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# Productivity and Technical Efficiency of Smallholding Tea Plantations in North Bengal− A DEA Analysis

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***Abstract***

*The proliferation of small tea growers into non-traditional areas is a very significant phenomenon of tea industry of North Bengal in recent years. The present study has estimated technical efficiency at the level of individual grower using the technique of Data Envelopment Analysis. The result shows that the mean efficiency of DMUs is quite high for the whole sample. However, it varies considerably across different classes of holdings. The study has indicated that there is ample potential for improvements in efficiency performance in terms of realisation of higher yield for all holding sizes of plantations, and especially for the bottom size class.*

**Keywords:** Small Tea Growers; DEA; Technical Efficiency; Potential Efficiency Improvement

**JEL Classification**: C14, C61, O12, O13

## I. INTRODUCTION

A significant phenomenon of the century old tea industry of North Bengal in the recent years is the large-scale proliferation of small tea smallholding sector in four district of the region, namely, North Dinajpur, Terai (the foothills of Darjeeling), Jalpaiguri and Coochbehar. Following this development, there has been a vast extension of tea plantations periphery into non-traditional areas which are mostly comprised of farmlands and were put under the cultivation of paddy and other traditional crops before the establishment of such plantations. The local people cultivating tea on individual small farm holdings in these districts are now being called small tea growers (STGs). They are mostly comprised of conventional farmers, besides educated youth from rural, semi-urban and urban areas (Majumdar, 2005).

The advent of small tea growers in this region could be noticed only in the late 1980s or early 1990s when many pineapple growers had started taking up tea cultivation due to the paucity of available market for their produce.The initial success with experimentation with tea had attracted many others to enter similar ventures. Since mid-1990s, the sector had started gaining momentum on a significant scale. This was largely attributable to the buoyant tea prices that prevailed during 1996-98 as well as the launch of Tenth Plan Tea Plantation Development Scheme of Tea Board of India (TBI) which envisaged a comprehensive development programme for the small grower segment (Sinha, 2002; FAO, 2003). Since then, the phenomenal growth trend of the sector has been continuing unbrokenly.

As far as the current scenario is concerned, the STGs are uniformly distributed in both Jalpaiguri and Darjeeling districts covering all the blocks. In Uttar Dinajpur district, they are scattered across three blocks, namely, Islampur, Chopra and Goalpukur. In Coochbehar, however, STGs are mostly present in Mekhliganj Block. As per the definition of Tea Board of India (TBI), STGs are those who possess less than 10.12 hectares (or 25 acres) of land under tea cultivation without having any processing unit. However, as it is revealed in several studies, most STGs in the North East India including North Bengal own less than 2 acres of land and tea cultivation is the only source of livelihood for them. During the last two decades, this sector has become a tremendous force to reckon within the contour of State's tea industry because of its commendable contribution to total tea acreage vis-a-vis total production of tea. As per the recent statistics of Ministry of Commerce and Industry, GOI (2014), there are now 35000 STGs with a total of 36000 hectares of land under cultivation of tea in North Bengal. But as most STGs still do not have official registration with TBI, the actual figures of number of growers and tea acreage are supposed to be much larger than the officially estimated figures. This has, in fact, got reflected through the sector's steady increase of production at an impressive rate over the years. The official statistics shows that production by STGs in this region has increased from 76.49 million kgs in 2011-12 to 92.63 million kgs in 2012-2013. The production has further increased to 97.47 million kgs in2013-2014 (*op cit*, 2014). According to the estimate of the confederation of Indian small tea growers association **(**CISTA), nearly 33 percent of total tea production of North Bengal comes from this sector. Thus, the changing organizational arrangement of the tea sector of the region induced by high proliferation of tea smallholders has brought about a striking change in the composition of tea output in this region. Not only in West Bengal is this changing composition of output is widely visible. It is squarely visible in the rest of the states of India which grow tea. It is relevant to mention here that TBI had prepared a perspective plan long ago for achieving the production target of 1,000 million kg by the year 2000. This target could not have been achieved till 2011. It is quite obvious that the fulfilment of one billion kg-mark in production is being propelled by STGs alone. In addition, in terms of employment generation, changing options of occupational choices, impact on living standard etc.the development of this sector has drawn attention of many academicians.

## II. THE OBJECTIVE OF THE STUDY

As mentioned previously, a striking feature of STGs in North Bengal is that a vast majority of them are small and marginal farmers who were cultivators of paddy and other types of traditional crops prior to establishment of their tea plantations. The logical implication that follows is that that the spread of STGs in this region is essentially attached with a rapid shift of land use from traditional subsistence agriculture to commercial agriculture of tea plantations. More specifically, the main form of land-use shift is the replacement of paddy field by tea gardens. In such a context, an important subject of inquiry would be to answer whether such a proliferation and the subsequent changing land-use pattern did occur in order for seizing economic incentives in the form of productivity and efficiency gains leading to remunerative use of land holdings. This paper is an attempt towards the estimation of plantation level technical efficiency (TE) **of** STGs in allocation and utilisation of their land, labour and other productive inputs in order to produce maximum potential output, which is green tea leaf. This evaluation is necessary to know whether outputs of farms are produced in the best and most profitable way, or alternatively, inputs are utilised in the least-cost way. Moreover, this evaluation helps identify the sources of inefficiency and therefore, the opportunities to improve the production performance of the STGs under consideration.

## III. METHODOLOGY AND MODEL

### Technical Efficiency and Data Envelopment Analysis (DEA)

TE is the ability and willingness of a farm to obtain maximum potential output from a given level of input used or to use minimum potential input to produce the given output. For estimating TE, a non-parametric linear programming (LP) method DEA has been used in this study. The other method that could have been used is the parametric stochastic frontier production function (SFP). Both are frontier methods which have originated from the seminal work of Farrell (1957) on efficiency measurement. But a potential advantage of DEA over SPF regression is that it does not require specification of a functional or distributional form, and can accommodate scale economy issues. DEA was introduced by Charnes, Cooper and Rhodes (CCR model, 1978, 1981) and further extended by Banker (1984), and Banker et al. (BCC model, 1984).

DEA provides a means of estimating relative efficiency levels within a homogeneous group of production units, which are usually termed as decision making units (DMUs) in the DEA literature. Thus, in DEA, the efficiency of a DMU is measured relative to the group's observed best practice DMUs which map a non-parametric frontier (or more technically speaking, a piecewise linear convex hull). It identifies efficient DMUs as those belong to the frontier, and inefficient ones, which lie above (or below) it. The standard DEA models have two alternative orientations –input-orientation and output-orientation. An input-oriented DEA reflects the minimum amount of inputs that is being utilised to produce a given level of output. An output-oriented DEA, on the other hand, reflects the greatest amount of output that can be produced from a given amount of input given the technology of production. With these two alternative orientations of the DEA models, technical efficiency can be defined either in the form of the ratio of observed to maximum potential output obtainable from the given input, or the ratio of minimum potential to observed input required to produce the given output (Lovell, 1993). The former approach constitutes the conventional output-based measure of TE while the latter the input-based measure of TE.

**DEA Model Specification**

DEA analysis requires choosing an appropriate DEA model to analyze the performance of DMUs) as because the efficiency scores are sensitive to the specification of the model. This essentially implies that one could obtain different sets of efficiency scores from the same data set with alternative specifications of the model. This could lead to miscalculation of efficiency scores and subsequently, wrong projections of inefficient DMUs onto the efficient frontier.

Usually, DEA analysis is carried out by choosing any one of the two basic DEA models, which are the CCR and the BCC models. The criterion of making a choice between these two basic DEA models must depend on our insight of the production technology under which the sample of DMUs operate. Suppose that we have reasons to believe that the production technology is such that DMUs can expand or contract the input-output combination to any extent and these projected input-output combinations would remain within the production possibility set. In economic parlance, it implies that the production technology has constant returns to scale. If this be the description of the production technology, then the choice of the DEA model is clearly the CCR model. On the other hand, we may predict that "a production possibility set with a piece-wise linear production frontier" is a fair characterization of the production technology under which the observed DMUs are actually operating. With this prediction, we are essentially making no assumption about returns to scale, or alternatively, we are making the assumption of variable returns to scale. Now given this assumption, our choice would definitely be the BCC model for efficiency estimation.

In the present study, the BCC model has been chosen as the production of green leaf output is subject to variable returns to scale (VRS) for a number of reasons as described below. It is important to mention at the outset that not only economic factors alone, but other non-economic factors have role to play in the production of green leaf. Two such important factors substantiating VRS assumption in the present study are respectively, the climatic and soil conditions factors under which small tea plantations operate in the North Bengal region. It has been cited in the literature that the annual yield distribution and potential yield of green leaf is largely influenced by seasonal fluctuations in weather variables including rainfall and temperature (Panda et. al., 2003). As far as the study region is concerned, the rainfall variable is subject to both spatial and inter-temporal variation in terms of total amount and distribution throughout the season. This provides a good justification of the assumption of VRS. The second important factor justifying the assumption of VRS is the recognition of the fact that small tea plantations in different sub-regions of non-traditional tea area are characterised by differences among a set of soil properties including pH of soil, EC and organic matter content.

Another important consideration regarding model specification is whether to select an input-oriented or output-oriented model. Intuitively speaking, the choice of input-or output-oriented models depends upon whether the production units under consideration have fixed or variable quantities of resources to produce outputs. In this study, an output orientation has been chosen for the reasons as follows. For the estimation of technical efficiency, a number of variables used in the analysis are essentially fixed factors of production. These include land area, number of bushes in the plantation area, meteorological factors influencing tea yield, soil condition factors, permanent family labour employed in a garden and others. Thus, the DMUs would seek to determine by how much output quantity can be proportionally expanded given the set of non-discretionary inputs. Hence, we select the output oriented BCC model. The input-oriented DEA model is less relevant for the present study.

On the basis of the model selection criteria mentioned above, it is, therefore, logical and rational to apply the following specific formulation of BCC output oriented model in our study

$$\begin{aligned} & \max\ \eta \\ & \text{subject to} \\ & X\,\mu \le x_k \\ & \eta y_k - Y\,\mu \le 0 \\ & e\,\lambda = 1 \\ & \qquad \lambda \ge 0 \end{aligned}$$

where $\eta$ = efficiency score, X = input vector, Y = output vector, $X\,\mu$ = actual convex combination of inputs, $x_k$= virtual input combination ($\because e\,\lambda = 1$ and$\lambda \ge 0$), $Y\,\mu$ = actual convex combination of outputs, and$y_k$ = maximum virtual output. This model will be used for the determination of technical efficiency of the different small tea plantations.

Finally, one important aspect to be considered at the time of model selection is the selection of input and output items along with the number of DMUs. To obtain meaningful results, a rough rule of thumb is

$$\text{Number of DMUs} > \max\{(\text{inputs} * \text{outputs}), 3 * (\text{inputs} + \text{outputs})\}$$

## IV. DATA AND VARIABLES

The data for the study are primary data collected from five locations where there has been high concentration of STGs. These include Chopra region of Uttar Dinajpur district and the Fatapukur, JahuriTalma, Helapkri-Bhotpatti and the Panbari regions of Jalpaiguri district. The method of sample drawing in the study region was designed to be cluster sampling where clusters consisted of these locations of tea smallholders. This sampling method permits us to draw sample randomly when no single list of population members exists, but local lists do exist. In the context of the present study, it is important to mention that in the absence of any complete enumeration survey undertaken either by the TBI or the State Government, no single exhaustive list of STGs in the region was available with the government departments. Only local lists of growers are available with primary producers' societies (PPSs) or self-help groups (SHGs) operating in different tea smallholding sub-regions. Due to this problem, the method of cluster sampling has been used for the collection of data from the survey respondents. In the context of the present study, the application of this method consists in drawing a random sample from a local list of growers who are enrolled with PPSs or SHGs. A total sample size of 78 STGs was used for the final analysis.

Small tea plantations employ multiple inputs to produce single output. The output is measured by the yield of green leaf in kg. The inputs used in the estimation of TE are categorised into two groups: (a) economic inputs like area under tea, irrigation, different items of fertilizers, labour days employed etc, and (b) inputs of soil condition parameters like soil pH value, soil electrical conductivity etc. One output and fifteen input variables are used in the study. The summary statistics related to the variables under study are depicted in Table 1.The table reveals that the size of mean land holding is 3.96 acre per grower, which means that green leaf production is mainly on a small-scale in the study area. The growers used an average 1465 labour days in their plantations for all the production operations. This is quite high and it shows the labour-intensive nature of tea growing activity. It is to be noted that this figure is inclusive of use of family labour. The table further reveals that there is a substantial difference in economic input usage across the growers, as for example, in the use of inorganic fertilizers. However, the difference is of relatively lower magnitude in so far as the soil related inputs are concerned. This is plausibly indicative of the fact land area converted to tea plantation are more or less of similar characteristics.

**TABLE I**
**Summary Statistics of Variables**

| Variables | Minimum Value | Maximum value | Sample Mean | Std. Deviation |
|---|---|---|---|---|
| **Output variable** | | | | |
| Green Leaf (in kg.) | 499.50 | 115000.00 | 22650.92 | 23746.98 |
| **Input variable** | | | | |
| **Economic input** | | | | |
| Tea Area (acre) | 0.50 | 20.00 | 3.96 | 4.00 |
| Irrigation (hours) | 0.00 | 1150.00 | 144.06 | 264.90 |
| Nitrogen fertilizer (kg) | 50.00 | 7200.00 | 1108.86 | 1267.04 |
| Potash Fertilizer (kg) | 35.00 | 3600.00 | 593.96 | 690.89 |
| Phosphate fertilizer (kg) | 0.00 | 4000.00 | 450.86 | 605.53 |
| No. of plants | 3000.00 | 106800.00 | 22721.65 | 22642.22 |
| Labour days employed in a plantation | 24.00 | 6300.00 | 1465.21 | 1320.78 |
| Foliar nutrients and pesticides | 1.00 | 110.00 | 17.80 | 19.31 |
| Cow dung manure | 1.00 | 450.23 | 55.24 | 77.93 |
| **Soil related input** | | | | |
| Soil pH value | 3.02 | 5.34 | 4.29 | 0.48 |

| | | | | |
|---|---|---|---|---|
| Soil electrical conductivity | 0.01 | 0.26 | 0.07 | 0.05 |
| Soil potash content | 9.03 | 113.70 | 36.70 | 21.46 |
| Soil phosphorus content | 4.80 | 32.79 | 17.14 | 6.86 |
| Soil sulphur content | 7.86 | 45.17 | 22.95 | 7.72 |
| Soil nitrogen content | 0.01 | 0.15 | 0.08 | 0.03 |

Source: Field Survey

## V. DEA RESULTS

It has already been described in the model specification section that an output-oriented BCC model is used to estimate the technical efficiency of the small tea plantations in the study locations. The descriptive statistics for TE scores are presented in Table 2 below.

**TABLE II**

**Descriptive statistics for TE Scores**

| Statistics | Value |
|---|---|
| Minimum TE (%) | 24.67% |
| Maximum TE (%) | 100% |
| Mean TE (%) | 84.50% |
| Std. Deviation (%) | 21.30% |
| Range | 75.33% |

Source: Field Survey

The table contains the summary statistics of estimated TE scores pertaining to STGs included in the sample. It can be observed that TE varies in wide range in which the minimum technical TE recorded is 24.67% while maximum TE is 100 %.The mean TE of the DMUs is estimated to be 85%which is quite an impressive figure. This indicates that, on an average, there is a possibility of 15% potential yield improvement in this sector. In other words, this essentially means that if 47% of the inefficient gardens can increase their yield by grossly 15%, they are capable of achieving the efficiency level of best performing gardens.

The frequency distribution of TE measures has been presented in the following table.

**TABLE III**

**The Percentage ranges of technical efficiency frequency distribution**

| TE Range (%) | % Distribution of Gardens |
|---|---|

| | |
|---|---|
| 20−29 | 1.28 |
| 30−39 | 2.56 |
| 40−49 | 7.69 |
| 50−59 | 6.41 |
| 60−69 | 3.85 |
| 70−79 | 7.69 |
| 80−89 | 14.10 |
| 90−100 | 3.85 |
| score of 100 | 52.56 |

Source: Field Survey

A perusal of Table 3 reveals that about53% of DMUs are found to be technically efficient with scores of 100%. They represent the best performing gardens within the sample. However, with the fixing of cut-off score for efficient DMUs to be 90% or more, the percentage of efficient DMUs improves to 57%. The justification for this flexible criterion, as argued by Ferreira (2005), is to avoid comprising the analysis through a DMU that stand outs as being outlier rather than for its true relative efficiency. Data recording errors and external factors are largely attributed for this flexibility. Looking at the cumulative percentage, it can be seen from the table that 78% of the DMUs within the sample are operating above 70% efficiency level. This is clearly an indication of impressive productivity performance of the sector. The percentage of technically inefficient DMUs is observed to be47% % with a TE score of less than 100%. However, only 12% of DMUs belong to the least efficient group with a TE score of less than 50%.Since the model fitted has an output-orientation, it could be inferred that the inefficient DMUs could potentially improve their yield while leaving their current input usage level unchanged.

A good proportion of DMUs with an efficiency score of 100% in DEA study clearly proves the contention of the study that the proliferation process of STGs has been driven and subsequently, accelerated by the higher rate of productivity, and hence a larger prospect of profit, that this emerging sector is capable of generating. There seems to be two-fold reasons for achieving higher technical efficiency gains − land productivity and bush productivity. In terms of land productivity, the reasons for efficiency gains seem to be the transformation of high fallow land into tea which is not a remunerative land use option for cultivation of paddy due to low rate of yield. The second source of efficiency gain is plausibly high bush productivity due to young age profile of existing tea bushes in small tea plantations. Another reason is perhaps the extensive use of cost –efficient cloned tea saplings which provides higher yield compared to seed stocks.

Mean efficiency scores for growers under different holding sizes are shown in the following table

**TABLE IV**

**Mean TE Score as per size class of plantations**

| Plantations by holding sizes | Mean Score | Std. Deviation |
|---|---|---|

| | | |
|---|---|---|
| Up to 2 acre | 77.94 | 23.45 |
| above 2 and below 4 acre | 85.51 | 23.16 |
| 4 and below 6 acre | 92.91 | 12.39 |
| 6 and below 10 acre | 87.45 | 18.35 |
| 10 and below 25 acre | 96.34 | 9.69 |

Source: Field Survey

From the above table it appears that the bottom class (i.e., up to 2 acre) is least efficient (about 78%), whereas top size class (i.e., 10 and below 25 acre) is most efficient (about 96%). Moreover, with the exception of the holding size '6 and below 10 acres', the average TE score increases with the increase in size class of land holdings. This seems to indicate a pattern of how the improvement of share of efficient DMUs is linked to a certain optimum class of land holding for attaining maximum efficiency gain.

**Sources of Technical Inefficiency**

From our DEA analysis, it appears that a noticeably large proportion of STGs are operating at a below optimal efficiency level. The examination of DEA results, which are not presented in details due to paucity of space, helps identifying some important sources of such inefficiencies. The results show that a number of DMUs had used many economic inputs such as fertilizer and foliar nutrients, as for example, more than what is required for optimum level of necessity. This above optimal level of use of such inputs, therefore, enhances the cost substantially without effectively contributing to production. One of the observations during our field survey may also be helpful to understand the situation of inefficient DMUs. It has been observed that many of the small tea growers are traditional paddy cultivators without having any experience in tea production. Because of their lack of training and experience, they are quite unaware of scientific farm management practises. This has probably prevented them from running their production operation in an efficient manner. Secondly, the DEA analysis shows that the mean TE score is lest for the category 'up to 2 acre'. Thus, this category has a relatively large number of inefficient DMUs compared to other four categories. This is perhaps the category where there is remarkably a large concentration of growers who have virtually been forced to switch from paddy cultivation to tea. The reason for this is that as tea plantation requires draining off excess water from the land, digging up high drainage trenches is absolutely necessary for tea plantation. But, it causes draining off water from adjacent land too making these tracts unproductive for traditional crop cultivation. Thus, the deep tranches that were cut to drain water on new plantations lowered the water table in surrounding farmlands, forcing other farmers to sell or transfer their holdings. It is this adverse ecological impacts of land-use transformation process, which have made their land unsuitable for both tea and paddy cultivation. This might have forced a large number of DMUs to function inefficiently, despite their sincere attempt to run their production operation in an efficient manner.

## VI. CONCLUSION

The study has revealed that there is ample potential for increasing yield for all size classes of plantations in the tea smallholding sector of North Bengal by approximately 15%. The scope for potential yield-gain is much higher for the bottom class (i.e., up to 2 acre) of STGs which turns out to be 22%. An important source of the yield gap problem is perhaps the set of factors relating to land suitability which are either in excess of or lower than what is optimally required for tea growing. The land suitability problem seems to be more pronounced for that class of growers who have converted their paddy land into tea plantations in the latter periods of the process of proliferation. It is important to mention here that an earlier study of the author )Majumdar, 2008) has identified soil potash content and soil electrical conductivity as most significant variables influencing the yield of green tea leaf. Thus, unless land has been made suitable to the required level by the application of proper agronomic practises, the efficiency performance cannot be improved upon even using high doses of other economic inputs. If this problem is given due attention, the yield gap problem could be mitigated.

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