Chapter 5

Examining DEA Scale Efficiency and Returns-to-Scale for Small Tea Plantations in North Bengal

5.1. Introduction:

The empirical work carried out in this chapter is, in fact, the continuation of the empirical exercise done in the previous chapter where an attempt was made to locate the inefficient gardens and also the factors contributing to their inefficiency. Because of the use of BCC model in the previous chapter, the sources of inefficiencies are to be interpreted in terms of inefficient operations of STGs resulting from over or under optimal utilisation of productive factors for producing output. This source of inefficiency is called pure technical inefficiency as it is obtained using BCC model of DEA. Along with this, we can also identify another source of inefficiency that might result from the inappropriate size of gardens under STGs. This second source of inefficiency is referred to as scale inefficiency. For its detection, we need to compute the CCR efficiency scores, besides the BCC efficiency scores. This is because of the fact that an efficiency score obtained using the CCR-model will comprise both scale efficiency and technical efficiency. Thus, in a case where a DMU is found to be inefficient, the researcher would be interested in decomposing this total inefficiency to see in what degree this is due to scale inefficiency or pure technical inefficiency or both. This is what we attempt to do in this chapter− the decomposition of overall inefficiency into the components of pure technical inefficiency and scale inefficiency. In addition, we also attempt to determine the nature of returns-to-scale so as to see whether the STGs are operating under constant returns to scale (CRS), increasing returns to scale (IRS) or decreasing returns to scale (DRS). This examination is needed in order to gain insight into the nature of production and cost economics inherent to this sector.

5.2. Estimation of Scale Efficiencies−The Theoretical Framework

As mentioned above, the inefficiencies of a decision-making unit (DMU) can result from two main sources: one is the inefficient operation of the DMU in implementing its production plan and the other is the divergence of a DMU from the appropriate plant size as it is more technically called most productive scale size (MPSS) in the DEA literature. It is to be noted here that the source of scale inefficiency is largely considered to be the non-conducive conditions confronting a DMU in carrying out a production operation. Examples include constraints on availability of land, constraints on access to finance etc. Among these two main sources of inefficiency, the former is called pure technical inefficiency while the latter scale inefficiency. The CCR and BCC efficiency scores could be used to gain insight into these two main sources of inefficiency. We know CCR model assumes constant returns to scale (CRS), whereas BCC assumes variable returns to scale (VRS). Though both models estimate the technical efficiency (TE), CCR actually gives the global TE. BCC model, on the other hand, being able to incorporate the observed DMUs in a production possibility set with the convexity property, gives local pure TE. This carries the implication that a CCR efficient DMU must operate globally such that it is scale efficient as well as pure technically efficient (PTE). The requirement for a BCC efficient DMU, on the other hand, is that it is only locally technically efficient. A DMU that is fully efficient (score of 1) in both under CCR and BCC is to be considered as operating at most productive scale size (MPSS), that is to say, at an input-output combination with the maximum average productivity. However, if a DMU is fully efficient under BCC considerations but having low score under CCR then the DMU is actually operating efficiently locally but not globally.

The interpretations of the CCR and BCC scores as given above allow us to measure scale efficiency of a DMU by the ratio of two scores. Accordingly, we can write

$$\text{Scale Efficiency } (SE_k) = \theta^*_{k,C} / \theta^*_{k,B}$$

where $\theta^*_{k,C}$ and $\theta^*_{k,B}$ are CCR and BCC scores of a DMU k. Thus, we see that, the key to determine a measure of scale efficiency is to make a comparison between the technical efficiency scores obtained under the alternative assumptions of constant returns to scale (CRS) and variable returns to scale (VRS) of production technology, respectively.

From the scale efficiency formula, we obtain

$$\theta^*_{k,C} = \theta^*_{k,B} * SE_k$$

This says that a measure of overall TE (OTE) of DMU k may be split into pure technical efficiency and scale efficiency

Technical Efficiency (TE) = Pure Technical Efficiency (PTE) * Scale Efficiency (SE)

This formulation helps identify the sources of inefficiency as it is mentioned above– either caused by inefficient technical operation or by non-attainment of MPSS due to the presence of avourable conditions. This decomposition of TE into the components of PTE and SE is explained graphically in the following figure

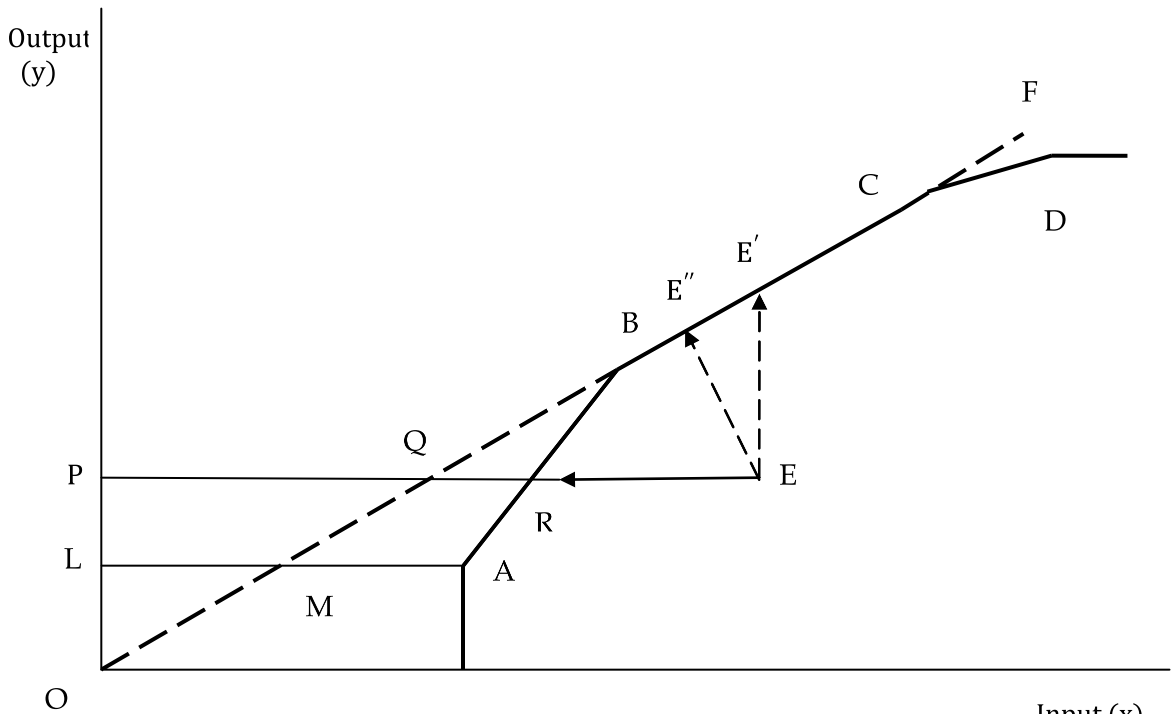

Figure 5.1 Scale Efficiency

In the above figure, the observed input-output bundles (x, y) are given for six DMUs, namely, A, B, C, D, E and F. The BCC efficient VRS frontier and the CCR efficient CRS frontier are shown as ARBCD and OQBCF, respectively. We consider the output-based measure of efficiency for our analysis.

Let us now consider the measure of scale efficiency of a DMU such as A which is on VRS frontier but being positioned below the CRS efficient frontier, is CCR inefficient. It, therefore, explains that A is operating efficiently locally but not globally due to scale inefficiency which is given by $\frac{\mathrm{LM}}{\mathrm{LA}}$. The same explanation applies for DMU D. Now we observe that DMU B and C are operating at the MPSS as those are both positioned on CRS as well as VRS frontier. Hence, these DMUs are fully scale efficient.

In case of DMU E, which is being neither CCR efficient nor BCC efficient, it's CCR score is $\frac{PQ}{PE}$ (TE) and BCC score is $\frac{PR}{PE}$. Therefore, as we described above, the SE for this DMU is obtained as

$$SE = \frac{PQ/_{PE}}{PR/_{PE}} = \frac{PQ}{PR}$$

Hence, $$\frac{PQ}{PE} = \frac{PQ}{PR} \times \frac{PR}{PE}$$

or Technical Efficiency = (Pure Technical Efficiency) × (Scale Efficiency)

This decomposition explains how much of the overall inefficiency of DMU 'E' is caused by inefficient operation and how much is caused by inefficiency due to scale.

To sum up, the use of the CCR efficient CRS frontier will result in measures of TE confounded by scale efficiencies (SE). By contrast, the use of the VRS frontier permits the calculation of TE devoid of these SE effects. Thus, the SE can be calculated by estimating TE scores for both the CCR and the BCC models and looking at the ratio of two scores.

5.3. Measuring Returns to Scale

The estimation of SE is needed in order to examine whether the inefficiency of a DMU results from its actual size being different from the MPSS. If $SE_k = 1$, it can be supposed that the DMU k is operating at the most efficient scale size, or to put alternatively, the DMU k operates at constant-returns-to scale (CRS). If $SE_k < 1$, this means there is scale inefficiency for the DMU k in terms of its deviation from MPSS. Thus, $(1-SE_k)$ gives us a measure of scale inefficiency of DMU k (Banker et al., 1984; Banker and Thrall, 1992; Banker et al., 1996). However, for a DMU that is not MPSS, the scale efficiency score does not indicate any thing about the nature of returns to scale, that is to say, whether the DMU k is operating under the conditions of decreasing returns-to -scale (DRS) or increasing returns-to-scale (IRS). Decreasing returns-to-scale (also known as diseconomies of scale) means that a DMU is too large to take full advantage of scale economies and has above-optimum scale size. In contrast, a DMU experiencing increasing returns-to-scale (also known as economies of scale) is too small in its scale of operations and, thus, operates at below-optimum scale size. The method to be followed for the determination of the nature of returns to scale is outlined below

Consider the following input-oriented CCR model for a representative DMU k

$$\text{Min } \theta$$

$$\text{s.t}$$

$$\sum_{j=1}^{N} \lambda_j x_{ij} \leq \theta x_{ik} \ (i=1, 2\cdots,n)$$

$$\sum_{j=1}^{N} \lambda_j y_{rj} \geq y_{rk} \ (r = 1, 2 \cdots, m)$$

$$\lambda_j \geq 0 \ (j = 1, 2, \cdots\cdots, N); \ \theta \text{ unrestricted}$$

where x_{ik} = amount of input i used by DMU k

y_{rk} = amount of output r produced by DMU k

m = the number of outputs

n = the number of inputs

N = the number of DMUs

λ_j's = the weights assigned to the individual input-output bundles, and

θ = a scalar

Suppose that the optimal solution for this problem is (θ^*, λ^*). Once the optimal values of λ's are known, the nature of returns to scale can be determined as follows:

i) If $\sum_{j=1}^{N} \lambda_j^* = 1$, the DMU k is said to operate under locally CRS;

ii) If $\sum_{j=1}^{N} \lambda_j^* < 1$ at all optimal solutions, the DMU k is said to operate under locally IRS;

iii) If $\sum_{j=1}^{N} \lambda_j^* > 1$ at all optimal solutions the DMU k is said to operate under locally DRS;

5.4 Empirical results

This section deals with empirical investigation of scale efficiency issue pertaining to small tea growers (STGs) of North Bengal. This has been done using efficiency scores obtained from CRS and VRS DEA models. In addition, DEA results on returns-to-scale are also examined at length. The original calculation is shown in the Appendix of this chapter. We present here only the relevant summary tables.

5.4.1. Scale Efficiency Results

The frequency distribution of SE scores are presented in the following table

Table5.1. Distribution of Scale Efficiency

Scale Efficiency Range (%)	Distribution of Gardens (%)
20-29	1.61
30-39	0.81
40-49	4.84
50-59	2.42
60-69	0.81
70-79	7.26
80-89	12.90
90-99	21.77
score of 100	47.58

Source: *Survey Data, 2007-08*

It can be observed from the above table that nearly half of the DMUs (around 48 percent) are fully scale efficient as they operate with SE score of 100 percent. As the average productivity of each of these units is maximised, they are said to be operating at MPSS. What this result transpires is the ability of a high percentage of plantation enterprises to choose the optimum scale of operation. It can also be seen that a good proportion of DMUs, around 22 percent, are operating with SE scores that range between 90 percent and 99 percent. Taking cumulative percentage, we can see from the table that approximately 70 percent of the DMUs within the sample are operating with 90 percent level of SE or above. The percentage of DMUs which are operating with SE scores in the range of above 50 percent and below 90 percent can be estimated to be around 23 percent. Finally, the percentage share of gardens operating with below 50 percent SE score is observed to be as low as only 7 percent. Thus, for a considerable number of DMUs, scale inefficiency, being measured by the divergence of a DMU from the MPSS, appears to be a major source of inefficiency. However, it remains to be examined the extent of scale inefficiency for the DMUs on an average.

5.4.2. Decomposition of TE: PTE and SE

The average scores of different efficiency measures are shown in the following table

Table5.2. Average Scores of Different Efficiency Measures

Type of Efficiency	Minimum (%)	Maximum (%)	Average Efficiency (%)
CCR	25.00	100	82.00
BCC	33.00	100	92.00
Scale efficiency	25.00	100	89.00

Source: *Survey Data, 2007-08*

From our empirical analysis, CCR and BCC scores have been estimated to be 82 percent and 92 percent, respectively. The BCC score is found to be higher than the CCR score. This is because of the fact that the BCC model calculates TE without any consideration of scale inefficiencies whereas the calculation of TE in the CCR model is inclusive of scale inefficiencies. Using CCR and BCC efficiency scores together, we can separate TE into the categories of PTE and SE. The difference between CCR and BCC efficiency scores suggests that there is scale inefficiency. The magnitude of scale inefficiency can be estimated to be (100−SE) = (100−89) % = 11 percent. This suggests that, on an average, the actual scale size of a DMU is smaller or greater than the most efficient plant size to the tune of about 11 percent. Besides scale inefficiency, there is another source of inefficiency which is attributable to pure technical inefficiency. As the BCC score indicates, it is of the magnitude of (100−92) % = 8 percent which is quite low. As shown in the above table, the different efficiency measures vary widely between maximum and minimum scores. This result points to the fact that there is large asymmetry among the individual STGs as regards their attainment of efficient level of production vis-à-vis scale size. It, therefore, appears from our analysis that the STGs under study are faced with the problems of both pure technical inefficiency and scale inefficiency in running their gardens. Among these two sources of inefficiency, the magnitude of scale inefficiency (about 11 %) is found to be larger than pure technical inefficiency (about 8%).

An inspection of table5.2 reveals that mean SE for STGs is quite high being 89 percent. The reason for this, as noted earlier, is the attainment of SE score in the range 90%−100% by around 70 percent of the total DMUs in the sample. Likewise, the average BCC efficiency score is also appreciably high being 92 percent. The robust average index for both SE and BCC measures is clearly indicative of an overall high level of productivity performance of the STGs included in the sample.

5.4.3. Nature of returns to Scale

One shortcoming of the SE measure is its inability to indicate whether the DMU is functioning under the IRS or DRS. This can be determined from the magnitude of optimal $\sum_{j=1}^{N} \lambda_j^*$ in the CCR model as outlined in section 4. The following table shows the break up DMUs under different forms of technology

Table5.3. Description of technology

Type of technology	Pure technical and scale efficient (%)	Pure technical efficient (%)	Neither pure technical nor scale efficient (%)
CRS	100	0	2.78
IRS	0	100	75
DRS	0	0	22
% of gardens	41.94	29.03	29.03

Source: *Survey Data, 2007-08*

As seen in the table, about 42 percent of the STGs are both pure technical and scale efficient, about 29 percent of the STGs are PTE only, and another 29 percent of the DMUs are neither pure technical efficient nor scale efficient. As expected, CRS prevails for all DMUs that are both PTE and SE. However, all the DMUs experiencing PTE only show IRS. The DMUs that are neither pure technical nor scale efficient come under all forms of technology− about 3 percent of them are operating under CRS, 75 percent of them are experiencing IRS, and 25 percent of them are subject to DRS. It, therefore, appears that about 58 percent of the DMUs are subject to experiencing scale inefficiency. It is also important to see that the only DMUs that are experiencing DRS are both technical and scale inefficient.

The preceding analysis, therefore, helps identify inappropriate size of STGs as a major cause of inefficiency. More specifically, it indicates two possible reasons for scale inefficiency. First of all, a notably large number of DMUs are operating under IRS and, therefore, be of sub-optimal scale size. Secondly, a smaller fraction of DMUs are operating under DRS and, therefore, be of above-optimal scale size. Besides scale efficiency, there is another source of inefficiency which is attributable to supervisory underperformance as indicated by BCC score.

Finally, we present below the overall distribution of DMUs under various descriptions of technology

Table 5.4. Description of the Technology

Categories	percentage of Gardens	Range of land area (in acre)
Constant returns to scale	41.94	0.67 to 24
Increasing returns to scale	51.61	0.76 to 18
decreasing returns to scale	6.45	6 to12

Source: *Survey Data, 2007-08*

The results displayed in the above table indicate that about 52 percent of the STGs are under IRS, 6 percent of the STGs are operating under DRS, and 42 percent of the STGs are under CRS and operating at MPSS. Thus, about 52 percent of the STGs are operating at below their optimal scale size and thus, exhibiting IRS. These gardens can increase their average productivity through an expansion in terms of size. In contrast, about 6 percent of STGs are operating at above MPSS and hence, displaying DRS. The downsizing of these gardens is required for achieving efficiency gain.

5.4.4 Gain in Cost Economics

From the above table, we see that about 42 percent of the STGs are operating at MPSS which corresponds to CRS. At MPSS, the average productivity of a DMU is maximised. As maximizing the average productivity is the same as minimizing the average cost, a DMU operates at minimum point of its long-run average cost curve at MPSS. The running of tea plantations under CRS technology has, therefore, an important economic implication that production operation is carried out at least cost. In addition, the above table indicates that about more than half of the STGs (52%) are operating under IRS. These STGs are, thus, operating under decreasing cost conditions. By increasing the scale size of the input and output bundles, they can increase their average productivity and reduce their cost further. In the aggregate, 94% of the STGs are operating under decreasing or minimum cost conditions. Only a relatively smaller proportion of STGs (6%) have been facing increasing cost conditions.

The principal factor contributing to cost efficiency gain of this sector seems to be its peasant mode of production organization. A salient feature characterizing this production organization is labour flexibility because of existence of factors like heavy dependence on use of family labour, very little existence of permanent labour force outside family labour, the unorganized nature of work which does not come under the domain of the labour laws such as the Plantation Labour Act (PLA) and the use of piece rate contracts for labour deployment. This labour flexibility is likely to provide them with ample scope for cost saving in production. It has been reported in a study that labour is found to be the most important item, with an average share of 46 per cent, in the cost of production structure of a small tea grower, besides manure, fertilizers and pesticides (Sarkar, 2008). This beneficial cost economics characterizing a sizeable number of DMUs might play the role of a ‘pull factor” behind the rapid spurt of small tea gardens in North Bengal.

In our data set, the minimum size of land holding is 0.67 acre while the maximum one is 24 acre. The results exhibited in the table reveals that the prevalence of a particular form of returns-to-scale is not linked to a certain optimum size of land holding as it varies in wide range for each description of technology. This is perhaps indicative of independence of land holding size with efficient functioning of smallholding tea plantations. Whatever be the size class of land well within the officially fixed limit of 25 acres, each plantation enterprise is potentially subject to experiencing maximum efficiency gain.

5.5 Conclusion

The results of the study reveal the existence of scale inefficiencies along with pure technical inefficiencies in smallholder tea plantation sector in North Bengal. The scale inefficiency problem has been found to be persisted with relatively larger degree than the pure technical inefficiency problem. Even if these problems exist, neither of them has been observed to be of very high magnitude. The average scale efficiency score has been worked out to be of the order 89 percent which implies a scale inefficiency score of 11 percent. On the contrary, the mean pure technical efficiency score has been figured out to be 92 percent which implies pure technical inefficiency score of 8 percent. Thus, the magnitudes of both forms of inefficiency appear to be quite low. This seems to suggest that neither pure technical inefficiency nor scale inefficiency does constitute any major constraint for the efficient functioning of small tea plantations at large.

There seems to be two-fold reasons for having higher PTE and SE scores and therefore, achieving higher overall technical efficiency gains. These are higher land productivity and bush productivity. In terms of land productivity, the reasons for efficiency gains seem to be the transformation of high fallow lands into tea which were not a remunerative land use option for cultivation of paddy due to low rate of yield. Another reason is perhaps the extensive use of cost –efficient cloned tea saplings which provides higher yield compared to seed stocks. The second source of efficiency gain is plausibly high bush productivity due to young age profile of existing tea bushes in small tea plantations.

The DEA results concerning returns-to-scale indicate that a vast majority of DMUs, whether or not efficient, are capable of operating under decreasing or minimum cost conditions and a relatively smaller proportion of DMUs have been facing increasing cost conditions. It is perhaps these efficiency gains in terms of cost saving that could perhaps be considered as a major "pull factor" contributing to proliferation of STGs in this region.

The result relating to effect of size of landholding on the productivity performance of STGs in the sample is not found significant. Irrespective of the size class of land, about 94 percent of STGs are operating under conditions of either CRS or IRS. This provides ample proof to assert that the land-use change from paddy cultivation to tea plantation has driven and subsequently, accelerated by the higher rate of productivity, and hence a larger prospect of profit, that this emerging sector can potentially generate. Thus, the introduction of growing tea on small and uneconomic agricultural land holdings can be seen to appear as a viable as well as profitable alternative model of farming for a vast majority of erstwhile crisis-ridden peasant cultivators in the study region.