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An Estimation of Technical Efficiency of Paddy Farmers in Haryana State of India

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I

INTRODUCTION

Agriculture is the back bone of the Indian economy because it contributes to the economic and social well-being of the entire nation through its influence on the gross domestic product and employment. About 65 per cent of the total working force is engaged in agriculture and the sector accounted for only about 25 per cent of Gross Domestic Product (GDP), whereas non-agriculture sector employed only about 35 per cent of the total workers but it accounted for about 75 per cent of GDP. This reflects upon the existence of much chronic poverty in the agriculture sector. Rice is one of the most important cereal crops in the world. In terms of paddy, the average production in the triennium (1999-2001) has been 601.18 million tonnes. India's share in the world rice production was about 22 per cent during 1999-2001 (FAO, 2003). India has the largest area under rice in the world but is the second largest producer of rice next only to China. The latter produces about 31 per cent of the world rice production. It is because of the fact that yield levels in India are less than half of yield levels in China. The other important rice producing countries are Indonesia, Bangladesh, Vietnam, Thailand, and Myanmar.

In India, rice constitutes about 42 per cent of the total foodgrains production accounting for about 24 per cent of the total cropped area. The rice production increased to 84.87 million tonnes in 2000-01 which was 31.68 million tonnes in 1960-61 registering compound growth rate of 2.14 per cent per annum. In Haryana State of India, rice covers about 17 per cent of the total cropped area and contributes about 22 per cent to the total foodgrains production of the state (Government of Haryana, 2002). The paddy production in Haryana State had increased from 223 thousand tonnes in 1966-67 to 2726 thousand tonnes in 2001-02 depicting an increase by about 7 per cent compound growth rate per annum. No doubt, India figures among the top producers but it is merely because of its large area and not due to efficiency in production. The increase in production is possible only through improvement in productivity of the crop. Productivity can be increased through one or combination of

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its determinants - the technology, the quantities and the types of resources used and the efficiency with which the resources are used. Of the various determinants, improvement in the efficiency of the resources already at the disposal of the farmers is of great concern. In this context technical efficiency in production of a crop assumes paramount importance. As far as technical efficiency in production is concerned, there are two possibilities. The policy makers can either attempt to enhance the uptake of improved technologies relevant particularly to the small-scale agricultural production by improving research and development processes, or they can take steps, which enable the farmers to improve technical efficiency in production. While the former probably requires a long time, considerable funds and efforts but are likely to yield long run benefit. Else, raising technical efficiency offers more immediate goals at modest costs, if it can be shown that substantial inefficiencies are present in agricultural production. The present study is based on an analysis of technical inefficiencies in production of paddy crop by the farmers. Therefore, an attempt has been made in this paper to investigate farm-specific technical efficiency for paddy farmers in Haryana. The study also seeks to investigate the influence of some farmer specific variables on the technical inefficiency of paddy production. In the present study, we employ the stochastic frontier approach for panel data proposed by Battese and Coelli (1995) in which the technical inefficiency effects are specified in terms of several explanatory variables. This approach allows us to predict the technical efficiency and also to indicate the trend of the efficiency over years. These information may help the policy makers/planners to formulate appropriate policies to improve technical efficiency of paddy cultivation.

II

ANALYTICAL TOOLS

2.1 Stochastic Frontier Production Function

A measure of technical efficiency was first introduced by Farrell (1957) for a cross section of firms by using a deterministic approach. This approach ignores any random factors that can influence the efficiency of a firm. Later on, a more satisfactory means of estimating technical efficiency viz., stochastic frontier model was independently developed by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977). Jondrow *et al.* (1982) made it possible to estimate technical efficiency for each farm. Different models of the technical inefficiency effects are available in the literature. Stochastic production function have two error terms, one to account for the existence of technical inefficiency of production and the other to account for factors such as measurement error in the output variable, weather, etc., and the combined effects of unknown inputs on production. The technical efficiency of individual sample farms can be predicted on the basis of cross section or panel data. Cross sectional data provide shop shot of producers and their efficiency. Panel data provide more reliable evidence on their performance because they enable us to track the performance of each producer through a sequence of time periods. The studies such as Pitt and Lee, 1981; Battese and Coelli, 1988, 1992; Kumbhakar, 1990; Huang and Liu, 1994; Rajasekharan and Krishnamoorthy, 1999; Mythili and Shanmugan, 2000, etc. have made use of panel data.

Bravo-Ureta and Pinheiro (1993) draw attention to those applications which attempt to investigate the relationship between technical efficiency and various socio-economic variables such as age and level of education of the farmers, farm size, access to credit, etc. The identification of factors which influence the level of technical efficiency of farmers is, indeed, very important. If efficiency varies across producers or through time, it is important to seek determinants of efficiency variation. Early studies adopted two stage approach. The first stage involves the estimation of stochastic frontier production function and the prediction of farm level technical inefficiency effects or (TE). In the second stage, the predicted technical inefficiency effects or (TE) are regressed against a vector of explanatory variables (farmer's specific factors). The studies such as Huang and Liu (1994), Battese and Coelli (1995), Wilson and Hardley (1998), etc., have discussed a single stage approach in which the explanatory variables are incorporated directly into the inefficiency error component. The Battese and Coelli (1995) stochastic frontier is specified for panel data where the model for technical inefficiency effects involves farmer's specific variables and the year of observation.

The present study uses the stochastic frontier production function approach for panel data to measure the technical efficiency in paddy production. The model developed by Battese and Coelli (1995) has been employed as it can accommodate unbalanced panel data associated with a sample of 'H' firms over 'T' time periods. Also it provides a measure of technical efficiency for the same firm, in each time periods considered. The production process is modelled with a single-output production frontier and technical inefficiency effects are modelled in terms of some farmer-specific variables in the production process. In the analysis of farmer efficiency/ inefficiency, it is not the average of observed relationships between farmers' inputs and outputs that is of interest but the maximum possible output that is obtainable from a given combination of inputs. Thus, frontier production function can be defined as the maximum feasible or potential output that can be produced by a firm with a given level of inputs and technology.

The general specification of the frontier production function considered is defined by

$$Y_{ht} = \exp(X_{ht}\beta + V_{ht} - U_{ht}) \qquad \text{....(1)}$$

where: Y_{ht} represents the output for the h-th firm in the t-th time period; X_{ht} is a (1xK) vector of inputs for the h-th firm in the 't-th' time period; β is a (Kx1) vector of parameters that describe the transformation process,

V_{ht} is assumed to be independent and identically distributed random error which have normal distribution with mean zero and unknown variance σ^2_v; and the U_{ht} are non-negative unobservable random variables associated with the technical inefficiency of production, such that, for the given technology and levels of inputs, the observed output falls short of its potential output. The U_{ht} is zero when the farm produces the potential output (full TE) and is greater than zero when production is below the frontier (less than full TE).

Following the model, the inefficiency effects, U_{ht} can be defined by:

$$U_{ht} = Z_{ht}\,\delta + W_{ht} \qquad \text{....(2)}$$

where: Z_{ht} is a (1 x M) vector of explanatory variables associated with the technical inefficiency effects;

δ is an (M x 1) vector of unknown parameters to be estimated; and the random variable, W_{ht} is defined by truncation of the normal distribution with mean zero and unknown variance, σ^2 such that U_{ht} is non-negative (i.e., $W_{ht} \geq Z_{ht}\,\delta$).

The technical inefficiency effects are assumed to be independent non-negative truncation of normal distribution with unknown variance, σ^2, and mean $Z_{ht}\delta$, h= 1, 2….N and t = 1, 2 and 3. Thus, mean may be different for different firms and time periods but the variances are assumed to be the same.

2.2 *Model Specification*

For empirical analysis, a translog stochastic frontier production function is specified as given below:

$$Ln(Y_{ht}) = \beta_0 + \sum_{i=1}^{6} \beta_i Ln(X_{iht}) + \sum_{i \leq j=1}^{6}\sum^{6} \beta_{ij} Ln(X_{iht}) Ln(X_{jht}) + V_{ht} - U_{ht} \qquad \text{....(3)}$$

Where: the subscripts 'h' and 't' refer to the h-th farmer and t-th year of observation, respectively.

Ln represents the natural logarithm (i.e. to base e),
Y represents the quantity of paddy (in kg),
X_1 represents the total human labour (in hours),[1]
X_2 represents the quantity of fertiliser (kg of NPK),
X_3 represents irrigation expenditure (in Rs.),
X_4 represents land area (in hectares),
X_5 represents expenditure on plant protection measures (insecticides) (in Rs.),
X_6 represents the year of observation where X_6 = 1, 2 and 3 for the years, 1996-97, 1997-98 and 1998-99.[2]
V_{ht} -U_{ht} is the random variables defined above.

The model for technical inefficiency effects in the stochastic frontier of equation (3) is defined by

$$U_{ht} = \delta_0 + \delta_1(\text{Family size}_{ht}) + \delta_2(\text{Age}_{ht}) + \delta_3(\text{Schooling}_{ht}) + \delta_3(\text{Land}_{ht}) + \delta_4(\text{Year}_{ht}) \quad \text{....(4)}$$

Where, family size is the average size of the family of the sample farmers and age and schooling are the age and years of formal schooling of the farmers (decision-maker/head of the family). Land is area under the crop defined above and year represents the year of observation (1, 2 and 3). The maximum likelihood estimates for all the parameters of the stochastic frontier and inefficiency model defined by equations (3) and (4), are simultaneously obtained by using the programme, FRONTIER, version 4.1 (see Coelli, 1994) which estimates the variance parameters which are expressed in terms of

$$\sigma^2_s = \sigma^2_v + \sigma^2 \text{ and } \gamma = \sigma^2/\sigma^2_s.$$

The technical efficiency of a farm can be defined as the ability and willingness of the farm to obtain the maximum possible outcome with a specified endowment of inputs, given the technology and environmental conditions surrounding the farm (Kalirajan and Shand, 1994).

We know that the actual production function can be written as follows:

$$Y_{ht} = f(X_{ht} : \beta)\exp(-u_{ht}) \quad \text{....(5)}$$

$0 \leq u_{ht} < \infty$ h = 1, 2, ...n ; t = 1, 2, ...T

Where: Y_{ht} represents the output for the h-th firm in the t-th time period; X_{ht} is a (1x K) vector of inputs for the h-th firm in the 't-th' time period; β is a (Kx1) vector of parameters that describe the transformation process; if f (.) is the frontier production function and u_{ht} is one sided (non-negative) residual term. If the farm is efficient (inefficient), the actual output produced is equal to (less than) the potiential output. So, the technical efficiency of production of the h-th farm in the appropriate data set, given the levels of his inputs is the ratio of actual output Y_{ht} to potiential output f (.) which could be produced by a fully-efficient firm, in which the inefficiency effect is zero. Thus, the technical efficiency of the h-th farmer in the t-th year of observation given the specification of the model, is defined by:

$$TE = Y_{ht}/f(X_{ht} : \beta) = \exp(-u_{ht}) \quad \text{....(6)}$$

The technical efficiency of a farmer is between zero and one and is inversely related to the level of technical inefficiency effects. The technical efficiencies are predicted using the conditional expectations of exp ($-u_{ht}$), given the composed error term of the stochastic frontier (Battese and Coelli, 1988). The programme FRONTIER 4.1 predicts the technical efficiencies for all farms in the periods in which they are observed.

The γ - parameter has value between zero and one. The γ is zero when U_{ht} equals to zero (full TE). If this is the case, the Ordinary Least Square (OLS) estimates are also ML estimates. The Cobb-Douglas production frontier is adequate in describing the production of the data if the coefficients of the second order terms are zero, i.e., $H_0 = \beta_{ij} = 0$, $i \leq j = 1, 2....6$. There will be no technical change if the coefficients of all variables involving years of observation are zero, i.e., $H_0 = \beta_6 = \beta_{i6} = 0$, i = 1, 2…6. Further the null hypothesis that the technical inefficiency effects are not present, $H_0 = \gamma = \delta_0 = \text{---}\ \delta_5 = 0$ and also the technical inefficiency effects are not influenced by the level of the explanatory variables is expressed by H_0: $\delta_1 = \delta_2 = \text{---}\delta_5 = 0$.

The hypotheses of interests are tested using the generalised likelihood-ratio test statistic. The decision whether to accept the corresponding null hypotheses depends upon the value of the test statistic obtained using generalised likelihood-ratio statistic which is defined by:

$$\lambda = -2\ Ln[L(H_0)/L(H_1)] \qquad ....(7)$$

Where: $L(H_0)$ and $L(H_1)$ are the values of the likelihood function for the frontier model under the specification of null and alternative hypotheses, H_0 and H_1, respectively. If the null hypothesis is true, then λ has approximately chi-square (or mixed chi-square) distribution with degrees of freedom equal to the difference between the parameters estimated under H_1 and H_0, respectively.

The variables family size, age and schooling are included in the model for the technical inefficiency effects to indicate the possible effects of farmers' characteristics on the efficiency of paddy production. As expected the sign on the δ_i parameter in inefficiency model are not clear in all cases. The age of the farmers could be expected to have positive or negative effect upon the size of the inefficiency effects. The older farmers are likely to have more farming experience and hence have less inefficiency. However, they are also likely to be more conservative and thus be less willing to adopt new practices, thereby perhaps having greater inefficiency in agricultural production.

As regards to schooling it is expected that greater level of formal education will be associated with smaller value for the inefficiency effects. The size of the coefficients of the land variable in the model for the inefficiency effects is expected to be negative. This expectation is partially based upon the likelihood that the farmers with smaller operation may have alternative income sources which are more important and hence put less efforts into their farming operations compared with the larger farmers.

The sign of the coefficient of the year variable in the model for the inefficiency effects is expected to be negative indicating that the levels of the inefficiency effects of the farmers tend to decrease over time. It implies that the farmers are expected to become more efficient over time. The time variable is also expected to influence the effect of those factors which are not included in the inefficiency model.

III

THE DATA

The data used are compiled under the Comprehensive Scheme on "Cost of Cultivation of Principal Crops" in Haryana, India. The farm level panel data for the years 1996-97, 1997-98 and 1998-99 are used for the estimation of the model. The survey on Cost of Cultivation of Principal Crops is undertaken under the auspices of the Directorate of Economics and Statistics, Ministry of Agriculture, Government of India. In Haryana State, the scheme is being implemented by CCS Haryana Agricultural University, Hisar, India. The farm level data is collected by adopting multi-stage stratified random sampling techniques. Under this scheme, the Haryana State has been classified into three zones according to the agro-climatic factors such as rainfall, irrigation pattern, soil characteristics, etc. The selection of tehsils, cluster of villages and farm households from each zone form the first, second and third stage of sampling units, respectively. The data are collected from 10 farms each from 30 clusters of villages from all the three zones which form a total sample of 300 farms each year. For the present study, 70 per cent of the total clusters from each zone have been selected. In totality 20 clusters, which constitute 200 farms formed the total sample in each year for compilation of the required information. As the present study is confined to paddy crop, there were only 93 farmers who cultivated the said crop. For some years, a few observations did not undertake paddy cultivation or were non existent. Therefore, the data set consists of 93 farm units constituting 231 total observations for all the three years. The required information on physical input-output data, factor-product prices, and other related variables were collected from the scheme for arriving at the objectives of the study.

IV

RESULTS AND DISCUSSION

A basic summary of the values of the key variables, defined in the model is presented in Table 1. The figures are for a per farm basis. The average paddy production per farm was 108 quintals (qtls) which ranged from 6 to 410 qtls. The area under paddy on the sample farms varied from a very small farm of 0.2 hectare to large farm of 11.20 hectares. Labour use was high with mean value of 1217 hours, cost incurred on plant protection measures was Rs. 2,111 and on an average, the sample farmers used 442 kg of fertilisers (NPK) per farm. In describing how the inefficiency effects in stochastic frontier production function vary across different farmers, five variables, viz., family size, age, schooling, land and year of observation were used. The sample farmers had a wide range of family size ranging from 1 to 23 members with an average of 6.73 members per family. The average age of the head of family ranges from 18 to 85 years, average being 46.31 years. The average education level of the farmers was 4.91 years of formal education. However, about 30 per cent of the sample farmers had no formal education, about 19 per cent had primary education and about 17 per cent had at least 10 years of formal education.

TABLE 1: SUMMARY STATISTICS OF STUDY VARIABLES IN THE STOCHASTIC FRONTIER MODEL FOR PADDY FARMERS IN HARYANA: 1996-99

(*per farm*)

Variable (1)	Mean (2)	Standard deviation (3)	Minimum (4)	Maximum (5)
Output (qtl.)	108.00	93.50	6.00	410.00
Human labour (man-days)	1217.05	1016.65	106.33	5334.00
Fertilisers (NPK) kg	441.82	418.27	23.00	2339.70
Irrigation expenditure (Rs.)	7854.49	7411.08	80.00	40900
Land (ha)	2.57	2.16	0.20	11.20
Insecticides (Rs.)	2111.05	3392.20	0	24780
Family size (No.)	6.73	3.07	1	23
Age (years)	46.31	13.99	18	85
Schooling (years)	4.91	4.55	0	14

The maximum-likelihood estimates of the parameters in the translog stochastic frontier production function are presented in Table 2. Tests of various null hypotheses associated with the models were carried out using likelihood-ratio (LR) statistic and the results are presented in Table 3. The null hypothesis, H_0: β_{ij} =0, i ≤ j = 1, 2…6, that the Cobb-Douglas frontier is an adequate representation of the data for paddy production is strongly rejected. The hypothesis, H_0: $\beta_6 = \beta i_{6} = 0$, i = 1, 2…6, that there is no technical change is rejected by the data. The generalised likelihood-ratio statistic for testing the null hypothesis, $H_0 = \gamma = \delta_0$ = --- δ_5 =0, that the inefficiency effects in the translog stochastic frontier are not present is calculated to be 121.92 and the critical value at 5 per cent level of significance is 13.40. Hence we do not accept the null hypothesis that there was no technical inefficiency effects. Thus, inefficiencies of production can not be assumed to be absent from the stochastic frontier production function for the given level of technology used by the farmers. If the null hypothesis is true, there are no frontier parameters in the regression equation, and the estimation becomes an ordinary least square estimates. Thus, the traditional average response function is not an adequate representation for the paddy production given the specification of stochastic frontier and inefficiency model. The last hypothesis, H_0: $\delta_1 = \delta_2$ = ---δ_5 = 0, specifies that the coefficients of the explanatory variables in the inefficiency model are simultaneously zero, is rejected by the data. Hence, the five variables together in the inefficiency model make a significant contribution in the explanation of the inefficiency effects associated with the crop production. Thus, given the specification of translog frontier production function, the above tests of hypotheses indicate that the preferred model is the model exhibiting technical change and also year effects in the technical inefficiency model. The parameter estimates are given in Table 2.

TABLE 2. ESTIMATES OF STOCHASTIC FRONTIER PRODUCTION FUNCTION WITH TIME VARYING INEFFICIENCY EFFECTS FOR PADDY FARMS IN HARYANA

Variable (1)	Parameter (2)	Coefficient value (3)	Standard error (4)
Stochastic Frontier			
Constant	β_0	16.8538	0.9814*
Labour	β_1	-2.8737	0.3547*
Fertiliser	β_2	-1.4193	0.2614*
Irrigation	β_3	-0.5816	0.2359**
Land	β_4	6.6027	0.3071*
Insecticides	β_5	0.1550	0.0603**
Year	β_6	-0.3462	0.2029**
Labour x Labour	β_{11}	0.3850	0.0612*
Fertiliser x Fertiliser	β_{22}	0.1700	0.0400*
Irrigation x Irrigation	β_{33}	0.0230	0.0298
Land x Land	β_{44}	0.5155	0.0402*
Insecticides x Insecticides	β_{55}	0.0114	0.0020*
Year x Year	β_{66}	0.0308	0.0161**
Labour x Fertiliser	β_{12}	-0.1777	0.0796**
Labour x Irrigation	β_{13}	-0.0308	0.0419
Labour x Land	β_{14}	-0.6463	0.0586*
Labour x Insecticides	β_{15}	-0.0233	0.0063*
Labour x Year	β_{16}	-0.1913	0.0247*
Fertiliser x Irrigation	β_{23}	0.0966	0.0309*
Fertiliser x Land	β_{24}	-0.2831	0.0482*
Fertiliser x Insecticides	β_{25}	-0.0164	0.0087**
Fertiliser x Year	β_{26}	0.1621	0.0254*
Irrigation x Land	β_{34}	-0.1004	0.0246*
Irrigation x Insecticides	β_{35}	-0.0095	0.0040**
Irrigation x Year	β_{36}	0.0464	0.0100*
Land x Insecticides	β_{45}	0.0382	0.0120*
Land x Year	β_{46}	-0.0531	0.0327***
Insecticides x Year	β_{56}	0.0254	0.0027*
Inefficiency Model			
Constant	δ_0	-1.2619	0.2690*
Family size	δ_1	-0.0161	0.0123***
Age	δ_2	0.0072	0.0041**
Schooling	δ_3	0.0049	0.0121
Land	δ_4	-0.0336	0.0573
Year	δ_5	0.2675	0.0603*
Variance Parameters			
	σ^2_s	0.2833	0.0331*
	γ	0.9999	0.000001*
Log-likelihood function		48.6134	

1. Figures in parentheses indicate standard errors.
2. *, ** and *** Significant at 1, 5 and 10 per cent probability level, respectively.

TABLE 3. LIKELIHOOD-RATIO TESTS OF HYPOTHESES FOR PARAMETERS OF THE STOCHASTIC FRONTIER PRODUCTION FUNCTION FOR PADDY FARMS IN HARYANA

Null Hypothesis (1)	Log-likelihood (2)	λ (3)	Critical value (4)	Decision (5)
Given Model	48.61			
$H_0 = \beta_{ij} = 0,\ i \le j = 1,2\ldots6$	7.26	82.70	32.67*	Reject
H_0: $\beta_6 = \beta i_{6=}$, $i = 1,2\ldots6$	27.40	42.42	14.07*	Reject
$H_0 = \gamma = \delta_0 = \text{---}\ \delta_5 = 0$	-12.35	121.92	13.40*	Reject
H_0: $\delta_1 = \delta_2 = \text{---}\delta_5 = 0$	43.60	10.02	9.23**	Reject

The critical value for this test involving $\gamma = 0$ is obtained from Table of Kodde and Palm (1986, p.1246).
* and ** indicate critical values at 0.05 and 0.1 level of significance.

The estimated coefficients of the explanatory variables for the technical inefficiency effects have important implications and needs to be discussed. A perusal of the factors affecting technical efficiencies suggests that family size, age of the farmers and year of observation had a significant effect on the technical efficiencies (inefficiencies) of the farmers. It is estimated that the coefficient of family labour in the model in the inefficiency effects is negative as expected. It is may be due to the fact that farms with large family size may be using more family labour compared to those having small family size which may be using more hired labour. Family labour is expected to be more efficient than hired labour. The age of the farmers has a positive effect upon the inefficiency effects. It implies that the older farmers are more technically inefficient than the younger farmers. It is because of the fact that the older farmers tend to be more conservative and thus less willing to adopt new farming practices, thereby perhaps having greater inefficiencies in paddy production. The coefficient of year variable in the model for the inefficiency effects is positive and statistically significant at 1 per cent level. This implies that the levels of the inefficiency effects of the paddy farmers is time varying and tend to increase over time. However, it is contended that with the increased technology, the farmers are expected to become more efficient over time. The main reason for regress in efficiency of the farmers may be attributed to the adverse climatic conditions particularly during the study years. The year variable in the inefficiency effects model may be observing up the influence of factors which are not included in the inefficiency effects model such as weather, etc. Farm size was not found to have any significant relationship with technical efficiency. This fact was also reported in a study conducted by Rao *et.al.*, (2003) for rice farmers of Andhra Pradesh, India. The coefficients of two variables namely schooling and land were not statistically different from zero.

The parameter γ is estimated to be close to 1.0 in the translog stochastic frontier and statistically significant at 1 per cent level suggesting that inefficiency effects are highly significant in the analysis of production of paddy by the farmers. The individual coefficients of the explanatory variables in the translog frontier are not directly interpretable. The elasticities of the mean output with respect to inputs, which are functions of the second order coefficients of the translog frontier and the levels of inputs are very important and the same have been calculated and discussed in the subsequent section.

4.1 Elasticities

The elasticities of mean production with respect to k-th inputs, i.e., human labour, fertiliser, irrigation expenditure, land area and expenditure on plant protection measures (insecticides) for the translog stochastic frontier production function are estimated at the mean values of the different inputs, using the maximum likelihood estimates of the parameters in the specified model. The elasticities are calculated using the following expression:

$$\frac{\partial \text{LnE}(Y_{ht})}{\partial \text{Ln}(X_k)} = \beta_{kk} + 2\beta_{kk}\text{Ln}(X_{kht}) + \sum_{j\neq k}^{5} \beta_{kj}\text{Ln}(X_{jht}) - C_{ht}\left(\frac{\partial \mu_{ht}}{\partial X_k}\right) \qquad \text{….(8)}$$

Where C_{ht} is defined as:

$$C_{ht} = 1 - \frac{1}{\sigma}\left\{\frac{\varphi\left(\frac{\mu_i}{\sigma} - \sigma\right)}{\phi\left(\frac{\mu_i}{\sigma} - \sigma\right)} - \frac{\varphi\left(\frac{\mu_i}{\sigma}\right)}{\phi\left(\frac{\mu_i}{\sigma}\right)}\right\} \qquad \text{….(9)}$$

φ and ø are the density and cumulative distribution functions, respectively, for the standard normal distribution.

The elasticities of mean paddy output and their estimated standard error are presented in Table 4. It is evident from the table that all the variables except human labour included in the model significantly influence the paddy production. The empirical results in the table further indicated that land had the major influence on output. The elasticity of frontier (best practice) production with respect to land under paddy was estimated to be 0.55 which is the largest of all the elasticity estimates made in the study. This indicated that, if the area under paddy were to be increased by 1 per cent, then the total paddy production were estimated to increase by 0.55 per cent. Further, the elasticity of fertiliser use was estimated to be 0.20. Thus, if fertiliser use were to increase by 1 per cent, then the mean production of paddy was estimated to increase by about 0.20 per cent for the best practice paddy production. The elasticity of output in respect of irrigation expenditure and insecticides were 0.13 and 0.32, respectively. The estimated elasticity of mean paddy output with respect to human labour is positive but very small, i.e., 0.054. The results also show that the elasticity of output with respect to human labour is estimated to be an increasing function of human labour but it is estimated to be a decreasing function of fertiliser, irrigation, land and insecticides. The elasticity of farm output with respect to fertiliser is estimated to be an increasing function of fertiliser and irrigation expenditure but decreasing function of human labour, land and insecticides expenditure. The elasticity of output with respect to land is estimated to be an increasing function of land and insecticides but decreasing function of human labour, fertiliser and irrigation expenditure. It is also observed that the elasticity of output with respect to irrigation expenditure is estimated to be an increasing function of irrigation expenditure and fertiliser but decreasing function of human labour, land and insecticides. The elasticity of output with respect to insecticides is estimated to be an increasing function of insecticides and land but decreasing function of human labour, fertiliser and irrigation expenditure. The returns to scale parameter was estimated to be 1.25 which indicates that the paddy cultivation in the state experienced increasing returns to scale.

TABLE 4. ELASTICITIES OF MEAN OUTPUT

Elasticity with respect to (1)	Elasticity (2)
Human labour	0.0544 (0.0392)
Fertiliser	0.1969 (0.0181)
Irrigation expenditure	0.1276 (0.0322)
Land	0.5476 (0.0297)
Insecticides	0.3233 (0.0160)

Note: Figures in parentheses indicate standard errors.

4.2 Technical Inefficiencies

The technical efficiency of each farm was predicted for each year in which they were observed. The mean efficiencies of each farm over the years have also been calculated. Because of the large number of observations involved, the individual technical efficiency values were not presented. However, for better indication of the distribution of individual efficiencies, a frequency distribution of predicted technical efficiencies within ranges of 0.05 for each year and mean efficiency of each farmer are presented in Table 5. The examination of technical efficiencies of the individual farmers revealed that there were wide variations in technical efficiencies. The predicted technical efficiencies for paddy farmers ranged from 0.39 to 0.99 in the first year (1996-97); from 0.32 to 0.99 in the second year (1997-98) and from 0.24 to 0.99 in the third year (1998-99) of study data. The coefficient of year of observation in the model for technical inefficiency effects is positive and statistically significant. It

TABLE 5: RELATIVE FREQUENCY DISTRIBUTION OF TECHNICAL EFFICIENCY OF PADDY FARMERS IN HARYANA

	First year		Second year		Third year		Mean	
Technical efficiency (1)	Frequency (2)	Percentage to total farmers (3)	Frequency (4)	Percentage to total farmers (5)	Frequency (6)	Percentage to total farmers (7)	Frequency (8)	Percentage to total farmers (9)
≤ 0.45	4	5.80	3	3.90	10	11.76	4	4.30
0.45-0.50	1	1.45	2	2.60	6	7.06	0	0.00
0.50-0.55	0	0.00	3	3.90	3	3.53	2	2.15
0.55-0.60	1	1.45	2	2.60	1	1.18	5	5.38
0.60-0.65	2	2.90	3	3.90	7	8.24	7	7.53
0.65-0.70	8	11.59	4	5.19	7	8.24	6	6.45
0.70-0.75	8	11.59	9	11.69	7	8.24	5	5.38
0.75-0.80	11	15.94	13	16.88	10	11.76	20	21.51
0.80-0.85	8	11.59	6	7.79	6	7.06	21	22.58
0.85-0.90	8	11.59	12	15.58	10	11.76	12	12.90
0.90-0.95	3	4.35	8	10.39	3	3.53	9	9.68
0.95-0.99	15	21.74	12	15.58	15	17.65	2	2.15
Mean	0.7978		0.7878		0.7252		0.7666	
Minimum	0.3864		0.3165		0.2428		0.3500	
Maximum	0.9959		0.9949		0.9933		0.9948	
Total number of sample farmers	69		77		85		93	

implies that the efficiencies are time varying and tend to decline over the years. The annual mean efficiency which was 0.80 in the first year observed declined slightly to 0.79 in second year which further declined sharply to 0.72 in the third year observed. The main reason for decline in technical efficiency may be attributed to weather related aberrations in the study area. There was a heavy rainfall during post monsoon in October 1998 resulting in damage to standing and matured paddy crop. This fact is confirmed by the data on average yield of paddy in the state during these periods of study years. The average yield of paddy in the state was recorded to be 30 qtls./hectare in 1996-97 which slightly declined to 28 qtls./hectare in the next year. The average yield of paddy further declined to 22 qtls./hectare in 1998-99 (Government of Haryana, 2002-03). Further it is observed that about 7 per cent of the farmers have technical efficiency lower than 0.5 in first year and second year each. This percentage increased to about 19 per cent in the third year. The percentage of farmers who had technical efficiency above 0.70 was about 77 in the first year and in the second year this percentage was more or less the same but it plummeted to 60 per cent in the third year. However, the highest percentage (17.65) of the farmers were in the efficiency level of above 0.95. The mean efficiencies of the farmers over the years ranged from 0.35 to 0.96. The mean efficiencies over the years indicate that only a small number (4.30 per cent) of the farmers had technical efficiency less than 0.50 and about 74 per cent of the sample farmers had technical efficiency equal or greater than 0.70. Majority of the farmers (44 per cent) had technical efficiency between 0.80

to 0.85 and about 12 per cent of the sample farmers had technical efficiency above 0.90. About one-fourth of the sample farmers in the third year were operating at technical efficiency level of less than or equal to 0.60. Therefore, there was a potential of increasing paddy production of these farmers using the same level of inputs and technology. The operation level of this group is very important because any attempt to bring the farmers to the frontier production will increase paddy production at the household's level and will add to the aggregate state production as well.

V

CONCLUSIONS

A translog stochastic frontier production function is used for the analysis of unbalanced panel data for three years for paddy farmers. The study revealed that the traditional average response function, which does not account for technical inefficiency of production, was not an adequate representation of the data. Also, it was found that the Cobb-Douglas functional form is not an adequate representation of the data. The technical efficiency showed wide variations across sample farms ranging from 0.24 to 0.99 in the last year of the study period. The results also show that the farm specific technical efficiencies estimated are time varying and tend to decline over time. The mean technical efficiency declined from 0.80 in first year to 0.72 in the last year, which indicates that average technical efficiency regressed/deteriorated through years in paddy production. Although there were high relative frequencies of the technical efficiency above 0.90, there were also some farmers who were quite poor in their technical efficiency performance. The mean level of technical efficiency over the years ranged from 0.35 to 0.99 with overall mean technical efficiency being 0.77. Thus, the study indicates that there is a scope to improve the productivity of the crop with the given level of inputs use and technology. If the efficiency is improved, farmers will gain considerably in terms of higher profits. Further, the technical inefficiencies of production of farmers are significantly related to age and year of observation. However, the inefficiencies of paddy production are not significantly related to schooling and land. There are certain other variables such as rainfall data, extension services, access to credit, research and development, farmers' training, etc., which may be important to be included in the inefficiency effects model. But, because of lack of information/data, these variables have not been modelled in inefficiency effects which could have provided an insight into the policy framework.

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NOTES

1. Human labour includes both family as well as hired labour. Labour man-days were converted to male equivalent units by treating female and child hours equivalent to 0.67 and 0.50 male hours, respectively.

2. The time-varying inefficiency model requires that the years of observation be coded as 1, 2, …..t (Battese and Broca, 1997).

REFERENCES

Aigner, D.J., C.A.K. Lovell and P. Schmidt (1977), "Formulating and Estimation of Stochastic Frontier Production Function Models", *Journal of Econometrics*, Vol.6, No.1, pp. 21-37.

Food and Agriculture Organization of the United Nations, *FAO Production, Year Book 2003,*Rome, Italy.

Battese, G. E. and S.S. Broca (1997), "Functional Forms of Stochastic Production Functions and Models for Technical Inefficiency Effects: A Comparative Study for Wheat Farmers in Pakistan", *Journal of Productivity Analysis*, Vol.8, pp. 395-414.

Battese, G. E. and T. J. Coelli (1988), "Prediction of Firm Level Technical Efficiencies with a Generalised Frontier Function and Panel Data", *Journal of Econometrics*, Vol.38, No.3, pp. 387-399.

Battese, G. E. and T. J. Coelli (1992), "Frontier Production Functions, Technical Efficiency and Panel Data: With Applications to Paddy Farmers in India", *Journal of Productivity Analysis*, Vol.3, No.3, pp. 153-169.

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*, Vol.20, pp. 325-332.

Bravo-Ureta, B. E. and A. E. Pinheiro (1993), "Efficiency Analysis of Developing Country Agriculture: A Review of The Frontier Function Literature", *Agriculture Resource Economic Review,* Vol. 22, pp. 88-101.

Coelli, Tim J. (1994), "A Guide to Frontier Version 4.1: A Computer Programme for Stochastic Frontier Production and Cost Function Estimations", CEPA Working Paper 96/07, University of New England, Armidale.

Farrell, M. J. (1957), "The Measurement of Production Efficiency", *Journal of the Royal Statistical Society*, Series A, Vol.120, Part 3, pp. 253-281.

Government of Haryana (2002-03), *Statistical Abstract of Haryana,* Economic and Statistical Organisation, Planning Department, Chandigarh, Haryana, India.

Huang, C.J. and J.T. Liu (1994), "Estimation of A Non-Neutral Stochastic Frontier Production Function", *Journal of Productivity Analysis,* Vol.5, pp. 171-180.

Jondrow, J.; C.A.K. Lovell; I.S. Materov and P. Schmidt (1982), "On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model", *Journal of Econometrics,* Vol.19, No.2, pp. 233-238.

Kalirajan, K.P. and R.T. Shand (1994), *Economics in Disequilibrium: An Approach from the Frontier*, Macmillan India Ltd., New Delhi.

Kodde, D. A. and F. C. Palm (1986), "Wald Criteria for Jointly Testing Equality and Inequality Restrictions", *Econometrica,* Vol. 54, pp. 1243-1248.

Kumbhakar, S.C. (1990), "Production Frontiers, Panel Data and Time-Varying Technical Inefficiency", *Journal of Econometrics*, Vol. 46, pp. 201-211.

Meeusen, W. and J. van den Broeck (1977), "Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error", *International Economic Review*, Vol.18, No.2, June, pp. 435-444.

Mythili, G. and K. R. Shanmugam (2000), "Technical Efficiency of Rice Growers in Tamil Nadu: A Study Based on Panel Data", *Indian Journal of Agricultural Economics*, Vol.55, No.1, January-March, pp. 15-25.

Pitt, M.M. and L.F. Lee (1981), "The Measurement and Sources of Technical Inefficiency in the Indonesian Weaving Industry", *Journal of Development Economics,* Vol. 9, No.1, January-March, pp. 43-64.

Rajasekharan, P. and S. Krishnamoorthy (1999), "Technical Efficiency of Natural Rubber Production in Kerala: A Panel Data Analysis", *Indian Journal of Agricultural Economics*, Vol. 54, No.4, October-December, pp. 545-553.

Rao, C.A. Rama.; K.R. Chowdry; Y.V.R. Reddy and G.V. Krishna Rao (2003), "Measuring and Explaining Technical Efficiency in Crop Production in Andhra Pradesh", *Indian Journal of Agricultural Economics*, Vol.58, No.4, October-December, pp. 768-780.

Wilson, P. and D. Hadley (1998), "Measuring and Explaining Technical Efficiency in U.K. Potato Production", *Journal of Agricultural Economics*, Vol. 49, pp. 294-305.