Pratidhwani the Echo
A Peer-Reviewed International Journal of Humanities & Social Science
ISSN: 2278-5264 (Online) 2321-9319 (Print)
Impact Factor: 6.28 *(Index Copernicus International)*
Volume-III, Issue-IV, April 2015, Page No. 15-21
Published by Dept. of Bengali, Karimganj College, Karimganj, Assam, India
Website: http://www.thecho.in

Measuring Technical Efficiency of Paddy Cultivators in South Hailakandi Blocks of Hailakandi District a Stochistic Production Frontier Approach

Dr. Manik Gupta
Assistant Professor, Department of Economics, S. K. Roy College, Katlicherra, Assam, India

Abstract
The contemporary study attempts to measure technical efficiency of paddy cultivators in South Hailakandi blocks which is also called Manipur Block of Hailakandi district on the basis of farm level primary data by estimating a Cobb-Douglas production frontier model with inefficiency effects. Only the 2012 cropping season is considered in the current study. Data on various farm inputs and paddy output in physical units is collected at the cultivator level using the standard interview method employing a well structured pretested agricultural survey schedule. The study concludes that human labour is the single most important and statistically significant factor in determining paddy output at the cultivator level. Other factors like seeds, fertilizers and pesticides are found statistically insignificant. Regarding inefficiency effects model, age of the cultivator has a negative influence on technical efficiency. The study finds substantial differences in farm level technical efficiency across different size classes of farmers. Among the non-input factors quality of life has a positive influence on technical efficiency. However indebtedness and percentage of self consumption, indicating distress level, are found to have negative influences on firm level technical efficiency. The distribution of technical efficiency (TE) is found to be positively skewed with mean TE only around 39 percent. The hypothesis of constant returns to scale is rejected at 5 percent level. The study prescribes more credit facilities for cultivators belonging to the below 1 hectare size class. The study also prescribes the government should pay attention to control informal money lending and expansion of round the year irrigation facilities along training programmes for HYV cultivation in the district for significant improvements in farm technical efficiency and thus for improvements in overall quality of life.
Key words: technical efficiency, inefficiency affects quality of life.

1. Introduction:

1.1 Agricultural Status of Hailakandi District: A brief outline: Agriculture is the main livelihood of life for the majority of population in Assam where about 90 percent of the total population living in rural areas depends on agriculture for their livelihood. Since independence, significant strides have been made in agricultural production in the State. Similarly, production of fruits and vegetables has also increased manifold during the same period. Assam is richly endowed with natural resources, favourable soil and climatic condition and suitable to grow various field crops, horticultural crops, spices and varieties of vegetables etc. Similarly, production of fruits and vegetables has also increased manifold during the same period. Being bestowed with the blessings of agro-climatic condition, the State has become the natural home of horticultural produce which includes cultivation of wide range of horticultural crops like fruits, vegetables, spices, plantation crops, nuts and corm crops.

About 70 per cent of cultivable areas of Assam are covered under rice and more than 90 per cent of the total area under food grains. Yet the State has been chronically suffering in food deficit and indebtedness. It is mainly because of the fact that agriculture in Assam remains slow due to low productivity of food crops primarily due to lack of assured water supply, adoption of traditional farm technology, recurring floods in some parts of the region, shortage of infrastructural and institutional support and also for high growth of population. With the gradual increase in the size of population, the increase in the production has failed to keep pace which leads to a fall in per capita availability of food. The State maintained near self sufficiency level in food production until 1960s. There after the State started to face the problem of food deficit continuously and the quantum of deficit has reached to the level of 30 per cent of the self sufficiency level.

In regards of tenure system near about 50 per cent of cultivators, have land on lease as part of operational holdings. So the mode of payment of rent is also not uniform in all places of Assam. In most of the cases the system is that the share the output between the landlord and the tenant cultivator, usually at 50/50 ratio. In some cases the cost of cultivation have share equally by both landlord and the tenant and some other cases the landlord shares only the cost of inputs, mainly fertilizers, while there are system that large section of the owner have not share any cost.

The cropping pattern is indicated by the shares of different crops in the gross cropped area. This may undergo changes overtime in response to changes in economic, technological or other environmental factors. A outstanding feature of the cropping pattern of the south Assam is the pre-dominance of paddy, which accounts for more than 90 per cent of total cropped area. The types of paddy are - Autumn Paddy or Ahu, Winter Paddy or Shali and summer paddy or Boro. In Hailakandi District total cultivable area of 29950 in the year 2005-06 the autumn paddy cultivation area is 5580 in hectare 23400 winter paddy in hectare and 970 hectare the summer paddy .The total population according to 2001 census was 542872in Hailakandi. And the literacy rate was 84.98 per cent according to the survey report of District Agricultural Plan.

The period of cultivation in Autumn Paddy is April to July and total production in recent period is 2100 kg per hectare. Period of cultivation for winter paddy is July to December and total production is 2000 kg per hector. Again, on the other hand Boro paddy cultivation period is Dec to May and total production is 2200 kg per hectare.

In Hailakandi District 15 to 20 percent are share croppers and remaining cultivators have own land for their cultivation though the individual cultivation area have not sufficient or even there is uneconomic holding. In respect of tenure, system those person who have enough land attached other cultivators to cultivate their land by the system of adhiya or equal share (like as 50:50 share). Even other agreements are also observed frequently.

Focus of the Study: The present study attempts to determine (estimate) the distribution of technical efficiency (TE) across the selected sample of paddy cultivators in the district of Hailakandi. **First**, the study attempts to determine farm level TE by adopting an appropriate econometric technique and then it analyses the distribution of TE. **Second**, the study attempts to identify a host of crucial non-input factors that may explain the inter-farmer variations in the level of technical efficiency. This will help to identify the causes of efficiency variations across cultivators. **Third**, the study tests whether large cultivators are more efficient. The **fourth** objective is to verify whether diversifiers are more efficient than non-diversifiers and whether multiple croppers are more efficient than mono croppers. **Finally** the study attempts to find the most appropriate form of production function that describes the underlying technical relationship between farm inputs and farm output.

The study shall adopt a transcendental logarithmic production frontier model with inefficiency effects incorporated in the random disturbance term (Battese and Coelli, 1995). The computations will be based on the Software Package *FRONTIER 4.1* for Windows.

The data for the study will entirely be primary in nature. The study is based on detailed break up information on farm outputs, farm inputs, number of crops per year, along with other crucial socioeconomic factors of a sample of 107 cultivators covering all South Hailakandi district. The sampling method is stratified and purposive. The objective is to have equal representation in the sample in terms of size class composition. The study finally attempts to give a set of policy suggestions aimed to improve the efficiency levels of paddy cultivators in the district of Hailakandi.

1.2 Necessity and Scope of The Study: The presence of inefficiency leads to four major consequences in the production process. First, it reduces the quantity of output for a given set of inputs. Second, some of the inputs will be either under-utilised or over-utilised. Third, it raises the cost of production. Finally, there will be a loss in profit. We classify efficiency into three categories, technical, allocative and scale. Technical efficiency refers to producer's behaviour relating to the production of output with a given quantity of inputs. Allocative efficiency is related to producer's choice of optimal input combination. And finally, scale efficiency is a situation of choice of right quantity of output, where price and marginal cost of production are assumed to be equal.

Now days, efficiency is the central issue in the sphere of production economics. Whether we consider a free enterprise economy, a mixed economy, a centrally planned economy, a developed economy, a developing economy, or for that matter the agricultural sector, the manufacturing sector or the services sector, the study of productive efficiency is not only relevant but is important from the viewpoint of policy making both at the micro and macro levels. In a densely populated developing country like India, resources are scarce but the burning economic problems for ensuring the livelihoods of such a huge pool of population require enormous amount of resources. The limited resources, if utilized efficiently, will possibly accelerate the generation of large income and surplus for re-investment. This ultimately can gear up the pace of development.

The concept of optimum is important in standard microeconomic analysis of producers' behaviour. In fact in each of the above mentioned functions, the concept of maximum or minimum is important. In the case of production function there has been a recent attempt to estimate the maximum possible output as a function of input quantities; in the case of cost function the minimum level of cost as a function of given input prices; and in the case of profit function the maximum possible profit as a function of output and input prices. Therefore instead of defining production function, cost function and profit function one should call them production frontier, cost frontier and profit frontier respectively. The word 'frontier' may be meaningfully applied in each case, because the functions set a limit to the range of possible observations. For instance, a farm may be observed to produce at a point below the production frontier, or above the cost frontier or below the profit frontier. Expressed otherwise, the firm is producing less than maximum output, incurring cost more than minimum level and receiving less than maximum possible profit. By this reasoning, no farm can lie above the production frontier or the profit frontier and above the cost frontier. The amount by which a farm lies below the production frontier, the profit frontier and above the cost frontier can be regarded as measures of inefficiency. Hence if a farm stays on the frontier it may be called efficient. It implies that deviation of the farm from frontiers – production, cost or profit – can be attributed to the presence of inefficiency.

This study aims to find the extent of farm level economic efficiency of a sample of cultivators from Hailakandi district of Assam. The study will also see the distribution of technical efficiency across cultivators along with the influence of selected non-input factors on the level of farm level technical efficiency.

Economic *efficiency* is an indefinable concept in which the policy makers have great stakes. The policy implications of economic *efficiency* infuse both the micro and the macro-economic level. Suppose, the *efficiency* of all farms irrespective of their sizes, is measured. Then, it can be determined that how much a given set of farms can increase their profit or net income through reallocation of inputs, use of a given technique of production and choice of appropriate output within a given set of inputs.

Evidently land holding in the district is highly unequal and is clearly dominated by small and marginal farmers. Thus it is related to understand whether fragmentation of land has at all caused any loss of both yield per hectare as well as that in efficiency. Around 90 percent of the cultivators depend on rainfall for agriculture and as such the post autumn paddy which grown during a relatively dry season suffers immensely due to lack of proper irrigation. .

The significance of the present study is twofold. First because it makes a pioneering attempt to measure farm level technical efficiency of selected paddy farmers of Hailakandi district. The distribution of technical efficiency across cultivators would reveal whether there is any size-efficiency relation (trade off or otherwise) in paddy cultivation in the district. Second certain non-input factors that may influence efficiency are age of the cultivator, education and awareness as captured by years of schooling, percentage of land leased in by the cultivator, joint or unitary family setup, farm mechanisation, self consumption among a few others. Other factors specific to the cultivator include mono croppers and multiple croppers. Cropping intensity may influence efficiency. Similarly diversification (as measured by value of non-paddy output divided by value of paddy in the last cropping season), may influence efficiency in paddy cultivation. This may be due to spreading attention into different crops round the year as opposed to concentrating on one crop only. Finally, indebtedness may play a role on the farm level technical efficiency. The study will travel a long way in identifying the true causes of inefficiency in paddy cultivation in Hailakandi district.

2.Review of Literature: The stochastic frontier analysis originated with two joint papers published nearly simultaneously by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977). The two papers were very similar in their approaches. In the same year a third paper on stochastic frontier analysis (SFA) was developed by Battese and Corra (1977 Meeusen and van den Broeck (1977) assigned an exponential distribution to *u*. Battese and Corra (1977) assigned a half normal distribution to, and Aigner, Lovell and Schmidt (1977) considered both distributions on *u*.

Jondrow, Lovell, Materov and Schmidt (1982) proposed that either the mean or the mode of the conditional distribution [u_i /v_i - u_i] would provide estimates of the technical inefficiency of each producer in the sample.

Reversing the sign on *u*, a methodology for estimating a stochastic cost frontier model along with firm specific cost inefficiency was first developed by Schmidt and Lovell (1979, 1980). However a deterministic cost frontier model was constructed and estimated by Forsund and Jansen (1977). Decomposition of cost inefficiency was essential. Schmidt and Lovell (1979) decomposed the estimates of *u* into estimates of the separate costs of technical and allocative inefficiency for the Cobb- Douglas cost function case. Schmidt (1985-86), Greene (1993,), present comprehensive surveys on the development of the stochastic cost frontier in recent years.

Kalirajan (1981) measured the specification of conventional production functions to a stochastic production frontier in order to explain productivity differences among firms.

3. Methodology:

3.1 Econometric Approach in this Study: The stochastic frontier production models are represented by specifying both the Cobb-Douglas model (for example, Seyoum et al., 1998 Son et al., 1993; Tadesse and Krishnamurthy, 1997) and the translog production model (eg Hallam and Machado, 1996; Kumbhakar, 1989). The Cobb-Douglas stochastic frontier model restricts the flexibility of the functional form on the Farmer's production technology by imposing the elasticity of scale to be constant and the elasticity of input substitution to be unity. The translog stochastic frontier model, a flexible function form, presumes no such restriction. Moreover, the Cobb-Douglas stochastic frontier model is a restricted form of and nested in the translog model. A representative functional form can be selected on the basis of statistical tests. Hence we shall adopt this approach.

Most empirical applications of stochastic in agriculture have investigated the source of farmer technical inefficiency using a two-stage approach(for example Tedesse and Krishnamurthy,1997,Hallamand Machado, 1996,) . The first stage estimates a stochastic frontier model by maximum likelihood technique and calculus the technical efficiency for each farm under the assumption that inefficiency effects are identical distributed. It ignores the fact the technical inefficiency is a function of farm specific variables. Once technical inefficiency is estimated, it is further regressed in the second stage on a set of farm specific factors that may explain differences in technical inefficiency among farms using OLS. The result in the second step contradict the assumption of identically distributed inefficiency effects in the stochastic frontier model since the technically inefficiency – the dependent variables- is one sided (Kumbhakar et al, 1991). Thus in the second stage the estimated technical inefficiency effects are modeled as a function of some farm-specific characteristics. This implies that inefficiency effects are not identically distributed unless the coefficients of the farm-specific are simultaneously equal to zero (Coelli et al., 1998). This two-stage approach, using a stochastic frontier, has been applied by Kalirajan (1981) and Pitt and Lee (1981) and by Heshmati and Kumbhakar (1997) for Panel data. Timmer (1971) was one of the first to apply this approach albeit using covariance analysis in stage one.

The problems of this stage method can be addressed using a one- stage formulation. This specifies the technical inefficiency effects (Kumbhakar et al.,) and estimates the stochastic frontier and the inefficiency effects simultaneously, given appropriate distributional assumptions (Battese and Coelli, 1995). The simultaneous estimation of the stochastic production frontiers and models of technical inefficiency using maximum likelihood techniques has been proposed by Kumbhakar et al. 1991), Reifschneider and Stevenson (1991), Haung and Lui (1994), Battese and Coelli (1995). This one-stage approach is statistically consistent and leads to more efficient inference with respect to the parameters (Coelli and Battese, 1996) The approach has been applied empirically by, among others, Coelli and Battese (1996) , Ajibefun et al. (1996) and Seymoun) et al. (1998).

The study adopts a transcendental logarithmic production frontier model with inefficiency effects [Battese and Coelli, 1995].

3.2 *Data*: The data used for the study is entirely primary in nature. A stratified purposive random sampling method is employed in order to select 107 cultivators in the district covering various village of the blocks of South Hailakandi. This was efficiently achieved by selection of Gram Panchayats in each block.

4. Empirical Analysis of Data: The agricultural survey on paddy cultivation was conducted in selected Gram Panchayats of Hailakandi district during the harvest of the last two successive cropping seasons of 2012, namely during summer crop harvest and autumn crop harvest. The obtained sample of 107 cultivators from Hailakandi district .Around 49 percent of the cultivators selected belong to the 1- 6 bigha size class, 38 percent belong to the 6 - 12 bigha size class and around 13 percent belong to 12 bigha and above category. Cultivators with size of holdings below 1 bigha were kept outside the purview of the study. Around 95 percent of the cultivators depend on rainfall for agriculture and as such the post autumn paddy which grown during a relatively dry season suffers immensely due to lack of proper irrigation.

From the sample data it is found that only around 11 percent of the farmers covering all size classes had access to mechanised equipments. HYV cultivation is very uncommon among the cultivators. For the largest size class average area under HYV was only 20 percent of their holdings. For the second largest size class the figure was around 12 percent and that for the smallest size class was 7 percent. In other words cultivators are strongly biased against HYV cultivation. More than 88 percent of them did not have knowledge of optimum timing of HYV seeds, optimum application of fertilizers in the desired proportion, or ideal spacing and watering. Moreover soil quality testing was unheard by all cultivators. Only 4 percent cultivators in the entire sample said that they had received some kind of benefits from government sponsored agricultural extension and support programmes. A majority of cultivators were of the opinion that proper training and demonstration of HYV paddy, round the year irrigation facilities along with formal agricultural credit at NABARD regulated interest rates and proper monitoring of KCC are key factors that could transform the region into a strong agricultural zone.

The list of variables with their units of measurement for the translog production frontier model (inputs along with output) is listed below:

***physical output** (kg) in the last cropping season in kg, **cultivated area** in bigha, man-days of **human labour** including women workers, cattle days of **animal labour**, expenditure (rental if any and all running costs) in Rs on **mechanised equipments**, value in Rs of **traditional farm equipments**, expenditure in Rs on **irrigation** facilities (including personalised micro-irrigation system), and **fertilisers** in kg, **pesticides** in ml., **irrigation** expenditure in Rs.*

The list of variables with their units of measurement for the inefficiency effects model is listed below:

***age** of the cultivator as a proxy for experience, total no. of years of **schooling** in the cultivator's household, existing **loans** in Rs, **area under HYV**, percentage of **land leased in** by the cultivator, **joint family** dummy (joint =1, 0 otherwise), **farm mechanisation** dummy (users of mechanised equipments =1, 0 otherwise), **self consumption** as a percentage of output, **multiple cropper dummy** (Multiple cropper =1. 0 otherwise), **diversification** (as measured by value of non-paddy output divided by value of paddy in the last two cropping seasons),*

Coming to estimates of the translog production frontier model, land, that is, the coefficient of area cultivated is positive but insignificant. Similar are the coefficients of irrigation, fertilizer and pesticides. However both animal as well as human labours are significant in determining output. Impact of mechanised equipments is insignificant but positive (rental paid on borrowed equipments). However that of traditional farm equipments is positive and significant. The *R* square value is moderately high at 0.52 which implies that 52 % of the total variation in output is explained by the inputs.

Since coefficients of the translog production function do not have any direct interpretation we turn to the elasticities of output with respect to the inputs. Output elasticity with respect to land turns out to be 0.46, that with respect to capital equipments (combined) is 0.02, that with respect to animal labour is 0.21, that with respect to human labour is 0.19, that with respect to fertilizer is 0.01 that with respect to pesticide is 0.003. The returns to scale turn out to be 0.673, which is clearly indicative of diminishing returns.

Turning to the inefficiency effects model, age of the cultivator as a proxy for experience seems to have a positive but insignificant influence on TE, i.e., older cultivators are more efficient. Education and awareness as captured by years of schooling in the household has a positive but insignificant impact on TE. In other words educated farm households have higher TE. The impact of percentage of HYV cultivation is near zero and insignificant. Percentage of land leased in by the cultivator has a positive influence on TE. That is farmers who have leased in more land with respect to their original owner ship are technically more efficient than others. Joint or unitary family setup has no impact on TE. Farm mechanisation has no influence on TE. Interestingly self consumption as a percentage of output seems to play a positive role in influencing TE. Profit after self consumption has a positive impact on TE which is expected. That is cultivators with greater profits are technically more efficient. However government support dummy has played no role in determining TE. But multiple croppers have less TE than others which is very surprising. Similarly diversifiers (as measured by value of non-paddy output divided by value of paddy in the last cropping season), have lower TE compared to others. This may be due to spreading attention into different crops round the year as opposed to concentrating on one crop only. Indebtedness plays a negative role on farm level TE. This is found from the inefficiency effects model where the value of the coefficient for loans, is positive and significant.

The study finds considerable differences in farm level technical efficiency across different size classes of farmers. Among the non-input factors quality of life has a positive influence on technical efficiency. However indebtedness and percentage of self consumption (a proxy for cultivator's distress level) are found to have negative influences on firm level technical efficiency. The distribution of technical efficiency (TE) is found to be positively skewed with mean TE only around 39 percent. The study prescribes more credit facilities for cultivators belonging to the 1 – 4 hectares size class. The government should pay attention to control informal money lending and expansion of round the year irrigation facilities along training programmes for HYV cultivation in the district for significant improvements in farm technical efficiency and thus for improvements in overall quality of life.

Bibliography:

1 . Ajibefun, I.A Battese, G .E. Darmola, A. G. (1996), "Investigation of Factors Influencing the Technical Efficiencies of small holder croppers in Nigeria", CEPA Working paper No0/96 Department of Econometrics, University of New England, Armidale, pp-19.

2. Ali, M. And Flinn J. C. (1989), "Profit Efficiency among Basmati rice producers in Pakistan Punjab", *American Journal of Agriculture Economics*, 71, 303-30.

3.Aigner, D. Lovell, C.A.K. and Schmidt, P. (1977), "Formulation and Estimation of Stochastic Production Models", Journal of Econometrics, **6**, pp. 21-37.

4. Battese, G.E. and Corra, G.S. (1977), "Estimation of Production Frontier Model: With application to the Pastoral Zone of Eastern Australia", *Australian Journal of Agricultural Economics*, **21**, pp. 167-177.

5. Battese, G.E. and Coelli, T. (1995), "A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data", *Empirical Economics*, Vol. 20, No. 2, pp. 325-32.

6 .Fϕrsund F.R. and Jansen, E.S. (1977), "On Estimating Average and Best Practice Homothetic Production Function via Cost Functions", *International Economic Review,* **18**, pp. 463-476.

7. Coellli, T. Battese, G. (1996) Identification of Factors which Influence the Technical Inefficiency of Indian Farmers, Australian Journal of Agricultural Economics, 40, 103-128.

8. Hallam, D. and F. Machado (1996), Efficiency Analysis With Panel Data :A Study of Portuguese Dairy Farms, European Review of Agriculture Economics, 12, 79-93.

9. Heshmati, A and S. C. Kumbhakar, 1997, Estimation of Technical efficiency in Swedish crop Farms: A Pseudo Panel Data Approach, Journal of Agriculture Economics, 48, 22-37.

10. Kalirajan, K.(1981), An Econometric Analysis of Yield Variability in Paddy Production, Canadian Journal of Agricultural Economics,29, 283-294.

11. Pitt, M.M., and L.F. Lee (1981), The Measurement and Sources of Technical Inefficiency in the Indonesian Weaving Industry, *Journal of Development Economics*, 9, 43-64.

12. Seyoum, E., Battese G.E., Fleming E.M.(1998), Technical Efficiency and Productivity of Maize Producers in Eastern Ethiopia :A Study of Farmers Within and Outside the Saskawa Global 2000 Project ,CEPA Working Papers, No. 6/96, Department of Econometrics, University of New England, Armidale. pp14.

13. Son T., V. H.T. Coelli, and E. Fleming (1993), Analysis of the Technical Efficiency of State Rubber Farms in Vietnam, *Agricultural Economics*, 9, 183-201.

14. Tadesse, B. and S. Krishnamurthy (1997), Technical Efficiency in Paddy Farms of Tamil Nadu: An Analysis based on Farm Size and Ecological Zone, *Agricultural economics*. 16, 185-192.

15. Greene, W. H. (1993), "The Econometric Approach to Efficiency Analysis", Fried Harold O., C.A. Knox Lovell and Shelton, S. Schmidt (1993), eds., *The Measurement of Productive Efficiency – Techniques and Applications*, Oxford University Press.

16. 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,* 19:2/3 (August), pp.233-238

17. Kumbhakar, Subal C. (1989), "Short-run Returns to Scale, Farm-size and Economic Efficiency", *Review of Economics and Statistics*, **71**, November..

18. Kumbhakar, Subal C., Ghosh, S. and McGuckin, J.T. (1991), "A Generalised Production Frontier Approach for Estimating Determinants of Inefficiency in U.S. Dairy Farms", *Journal of Business and Economic Statistics*, **9**, No. 3, July, pp. 287-296.

19. Meeusen,W. and van den Broeck, J. (1977), "Efficiency Estimation From Cobb-Douglas Production Functions with Composed Error", *International Economic Review*, **18**, pp.435-444.

20. Schmidt, P., (1985-86), "Frontier Production Functions", *Econometric Reviews*, **4** (2), pp. 289-328.

21. Schmidt, Peter and C.A.Knox Lovell (1979), "Estimating Technical and Allocative Inefficiency Relative to Stochastic Production and Cost Frontiers", *Journal of Econometrics*, **9**, Feb, pp. 343-366.

22 .Schmidt, Peter and C.A.Knox Lovell (1980), "Estimating Stochastic Production and Cost Frontiers When Technical and Allocative Inefficiency are Correlated", *Journal of Econometrics*, **13**, pp. 83-100.

23. Stevenson, R.E. (1980), 'Likelihood Functions for Generalized Stochastic Frontier Estimation,' *Journal of Econometrics*, 13:1 (May), pp. 57-66.

24. Timmer, C.P. (1971), "Using a Probabilistic Frontier Function to Measure Technical Efficiency", *Journal of Political Economy*, **79**, No. 4, July-Aug, pp. 776-794.

25. Wadud, A. Md. and Ben White (2002), 'The Determinants of Technical Inefficiency of Farms in Bangladesh,' *Indian Economic Review*, Vol.2 pp. 183-97.