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Full Length Research Paper

Productive efficiency of tea industry: A stochastic frontier approach

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In an economy where recourses are scarce and opportunities for a new technology are lacking, studies will be able to show the possibility of raising productivity by improving the industry's efficiency. This study attempts to measure the status of technical efficiency of tea-producing industry for panel data in Bangladesh using the stochastic frontier production function, incorporating technical inefficiency effect model. It was observed that Translog Production Function is more preferable than Cobb-Douglas Production Function. The study estimates that the average technical efficiency of tea producing industries in Bangladesh is 59%. Therefore, the results indicated that there is a great potential exists for tea industry to further increase the value added by 41% using the available input, technology and efficiency improvement, thereby reducing the cost of production. The study identifies that the mean efficiency of tea industries for value added vary among the regions and year-wise mean efficiency seems to be unstable during the study period and therefore, continued efforts to update technologies and equipment are required in pursuit of efficiency in tea industry.

Key words: Technical efficiency, stochastic frontier, translog production, likelihood ratio test, tea industry.

INTRODUCTION

The tea producing industry has been traditionally regarded as one of the major agro-based labor intensive industry and occupies an important role in the national economy of Bangladesh. The role of Bangladesh tea industry in global context is insignificant. It is only 1.68% of the global tea production and 0.58% of the world tea export. It seems that its export is gradually declining. If this trend continues, Bangladesh will turn into a tea importing country by 2015 (Monjur, 2004; Mahmud, 2004). As a result, international comparisons of the tea industry's efficiency have been of great interest to firms in the industry as well as policymakers. The large tea producing countries like India and Sri Lanka produce more than Bangladesh, where India and Sri Lanka's production level is 16 and 12 times higher than Bangladesh (BCS, 1997 - 98). It was found that in 1998, on an average only 1,145 kg of tea was produced per hectare in Bangladesh. Whereas, in the same year, production level per hectare in India and Sri Lanka was 1708 and 2030 kg, respectively (Majumder, 2003).

The concept of the technical efficiency of firms has been pivotal for the development and application of econometric models of frontier functions. Although technical efficiency may be defined in different ways [see, example, Fare et al. (1985)], we consider the definition of the technical efficiency of a given firm (at a given time period) as the ratio of its mean production (conditional on its levels of factor inputs and firm effects) to the corresponding mean production if the firm utilized its levels of inputs most efficiently [see Battese and Coelli, 1988]. Efficiency is an important factor of productivity growth as well as stability of production in developing agricultural economics. In view of slow growth and increasing instability in tea production in Bangladesh (Monjur, 2004), the tea economy of Bangladesh is expected to be benefited to a great extent from the study on technical efficiency studies. Estimates on the extent of inefficiencies could help decide whether to improve efficiency or to develop new technology to raise tea productivity in Bangladesh.

There are some studies that have been carried out to analysis for the measurement of efficiency of tea industries.

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They include among others: Hazarika and Subramanian (1999) for Asam tea industry in India; Ariyawardana (2003) for value added tea producers in Sri Lanka; Basnayake and Gunaratne (2002), and Rohan Jayatilake (2009) for tea small holdings in Sri Lanka; Baten et. el. (2009) for seven tea regions of Bangladesh; and Nghia Dai Tran (2009) for different tea production systems in Thai Nguyen Province. Besides Daniela et al. (2008), and Fahr and Sunde (2005) investigated empirically the spatial variation of productivity across Brazilian regions applying stochastic frontier analysis to manufacturing data. Haque (2006, 2007) examined and compared the value chain models that are adopted by the tea industries of Bangladesh and Japan using some descriptive statistics analysis. These studies do not adopt a stochastic frontier model, which is generally thought as an essential for productivity analysis and for measuring technical efficiency of tea industry.

The stochastic frontier production function, which was independently proposed by Aigner et al. (1977), Meeusen and van den Broeck (1977) has been a significant contribution to the econometric modeling of production and the estimation of technical efficiency of firms. The stochastic frontier involved two random components, one associated with the presence of technical inefficiency and the other being a traditional random error. Applications of frontier functions have involved both cross-sectional and panel data. These studies have made a number of distributional assumptions for the random variables involved and have considered various estimators for the parameters of these models. Survey papers on frontier functions have been presented by Forsoud et al. (1980), Schmidt (1986), Bauer (1990) and Battese (1992), the latter article giving particular attention to applications in agricultural economics. Beck (1991) and Ley (1990), have compiled extensive bibliographies on empirical applications of frontier functions and efficiency analysis.

However, a few empirical researches have been carried out to estimate the technical efficiency of the tea industries in Bangladesh using stochastic frontier model. Therefore, there is a great need to research the production efficiency of the tea industries, which may contribute largely to the present low performance of the tea industry in Bangladesh. The aim of this study is to estimate the inefficiency of tea industries in Bangladesh and identify the factors causing technical inefficiency of tea industries. In this study, an effort has been made to analyze in measuring technical efficiency of tea industry using the stochastic frontier production function model specified by Battese and Coelli (1995), for the panel data. To determine the sources of inefficiency to improve the existing situations in tea industry are also of our interest.

MATERIALS AND METHODS

In stochastic frontier analysis, the assumption is that the production function of the fully efficient firm is known. Fried, Lovell et al., (1993), have shown that econometric approaches like the stochastic frontier analysis can distinguish the effects of noise from the effects of inefficiency. Since one of the objectives of this research is to examine the production efficiency (scores) of tea industries in Bangladesh, the Stochastic Frontier Analysis was selected as the tool to measure efficiency in this study. We employed a stochastic production frontier approach introduced by Battese and Coelli (1995), and it can be written as

$$Y_{it} = \beta X_{it} + (V_{it} - U_{it}), \quad i = 1, 2, ... \; ..., N; \quad t = 1, 2, ..., T \quad .... \; ..(1)$$

Where Y_{it} the logarithm of output of the ith tea industry is in tth period X_{it} is a vector of input quantities;

V_{it}'s random variables which are assumed to be i.i.d., $N(0, \sigma_v^2)$ and independent of U_{it} ;

U_{it}'s are non-negative random variables which are assumed to account for technical inefficiency in production and to be independently distributed as truncations at zero of the $N(\mu, \sigma_u^2)$ distribution; where $U_{it} = Z_{it}\delta$; where; Z_{it} is a $(1 \times p)$ vector of variables which may influence the inefficiency of tea industry and δ is a $(p \times 1)$ vector of parameters to be estimated. The parameterization from Battese and Corra (1977), are used, replacing σ_u^2 and σ_v^2 with $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and the parameters are estimated by Maximum Likelihood approach.

The Technical inefficiency effect U_{it} in the stochastic frontier model is specified as follows;

$$U_{it} = Z_{it}\delta + W_{it} \quad .... \; .(2),$$

Where, the random variable W_{it} follows truncated normal distribution with mean zero and variance σ^2, such that the point of truncation is $-Z_{it}\delta.$ Parameters of the stochastic frontier given by Equation (1) and inefficiency model given by Equation (2) are simultaneously estimated by using maximum likelihood estimation. After obtaining the estimates of U_{it}, the technical efficiency of the I - th tea industry at t - th time period is given by:

$$TE_{it} = \exp(-U_{it}) = \exp(-Z_{it}\delta - W_{it}) \; ....(3).$$

Selecting the functional form of the production function

In order to select the best specification for the production function (Cobb - Douglas or Translog), for the given data set, we conducted hypothesis tests for the parameters of the stochastic frontier production model using the generalized likelihood - Ratio (LR) statistic defined by

$$\lambda = -2\{\ln[L(H_0)/L(H_1)]\} = -2\{\ln[L(H_0)] - \ln[L(H_1)]\}. \; .... \quad (4)$$

Where $\ln[L(H_0)]$ the value of the log likelihood functions for the stochastic frontier is estimated by pooling the data for all the seven regions under null hypothesis, and $\ln[L(H_1)]$ is the sum of the values of the log - likelihood functions for the seven stochastic production functions (North Sylhet + Juri + Lungla + Manu-Doloi + Balisera + Luskerpore + Chittagong) estimated separately under alternative hypothesis.

Specification of the Stochastic Frontier Translog (Value Added) Model

The functional form of the stochastic frontier Translog production model is defined as:

$$\ln(Y_{it}) = \beta_0 + \beta_1 T + \beta_2 \ln A_{it} +$$
$$+ \beta_{12} \ln A_{it} * T + \beta_{13} \ln L_{it} * T +$$
$$\beta_3 \ln L_{it} + \frac{1}{2}\left(\beta_{11} T^2 + \beta_{22} \ln A_{it}^{\ 2} + \beta_{33} \ln L_{it}^{\ 2}\right)$$
$$\beta_{23} \ln A_{it} * \ln L_{it} + V_{it} - U_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(5),$$

Where, the subscripts i and t represent the i-th tea industry and the t-th year of observation, respectively; $i = 1,2,...,7$; $t = 1,2,...,15$;

Y_{it} denotes the output variables (Value added) of the ith tea industry in the t-th period in values (taka);

T represents time;

A_{it} denotes area of ith tea industry in the t-th period;

L_{it} represents labor of ith tea industry in the t-th period;

"ln" refers to the natural logarithm; the β_i's are unknown parameters to be estimated; V_{it} follows $N(0, \sigma_v^{\ 2})$ and U_{it} follows a truncations at zero of the $N(\mu, \sigma_u^{\ 2})$ distribution and guarantees inefficiency to be positive only.

Identifying sources of technical inefficiency and hypothesis tests

The tea industry specific inefficiency is considered as a function of some explanatory variables and the inefficiency effects model is defined as:

$$U_{it} = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + W_{it} \ldots\ldots\ldots\ldots(6),$$

where δ_0 is the intercept term and δ_j $(j = 1,2,3)$ is the parameter for the j-th explanatory variable and Z_1= Temperature, Z_2= Rainfall, Z_3= Herfindahl-Hirschman index.

The hypothesis tests are obtained using the generalized likelihood-ratio test statistic (4). This test statistic is assumed to be asymptotically distributed as mixture of chi-square distribution with degree of freedom equal to the number of restrictions involved. The restrictions imposed by the null hypothesis are rejected when λ exceeds the critical value (Taymaz and Saatci, 1997, p. 474).

These are obtained by using the values of the log-likelihood functions for tea industries and the stochastic frontier production function.

Given the specification of the stochastic frontier production function, defined by (5), the null hypothesis that technical inefficiency is not present in these model, is defined by $H_0 : \gamma = 0,$ where γ is the variance ratio, explaining the total variation in output from the frontier level of output attributed to technical efficiency and defined by $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$. This is done with the calculation of the maximum likelihood estimates for the parameters of the stochastic frontier models by using the computer program FRONTIER version 4.1 developed by Coelli (1996). If the null hypothesis is accepted this would indicate that $\sigma_u^{\ 2}$ is zero, hence that the U_{it} term should be removed from the model, leaving a specification with parameters that can be consistently estimated using ordinary least square (OLS). Further, the null hypothesis that the technical inefficiency effects are time invariant defined as $H_0 : \eta = 0$. If the null hypothesis is true, the generalized likelihood ratio statistic λ is asymptotically distributed as a chi-square (or mixed chi-square) random variable.

Data description and variable construction

The data were collected from the various issues of Annual Report of *Bangladeshyio Cha Sansad (BCS)* and *International Tea Committee (ITC)* etc. Our study covers total Tea Industry that is available, under registered tea gardens of Bangladesh over the reference period 1990 to 2004.

Value added (Y)

Value added figures are used in this study to represent output and is equal to the value of products and is measured in values (taka). This value added figure is manipulated by the price of yield per hectare and it is treated as gross production or gross output. To obtain the gross output series in constant prices, the yearly current values were deflated by the industry price index of the relevant year. In this analysis gross value added (output) is dependent variable.

Area (A)

Area is one of the essential inputs in measuring productivity. Gross fixed area under tea is used in this study.

Labor (L)

The number of employees directly or indirectly in production is used in this study as a labor input. It covers all workers including administrative, technical, clerical, sales and purchase staff. Thus all production and non-production workers except temporary daily casuals and on paid workers are included in the analysis. In brief, they include production workers, salaried employees, and working proprietors. The best measure of labor input is the number of hours worked. As no such data are available for any industry, employment figures were taken as the second measure and were weighted by the base year wage rate to obtain measure of labor input.

Time (T)

To find the productive efficiency of a i-th tea industry over time we have used time as the input variable. In this study we have used data of 15 years from 1990 to 2004. Explanatory Variables which influence the level of inefficiency is considered also in this study:

Table 1. OLS and MLE estimates of stochastic frontier translog (Value added) model.

Variable	Parameters	Estimated OLS Estimates	Estimated MLE Estimates
Constant	β_0	-17.735 ** (10.448)	- 17.263 * (0.990)
Time	β_1	- 0.023 @ (0.216)	- 0.211 @ (0.170)
Area	β_2	5.983 ** (3.085)	6.141 * (0.748)
Labor	β_3	-1.878 @ (1.881)	- 1.283 * (0.675)
Time * Time	β_{11}	39.987 @ (0.009)	- 92.152 * (55.747)
Area * Area	β_{22}	- 2.161 ** (1.019)	- 2.839 * (0.547)
Labor * Labor	β_{33}	-1.808 ** (0.953)	- 2.257 * (0.568)
Time * area	β_{12}	- 0.079 @ (0.211)	0.098 @ (0.137)
Time * Labor	β_{13}	0.071 @ (0.211)	- 0.070 @ (0.135)
Area * Labor	β_{14}	1.839 ** (0.959)	2.313 * (0.545)
Sigma - squared	σ^2	0.058	
Log likelihood function		**6.001**	**25.203**

N=105 and *, **, *** significance level at 1%, 5%, 10% consecutively, @ means insignificant, and values in the parentheses indicate Standard Error.

Temperature (Z_1)

Temperature is used as influencing variables which are not deflated but actual measurement and its unit of measurement is Fahrenheit.

Rainfall (Z_2)

Rainfall is used as influencing variables which are not deflated but actual measurement and its unit of measurement is millimeter.

Herfindahl - Hirschman Index (Z_3)

The Herfindahl-Hirschman index takes into accounts both the relative size and number of tea industries. Mathematically, HHI is described as follow: $HHI = \sum_{i=1}^{N} S_i^2$ where N is the number of industries and S_i is share of the i^{th} tea. HHI is known as measure of competition which is measured as the sum of squared of the output share of each tea industry in the output of considered total tea industries in Bangladesh.

RESULTS AND DISCUSSION

Selection of the translog production function

We have tested the hypothesis whether the Translog production function is an adequate representation of the data or not using Equation (5). The values of the log likelihood for the Cobb-Douglas and Translog production frontiers are 18.93 and 25.203, respectively. By employing Equation (4), we have estimated the values of Likelihood Ratio for the Cobb-Douglas and Translog production are 34.267 and 38.389, respectively. These values are compared with the upper five percent points for $\chi^2_{(3,0.05)}$ and $\chi^2_{(9,0.05)}$ which are 3.85 and 10.25, respectively. Finally it is concluded that the null hypothesis $H_0 : \beta_{ij} = 0$ is strongly rejected and it indicates that Translog Production Function is more preferable than Cobb-Douglas Production Function.

Estimating the stochastic frontier translog model

The results of the Ordinary Least Square (OLS) and Maximum-likelihood Estimation (MLE), for the Translog production function as described in Equation (5) are reported in Table 1. From the OLS estimation we have observed that a total of 4 coefficients out of 9 are statistically significant at 5% level, indicating the importance of some of the interactions and non - linearity among variables. The direct effects of area, interaction effects of area and labor, square terms or second order parameters of area and labor are significantly different from zero. These implied that there exists having a major role in tea production. The area remains the single most important input with an output elasticity of 5.983, followed by labor -1.878, respectively. Reasonably enough, for a labor surplus economy, labor has the negative output (value added) elasticity and is found to be insignificant in the production process. This implies that labor does not affect the yield of the tea significantly. The variable time, second order parameter of time, interaction of time and labor and interaction of time and area are found to be insignificant. So we can say that the area and labor with interaction to time do not affect on the value added (production) in tea industries of Bangladesh.

The sign of coefficients of all variables in Equation (5), when estimated with MLE technique are negative but significant except area and its interaction with labor,

Table 2. Region wise mean efficiency of value added for the selected tea regions in Bangladesh.

Year	North Sylhet	Jury alley	Lungla	Manu-doloi	Balisera	Luskerpore	Ctg. Dist.	Mean efficiency
1990	0.38	0.47	0.43	0.61	0.49	0.92	0.34	**0.52**
1991	0.40	0.52	0.41	0.67	0.78	0.72	0.34	**0.55**
1992	0.35	0.48	0.29	0.59	0.70	0.60	0.29	**0.47**
1993	0.32	0.41	0.31	0.55	0.67	0.60	0.30	**0.45**
1994	0.35	0.54	0.36	0.65	0.77	0.68	0.35	**0.53**
1995	0.30	0.48	0.32	0.53	0.60	0.54	0.28	**0.44**
1996	0.37	0.66	0.47	0.74	0.90	0.74	0.42	**0.61**
1997	0.32	0.46	0.31	0.49	0.50	0.52	0.32	**0.42**
1998	0.62	0.90	0.61	0.96	0.95	1.00	0.58	**0.80**
1999	0.38	0.64	0.44	0.70	0.75	0.67	0.42	**0.57**
2000	0.51	0.65	0.49	0.76	0.85	0.63	0.61	**0.64**
2001	0.57	0.72	0.49	0.86	0.82	0.64	0.80	**0.70**
2002	0.50	0.61	0.44	0.79	0.84	0.58	0.58	**0.62**
2003	0.60	0.76	0.52	0.97	1.00	0.70	0.69	**0.75**
2004	0.58	0.72	0.51	0.92	0.95	0.67	0.69	**0.72**
Mean	**0.44**	**0.60**	**0.43**	**0.72**	**0.77**	**0.68**	**0.47**	

interaction in between area and labor which are positive. In this analysis, it is found that the variable time and its interaction with area and labor are insignificant. The direct effects of area, labor, square terms or second order parameters of area and labor and interaction of area and labor are significantly different from zero. This indicates that the rejection of the Cobb-Douglas model as an adequate representation of Bangladesh Tea Industry is justified, because the function is non - linear in some dimensions and there are important interactions among the variables. The variables' area and labor appear to be the major determinants of tea production. However, area remains the single most important input with an output (value added) elasticity of 6.141, followed by labor - 1.283, respectively. Reasonably enough, for a labor surplus economy, labor has the negative output (value added) elasticity and is found to be insignificant at 5% level in the production process. The coefficients of interaction of time with area and labor are 0.098 and - 0.070, respectively indicating that value added (production) is explained only by 9 and 7% by these interaction variables. So from this result we may conclude that the area and labor with time interaction have low output (value added) elasticity. We have observed that the variable area shows significant affect for both OLS and MLE estimation of the Translog stochastic frontier production function. The coefficient on the time trend variable indicates that there is a negative technological progress but it declines downwards with an annual rate of 21.1% per annum and the effect is nonlinear, as indicated by the significant coefficients of the squared terms. Overall these findings support the results of Baten et al. (2009).

Table 2 reveals that the technical efficiency of Bangladesh Tea industry during the period 1990 to 2004 is found to be 0.59 ranging from a minimum of 0.28 to a maximum of 1.00 for value added for the selected tea regions. This implies that 59 percent of potential value added is being realized by the tea industry of Bangladesh. In the present study, none of the estimates had achieved zero level efficiency, while only Balisera in 2003 and Luskerpore in 1998 achieved full level efficiency (100%). The findings also suggest that 41% technical inefficiency exists in the value added of tea. In other words, 59% of the tea estates were able to produce on the production frontier, and 41% were off-frontier of varying degrees for value added. There is wide variation in the technical efficiencies among the different tea producing region. However, the overall value added efficiency for all regions is steadily increasing over time except the year 2004 presented in Figure 1. The highest mean efficiency was in 1998 and it was more than 80% which is 50% higher than previous year. The average efficiency in 2004 was 4% lower than 2003. We observed that the value added efficiency in tea producing regions (like north Sylhet, Jury and Ctg.) in Bangladesh during the period 1990 - 2004 have lower efficiency comparable to other regions. The year wise value added average productive efficiency has been illustrated also by Figure 2 separately. Year wise value added (productive) efficiency seems to be unstable during the study period. The efficiency for value added was least for the year 1997 but its highest efficiency for the year 1998. It is hope that there has been a general improvement occurred after the year 1997.

Following the Figure 3, we have also observed that Balisera and Manu - Doloi are most efficient in producing tea with 77 and 72% respectively. This result indicates that big size (measuring their total area, technology) regions are comparatively more efficient. The lowest efficiency is in the Lungla (42%). From the analysis we

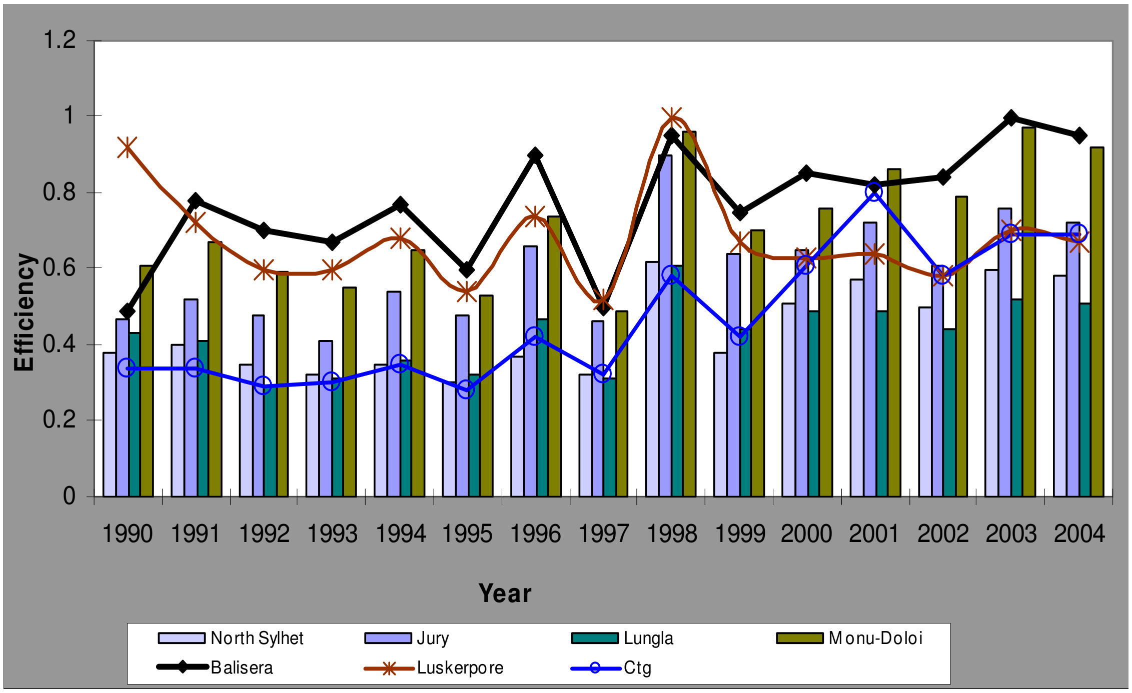

Figure 1. Value added efficiency in tea producing regions in Bangladesh, 1990 - 2004.

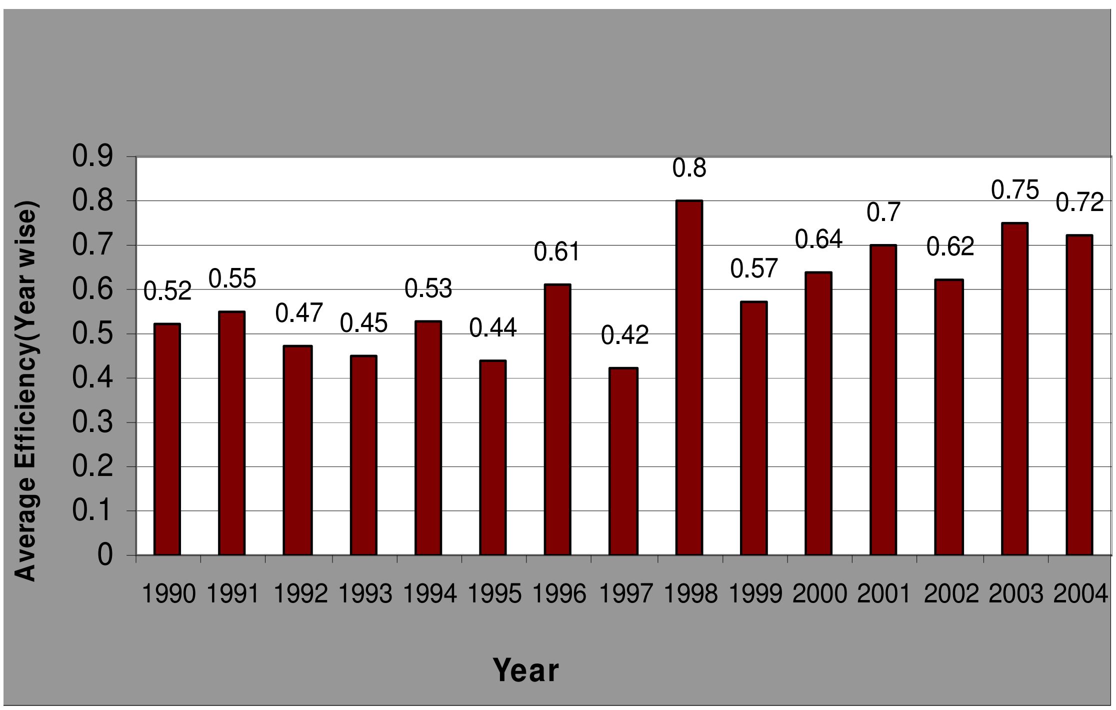

Figure 2. Year-wise value added average efficiency in tea industries of Bangladesh, 1990 - 2004.

observed that the Lungla valley and North Sylhet are so far lowered efficient in producing tea comparing to other regions. May be these less efficient regions are concentrating in other services rather than value added.

Estimating the inefficiency effect model

In order to investigate the determinants of inefficiency, we have estimated the technical inefficiency model described

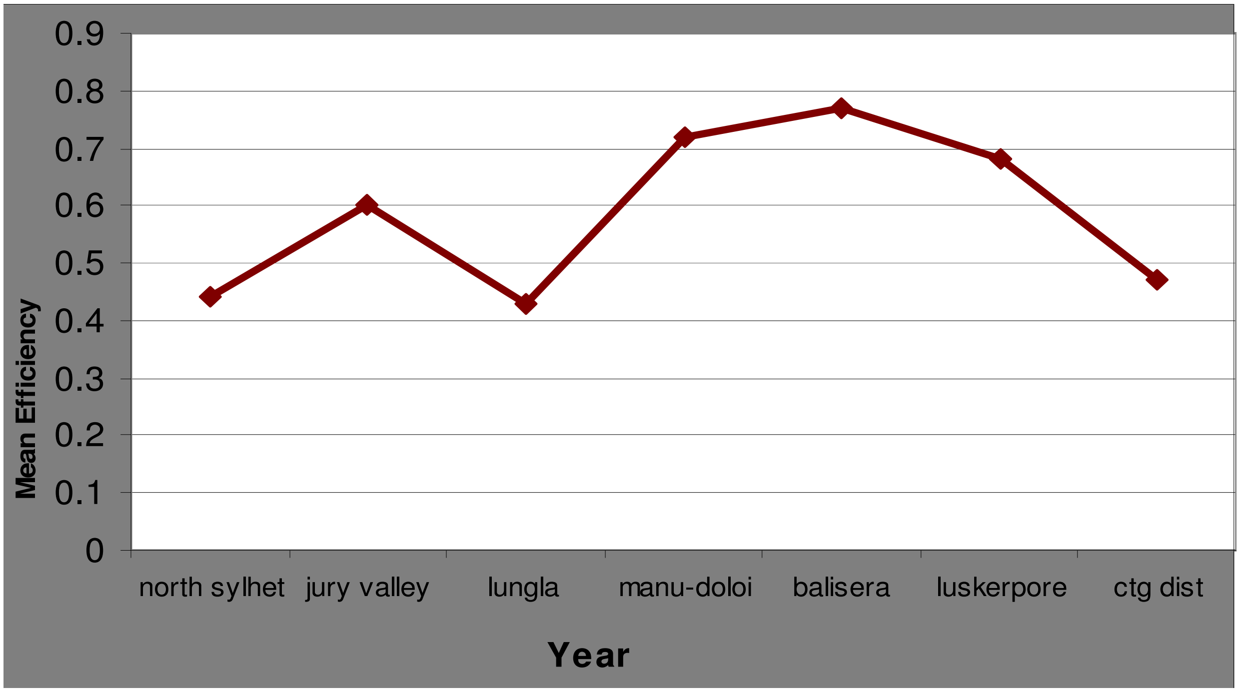

Figure 3. Region - wise value added average efficiency in tea industries of Bangladesh, 1990 - 2004.

Table 3. Inefficiency effects model for value added.

Variable	Parameters	MLE Coefficients
Constant	δ_0	4.677* (0.959)
Temperature	δ_1	0.500** (0.285)
Rainfall	δ_2	0.077@ (0.088)
HHI	δ_3	-1.088* (0.155)
sigma-squared	σ^2	0.041* (0.008)
gamma	γ	0.999* (0.00001)

*, **, *** indicate significance level at 1,5 and10% consecutively, values in the parentheses indicate S.E. and @ indicates Insignificance.

in Equation (6) presented in Table 3. The sign of co-efficients of the variable HHI is negative but significant impact on tea production. These indicate that HHI variable is inversely related with inefficiency. The variable temperature significantly contributes to improved technical efficiency in tea production and this implies that temperature should be one of the major variables in order to improve technical efficiency in tea production. The sign of the coefficient of rainfall indicates that rainfall is less efficient although the coefficient is not statistically significant. Using the composed error terms of the stochastic frontier model, it is defined by $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$ which is a measure of level of the inefficiency in the variance parameter and it ranges between 0 and 1. It is observed that the MLE estimate of γ is 0.999 with estimated standard error of 0.00001. The value of γ is significantly different from one indicating that random shocks are playing a significant role in explaining the variation in tea production, which is expected in tea production where uncertainty is assumed to be the main source of variation. This implies that the stochastic production frontier is significantly different from the deterministic frontier, which does not include a random error. This indicates that the random component of the inefficiency effects does make a significant contribution in the analysis. In the MLE estimation, γ is positive and significant at 1% level, implying that tea industry specific technical efficiency is important in explaining the total variability of value added produced. However, it should be noted that 99 percent of the variation in production is due to technical inefficiency and only 1 percent is due to the stochastic random error.

Results of hypothesis tests

The results of various hypotheses tests for the specification model (5) are presented in Table 4. The value of log likelihood function for OLS and MLE allow to test whether technical inefficiency exists or not. In case technical inefficiency does not exist then technically, there will be no difference in the parameters of OLS and MLE. The null hypothesis which includes the restriction that γ is zero does not have a chi-square distribution, because the restriction defines a point on the boundary of parameter space γ. The first null hypothesis $H_0 : \gamma = 0$ for the

Table 4. Likelihood-Ratio Test of Hypothesis of the Stochastic Frontier Translog Model.

Null Hypothesis	Log-likelihood Function	Test Statistic λ	Critical Value*	Decision
$H_0 : \gamma = 0$	6.0085	38.389	10.25	Reject H_0
$H_0 : \beta_{ij} = 0$	1.8002	34.267	3.85	Reject H_0
$H_0 : \eta = 0$	6.019	40.419	5.21	Reject H_0

Notes: All critical values are at 5% level of significance.
*The critical values are obtained from table of Kodde and Palm (1986).

Value added specification model which specify that there is no technical inefficiency effects in the model. The value of the logarithm of the likelihood function provides generalized likelihood ratio test statistic of 38.389, which is larger than the critical value of 10.25. So the hypothesis is rejected and we can conclude that there is a technical inefficiency effect, given the specifications of the stochastic frontier and inefficiency effect model. Hence the stochastic frontier model does appear to be a significant improvement over an average production function that supports the results of Basnayake and Gunaratne (2002). The second null hypothesis $H_0 : \beta_{ij} = 0$ indicates that Cobb-Douglas Production Function is more preferable than Translog Production Function. From the outcome, it is observed that the null hypothesis is strongly rejected and Translog Production Function is statistically more favorable. The third null hypothesis is $H_0 : \eta = 0$, which specifies that the technical inefficiency effect does not vary significantly over time. The null hypothesis is rejected indicating that the technical inefficiency effect varies significantly.

There are not many studies carried out to estimate production efficiency using tea industries data in Bangladesh. Recently, Baten et. al., (2009) used panel data to estimate the production frontier and the technical inefficiency effects of tea production using a Stochastic Frontier Analysis (SFA) methodology. Their studies fail to consider value added (output variable) for the measurement of tea productive efficiency. Our results are mostly compatible in measuring industries or firm's performance to some international studies such as Fahr and Sunde (2005) and Schettini et. al. (2008). It was found that the technical efficiency estimates are highly sensitive to the functional form specified because the Translog model yielded different technical efficiencies. However, the Translog specification is used in the interpretation as it is accepted by the data. The second stage analysis, which identifies the determinants of the inefficiency, should be done for a meaningful policy implication. Labors are found to be more inefficient even when they are expected to be major determinants of tea production industry. This may be because their lacking of knowledge and information provided them the extension officers. Therefore it is necessary to increase educational facilities in the area. This study, however, emphasize the potential improvement of Bangladesh tea industry through industry efficiency improvement, which can allow Bangladesh to regain the competitiveness in the world tea market.

Concluding remarks

This study focused on the estimation of the technical efficiency of the tea producing industries in Bangladesh, applying the Stochastic Frontier Approach and to identify the factors causing inefficiency over the reference period 1990 to 2004. The rejection of the Cobb-Douglas model as an adequate representation of Bangladesh Tea Industry was justified, because the function is non-linear in some dimensions and there are important interactions among the variables. The variables, both area and labor, disappeared to be the major determinants on the tea industry production. According to the results obtained from the stochastic frontier estimation, the average technical efficiency of tea industry given by the Translog model is 59%. This indicates that there is a scope to further increase the output by 41% without increasing the levels of inputs.

From the inefficiency effects model, we have found that the variable HHI shows negative but impact on tea production and temperature, significantly contributed to improve technical efficiency in tea production. We concluded that temperature was one of the major variables in order to improve technical efficiency in tea production in Bangladesh, but it is surprising about rainfall which was found less efficient although, it is not statistically significant. For the MLE, γ is estimated at 0.99, this can be interpreted that 99% of random variation is the Value added among the tea industry production due to inefficiency.

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