important factors for determining technical efficiency. Large farms were more efficient than small and medium farms.

Battese, Coelli, and Colby (1989) used panel data for estimating the i^{th} level technical efficiencies of individual farmers in Indian village. His farm level study from the Aurepalle village shows that family and hired labor are homogeneous and the variance of production is proportional to the squared of the mean production.

Kalirajan (1981) estimated the technical efficiencies of 70 farmers of Tamil Nadu in India. The Cobb-Douglas production was estimated by the maximum likelihood method; and using the estimates he identified the farmer specific variability. His empirical results found that farmers' application of technology and access to extension advice were significant factors for farmers' production variability.

3 Data and Methodology

3.1 Data

Data of this paper is primary. Farm level IRRI rice cultivation data of three village farms——Kaigram, Anolia, and Khajuria—are collected by the author through surveys during 2004. One hundred twelve farmers who cultivate IRRI paddy are randomly selected from among twelve hundred farmers of the three villages in Singra police station, 17 miles north of the Natore district. Rice is not only a food crop but also a cash crop for the farmers of these villages. Data for rice production, land, labor, tractors, and fertilizer-insecticides are collected from a survey and then compiled by the author. Since the rice cultivation is entirely dependent upon irrigation, the data for land consists of irrigated land only. Family and hired labor are assumed to substitute for each other. As such, this paper uses labor as the sum of family and hired labor. Production data is measured in monds (1 mond=40kg). Data for capital is measured in Bangladeshi currency, TK. Data for land is measured in bigha (1 bigha=33 decimal).

3.2 Methodology

Stochastic frontier function is an appropriate method for estimating technical inefficiencies/efficiencies.

Aigner and Chu (1968), Afriat (1972), and Schmidt (1976) made an important contribution in providing econometric modeling of the "frontier" production function. However, the model proposed independently by Aigner, Lovell and Schmidt (1977), and Meeusen and Van Den Broeck (1977) received considerable attention in deriving efficient frontier. The model was later modified and applied in a number of studies including Battese and Corra (1977), Battese and Coelli (1995), Lee and Tyler (1978), and Kalirajan (1982).

Measuring technical efficiency is an important component of the stochastic frontier production function where the technical efficiency of a given firm was defined as "the ratio of the observed production to the corresponding frontier value associated with the given firm's factor inputs" (Battese, Coelli, and Colby 1989, p. 328). Following Battese and Coelli (1988) this paper defines the technical efficiency of ith firm as:

$$\text{TEi} = \frac{E(Yit^* \mid Uit, xit, t = 1,2,..)}{E(Yit^* \mid Uit = 0, xit = 1,2,..)}, \qquad (1)$$

Equation (1) says that the technical efficiency of a given firm is a ratio of its mean observed production, to the corresponding mean production, if the firm effect Ut = zero. Y*it is the value of i^{th} firm production at t^{th} time and $0 \leq TE \leq 1$.

If TE=1, technical inefficiency = 0, on the other hand, if TE=0, technical inefficiency of ith firm is 100 percent.

The technical efficiency of the ith farm in (1) is derived and estimated from the stochastic frontier production model which is:

$$Q_{it} = \exp(X_{it}\beta + V_{it} - U_{it}) \qquad (2)$$

Where Q_{it} = quantity of output for i-th firm (i=1,2,….N) at t-th time (t=1,2,…T)

X_{it} is a (1x k) vector of inputs and other explanatory variables used for the quantity of output of ith firm and t-th observation. They are land, labor, and capital.
β is a (k x 1) vector of unknown parameters to be estimated.
V_{its} are random error variables and assumed to be independent and identically distributed as $N(0,\sigma_v 2)$ random variables, independent of U_{it} . $\sigma_v 2$ is independent of $U_{it.}$
U_{its} are non-negative random variables associated with ith firm technical inefficiency of production and assumed to be independently and identically distributed truncations (at zero) of the $N(\mu, \sigma 2)$.
Where u_{it} is a (1x k) vector of farm specific variables, Z_{it}, like level of education, amount of fertilizer, ages of experience. These farm specific variables have impact on production variability.
The ratio of the observed output of the ith firm to potential output determined by the frontier function, given the input vector xi provides the definition of ith firm technical efficiency (TEi):

$$TEi = \frac{yi}{ecp(xiB} = \frac{\exp(xiB - ui}{\exp(xiB)} = \exp(-u_i) \qquad (3)$$

(3) is the measure of technical efficiency for the ith firm.
The mean technical efficiency of firms in the industry which corresponds to (3),according to Battese and Coelli, can be expressed and estimated as:

$$TE = \{\frac{1-\Phi[\sigma - \mu/\sigma]}{1-\Phi(-\mu/\sigma}\}\exp(-\mu + \tfrac{1}{2}\sigma^2) \qquad (4)$$

Thus, when μ = 0, the mean technical efficiency provided in (4) equals to what derived by Lee and Tylor (1978) which is:

$$TE = 2[1-\Phi(\sigma)]\exp(1/2\,\sigma^2) \qquad (5)$$

The method of maximum likelihood estimated proposed by Battese and Coelli (1993) is used for simultaneous estimation of the parameters of the stochastic frontier and the model of technical inefficiency effects. The likelihood function expressed in terms of variance parameters is:
σ^2, represents the variance of inefficiency of farm output due to technical inefficiency.
$\sigma^2_s = \sigma^2_v + \sigma^2$ and $\gamma = \sigma^2 / \sigma^2_s$ which explains the proportion of the deviation (variance) of output arising from u_i, inefficiency components to total variability, σ^2_s.
LR= Log likelihood ratio. = $-2[(L_1) - (L_2)]$. It tests the null hypothesis of no inefficiency effects.
The stochastic frontier production function to be estimated is:

$$Ln(Q_{it}) = \beta_0 + \beta_i X_{it} + V_{it} - \alpha Z_{it} \qquad (7)$$

where Q_{it} is the log total output for the ith farmer;
X_i consist of
Lnd_{it} = total log irrigated lands under cultivation for ith farmer;
N_{it} = total log labor (family and hired)

Trk_{it} = total log value of tractor hired or rented for cultivation
Zi the efficiency is regressed on frt, Noed, BSS, ASS, Exp)
Where frt= fertilizer, Noed= no education, BSS= below secondary school, ASS= above secondary school, and Exp= ages of experience.
The maximum likelihood estimates of the parameters of the model (7) are obtained by using the computer program, FRONTIER 4.1 developed by Coelli (1996).

4 Empirical Results

Empirical results of the Frontier model are presented in Table 1 and the average technical efficiencies at the individual farm level are provided in Table 1.

Table 1: Maximum Likelihood Estimate of Frontier Model

Frontier Model		Number of observation =117	
Log Likelihood1 = -40.88		Probability > Chi^2 = 0.000	
Log likelihood2=-27.04			
LR= -2(40.88 +27.04)=27.00		Probability > Chi^2 = 0.000	
Log Q	Coefficient	Std error	t-ratio
β_0	3.37	0.44	7.53
Lnlnd	0.91	0.06	15.12*
LnN	0.018	0.064	0.281
LnTrk	0.007	0.006	0.111
frt	0.90	0.36	2.52*
Ned	0.014	0.90	0.015
BSS	0.38	0.33	1.15
ASS	0.34	0.19	1.79***
Exp	0.053	0.024	2.2**
σ^2	0.37	0.11	3.33**
γ	0.82	0.05	13.9*

*=Significant at a level 1%, **=Significant at a level 5%, ***=Significant at a level 10%,

Table 1 shows that the quality of land is a significant factor paddy (rice) production at the farm level. Labor and tractor (capital) are not significant factors.
In explain efficiency, the high t-ration indicates that fertilizer (frt), education higher than secondary school (ASS) and farming age of experience (Exp) are significant factors for efficient production. The government of Bangladesh should lay emphasis on imparting education to farmers.
γ=0.829 indicates that 82.9 percent of the variation of the farm's output from the maximum yield is due to the efficiency component as opposed to random variable, and is significant. The significant of γ implies that productivity differences were mainly attributed to farm's level variability of farmer's inputs. Among factors that are significant in yielding production differences are fertilizer (frt), level of education (ASS), and years of cultivation experience (Exp).
The significance of estimates γ and σ^2 suggests that the distribution of U is truncated normal and V is normal.

The significance of LR ratio=27.0 rejects the null hypothesis of no inefficiency. σ^2=0.37 indicates that 37 percent of the variation of output is due to the inefficiency factors and it is significant.

Table 2: Technical efficiencies of individual farm

Farm	efficiency	Farm	efficiency	Farm	efficiency
1	0.79	39	0.92	77	0.79
2	0.9	40	0.87	78	0.85
3	0.91	41	0.83	79	0.86
4	0.9	42	0.89	80	0.88
5	0.91	43	0.9	81	0.77
6	0.9	44	0.85	82	0.86
7	0.9	45	0.84	83	0.85
8	0.86	46	0.83	84	0.84
9	0.94	47	0.82	85	0.84
10	0.84	48	0.86	86	0.87
11	0.88	49	0.86	87	0.86
12	0.9	50	0.8	88	0.82
13	0.91	51	0.85	89	0.84
14	0.88	52	0.86	90	0.9
15	0.86	53	0.87	91	0.9
16	0.885	54	0.8	92	0.9
17	0.88	55	0.85	93	0.87
18	0.84	56	0.83	94	0.88
19	0.88	57	0.68	95	0.91
20	0.87	58	0.77	96	0.89
21	0.88	59	0.53	97	0.91
22	0.85	60	0.91	98	0.92
23	0.89	61	0.96	99	0.86
24	0.89	62	0.87	100	0.93
25	0.91	63	0.81	101	0.94
26	0.91	64	0.88	102	0.94
27	0.88	65	0.86	103	0.92
28	0.88	66	0.33	104	0.9
29	0.88	67	0.84	105	0.94
30	0.89	68	0.64	106	0.92
31	0.88	69	0.69	107	0.91
32	0.78	70	0.88		
33	0.89	71	0.81		
34	0.86	72	0.84		
35	0.81	73	0.73		
36	0.88	74	0.78		
37	0.89	75	0.87		
38	0.81	76	0.16		

The mean efficiency =85.5

Table 2 shows that the mean technical efficiency of the paddy (IRRI) farmers of three villages in the northern part of Bangladesh is 85.21 percent.

The frequency distribution of farm level technical efficiency is presented in Table 3.

Table 3: Frequency distribution of technical efficiency

Efficiency Range	Frequency of occurrences	Relative frequency (%)	Cumulative relative frequency (%)
Less than 0.40	2	1.86	1.86
0.40—0.70	3	2.80	4.47
0.70—0.90	75	70.09	74.76
0.9 and above	27	25.23	100
Total	107	100	

Table 3 shows that only 4.47 percent of farms in the sample of three villages in the district of Natore, Bangladesh have technical efficiency less than 70 percent in rice cultivation. Twenty seven farms have the technical efficiency higher than 90 percent. The technical efficiencies of 106 farms in the sample are in the range between 16.5 percent and 90.5 percent.

5 Conclusion

The stochastic frontier production frontier is applied in estimating the farm level technical efficiencies IRRI rice cultivation in the northern part of Bangladesh. The estimate shows that the average technical efficiency for the high yielding rice (IRRI) cultivation is 85.2 percent.

The farm level technical efficiency ranges between 16.5 percent and 94.5 percent. Twenty-five percent of the farms have technical efficiencies above 70 percent.

Secondary school education (SS), years of cultivation experience, and use of fertilizers are positively and significantly related to technical efficiency.

References:

[1] Afriat, S.N. 1972. “Efficiency estimation of production functions”, *International Economic Review,* **13**, 568-598.

[2] Aigner, D. J. and S. F. Chau .1968. “On estimating industry production function”, *American Economic Review,* **58**, 826-839.

[3] Aigner, D.J., C.A.C. Lovell, and P. Schmidt .1977. “Formulation and estimation of stochastic frontier production function models”, *Journal of Econometrics,* **6**, 21-37.

[4] Battese, G.E. and T.J.Coelli.1995. “A model for technical inefficiency effects in a stochastic frontier production function for panel data”, *Empirical Economics,* **20**, 325-332.

[5] Battese, G.E, T.J. Coelli, and T.C. Colby. 1989. “Estimation of Frontier Production Functions and the efficiencies of Indian farm using panel data from ICRISAT’s Village”, Journal of Quantitative Economics, **5**(2), 327-348

[6] Battese, G.E. and T.J. Coelli. 1992. “Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India”, *Journal of Productivity Analysis*, **3**, 153-169.

[7] Battese, G.E. and G.S.Corra.1977. "Estimation of a production frontier model: With application to the Pastoral Zone of Eastern Australia", *Australian Journal of Agricultural Economics,* **21**, 169-179.
[8] Coelli, T.J. 1996. "A Guide to Frontier Version 4.1: A computer program for stochastic frontier production and cost function estimation", CEPA **Working paper**, N0. **7/96**, University of New England, Australis.
[9] Kalirajan, K. 1981. "On econometric analysis of yield variability in paddy production", Canadian *Jounal of Agricultural Economics*, **29**, 283-294.
[10] Kumbhakar, S.C., S. Ghosh, and J.T. McGuckin. 1991. "A generalized production frontier approach for estimating determinants of inefficiency in U.S. Dairy farm", Journal of Business Statistics, **9**(3), 279-286.
[11] Lee, L.F.and W.G.Tyler .1978. "A stochastic frontier production function and average efficiency: A empirical analysis", *Journal of Econometrics,* 7, 385-390.
[12] Meesuen, W, and J, van den Broeck .1977. "Efficiency estimation from Cobb-Douglas production functions with composed error", *International Economic Review*, **18**, 435-444.
[13] Schmidt, P .1976. "On the statistical estimation of parametric frontier production functions", *Review of Economics and Statistics*, **58**, 238-239.