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Performance Measurement and Benchmarking of Indian Tea Industry Using Non-parametric Model Data Envelopment Analysis

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Abstract

In this paper, we have undertaken a study to analyze the efficiency of the Indian tea industry and its technical and allocative efficiency using a specialized model of data envelopment analysis (DEA) which identifies the factors causing technical and allocative inefficiency of tea industry as well as show the robustness of technical efficiency estimates with respect to functional form specification. The Decision Making Units (DMU's) i.e. the tea farms were selected from Assam, West Bengal. They were then defined and refined by establishing the important parameters and identifying the key decision variables. Data was collected form 38 tea farms and by analysing the data we found that, 7 out of 31 DMU's were efficient. The efficient DMU's acted as a reference set for the inefficient ones. Thus, having a serious managerial implication for the inefficient DMU's to benchmark the efficient one's and to adapt an optimal path for improvement in their performance.

Keywords

Data envelopment analysis, efficiency measurement, tea industry

Introduction

The major driving force behind the country's tea sector growth is the prospect of India's tea industry, particularly of Assam which not only produces around 53% of the country's total production, but also employs more than 10% of the state's work force or around 12 lakh people. However, the share of Assam in the country's tea production in course of last three-and-half decades has remained confined to a narrow range from 51% in 1970-71 to 53% in 2003-04 due to decline in per hectare productivity though the area under the plantation rose from 182 thousand hectares to 280 thousand hectares in the period with the number of tea estates rising from just 750 to as many as 32,000. Thus our tea exports as proportion to production has declined from 24% in 1998-99 to 15% in 2005-08, though it was 25% in the previous year.

Farm or tea estate efficiency and the question of how to measure it, is an important subject in developing countries (Shah, 2005; Hazarika and Subramanian, 1999). There are four major approaches to measure efficiency (Coelli et al., 1998). These are the non-parametric programming approach (Charnes et al., 1978) the parametric programming approach (Aigner and Chu, 1968; Ali and Chaudry, 1990) the deterministic statistical approach (Afriat, 1972; Schippers, 2000; Fleming et al., 2004). Among these, the stochastic frontier and non-parametric programming, known as Data Envelopment Analysis (DEA), are the most popular approaches. Hazarika and Subramanian (1999) have estimated the technical efficiency of tea industry in Assam using the stochastic frontier production model. Their study concentrates on the productivity and production factors only. Mahesh et al. (2002) analyzed the technical efficiency of Indian tea production and concluded that there existence was a good scope for improving tea productivity with the proper allocation of existing resources. Ariyawardana (2003) examined the sources of competitive advantage and studied how it was related to the performance of the tea growers in Sri-Lanka. His study provided a deep understanding of this issue from the management point of view but failed to focus on the efficiency of tea industries. Mahmud (2004) observed that the demand of tea in the market of Bangladesh was increasing 3.5 % each year and the supply of tea was increasing only by 1% each year. Haque (2006) explained the possibility of alliance among the closely located tea gardens situated in the South-eastern part of Bangladesh. None of the above studies uses the DEA technique to evaluate the performance and there is no international comparison till date. Furthermore, these studies do not adopt with a stochastic frontier analysis for the productivity and efficiency measurement of tea industry, which is generally thought as an essential analytical analysis for tea industry. The stochastic frontier production function postulates the existence of technical inefficiencies of production of firms involved in producing a particular output. Most theoretical stochastic frontier production functions have not explicitly formulated a model for these technical inefficiency effects in terms of explanatory variables. So far little rigorous work has been undertaken to study quantitatively the efficiency levels of existing tea production in India relative to peers with a purpose of identifying ways of improving tea farms performance.

The problems of high cost production and stagnant productivity, needs to be addressed on an urgent basis. In this paper, we have undertaken studies to analyze the efficiency of tea industry and its technical and allocative efficiency using a specialized model of data envelopment analysis which identifies the factors causing technical and allocative inefficiency of tea industry as well as show the robustness of technical efficiency estimates with respect to functional form specification.

Our paper is organized as follows: section 2 we discuss the methods and materials, section 3 deals with the DEA analysis and section 4 concludes the paper.

Research Method

Research Questions

Problems	Research Questions	Research Objectives
The intense competition in the international market, rising production costs, declining export and stagnant productivity	What is the efficiency of tea industry in India?	To measure the efficiency of tea estates in India using linear programming DEA. With this we will be able to rank the tea estates
	What is the competitive position of tea estates and their benchmarks?	To identify reference sets and benchmarks for improving the projection of inefficient tea estates.

Table 1: Research problems translated into research objective

Variables Measured

The efficiency of tea estates in Assam and West Bengal has been estimated. With this we are able to rank the tea estates. The factors that affect their efficiency have also been identified. The input variables include farm area, number of tea bushes per farm per year, cost of fertilizer per hectare per year, labor wage rate per man-day in each farm, size of factory (market share / sales level) and output (kgs of made tea).

Methods of Data Gathering

Primary data on the variables to be measured for efficiency has been gathered through personal interviews and secondary sources.A drafted questionnaire for this purpose was presented to the tea farm managers during focus group discussions (FGDs).The purpose of the FGDs is to generate information that will be used to gather accurate data for the variables detected to measure the efficiency. A feasibility study was done by going to a few representative tea estates to data through focus in depth interviews. The research instrument was accordingly modified with the given inputs from the concerned tea estates. The Tea board of India was referred in order to extract the detailed database of different tea companies in India as well as to determine the sample size of the study.

For the tea farms, the points for discussion included the current situation of tea industry and in particular their tea estate; the critical resources and throughput. Secondary data on the variables was collected for the variables detected by FGDs from the tea estates and tea board of India.

The questionnaire was first pre-tested to evaluate its effectiveness. Feedback from the pre-test was used to revise the questionnaire. The enumerators were tea garden managers, labor heads, brokers and professional tea testers at the main public auction center of Assam and Darjeeling.

The core of the fieldwork was conducted in Assam and West Bengal. The resource and throughput data which is secondary data in nature was collected from specific tea estates of large tea estates with factories or production facilities (unit of analysis for *phase 1*). A multi-stage area cluster sampling technique was used to obtain representative cases of the Assam, Darjeeling.

Sampling Procedure

The samples to be drawn from the sampling frame involves use distinctive sampling techniques namely probability sampling and non-probability sampling. In our case, as the samples i.e. the tea estates with indigenous manufacturing units have been drawn from the population under study, which geographically disbursed so cluster sampling is used. In cluster sampling, it is be reasonable to divide the population into certain homogeneous groups known as clusters. As the elements in a cluster are homogeneous, it reduces the statistical efficiency of the study undertaken. However, the statistical inefficiency will balance the cost effectiveness in data collection when we will apply cluster sampling.

The purpose of cluster sampling is to sample economically while retaining the characteristics of a probability sample. In our cluster sample, the primary sampling unit will no longer be the individual element in the population but a larger cluster of elements located in proximity to one another. In our study, we used area sample that is the most popular type of cluster sampling. Ideally, a cluster should be as heterogeneous as the population itself-a mirror image of the population. A problem may arise with cluster sampling if the characteristics of the elements within the cluster are too similar. This problem is mitigated by constructing clusters composed of diverse elements and by selecting a large number of sample clusters.

We know that with the increase in sample size, the chances of sample representing the population will also increase, which in turn will enhance the accuracy of the study. For purposes of efficiency measurement it will be divided into three zones: Assam, Dooars, and Darjeeling. These zones will be the strata of the study. Using cluster analysis we have taken 38 samples.

Data Analysis

Data gathered was cross sectional in nature. The qualitative data was coded in order to transfer the data from the survey to the computer and finally create a data matrix. We used linear programming data envelopment analysis to analyze quantitative data for the first research problem as follows:

Assume that there are n DMUs, each with m inputs and s outputs. We define the set of all DMUs as J^1, $J^1 = \{DMU_j,\ j = 1,\ldots n\}$ and the set of efficient DMUs in J^1 as E^1. Then the sequences of J^l and E^l are defined interactively a where $E^l = \{DMU_p \in J^l \mid \phi_p^l \ge 1\}$, and ϕ_p^l is the optimal value to the following linear programming problem: $\max\limits_{\lambda_j,\phi} \phi_p^l = \phi$

s.t.

$$\sum_{i \in J^l} \lambda_i x_{ji} - x_{jp} \le 0 \qquad \forall j$$

$$\sum_{i \in J^l} \lambda_i y_{ki} - y_{kp} \ge 0 \qquad \forall k$$

$$\lambda_i \ge 0, \quad i \in J^l \ \textbf{(1)}$$

Where, $k = 1$ to s $j = 1$ to $mi = 1$ to n y_{ki} = amount of output k produced by DMUi, x_{ji} = amount of input j utilized by DMUi.When $l = 1$, model (1) represent actual CCR model.The following algorithm accomplishes subsequent stratums.

Step 1: Set$l = 1$. Evaluate the entire set of DMUs, J^1, to obtain the set, E^1, of first-level frontier DMUs (which is equivalent to classical CCR DEA model) i.e. when$l = 1$, the procedure runs a complete envelopment model on all nDMUs and E^1 consists of all of the DMUs on the resulting overall best-practice efficient frontier.

Step 2: Exclude the frontier DMUs from future DEA runs and set $J^{l+1} = J^{l} - E^{l}$.

Step 3: If $J^{l+1} \geq 3(m+s)$ (Banker et al, 1984), then stop. Otherwise, evaluate the remaining subset of 'inefficient' DMUs, J^{l+1}, to obtain the new best-practice frontier E^{l+1}.

Step 4: Let$l = l + 1$ and go to step 2.

Stopping Rule: The algorithm stops when $J^{l+1} \geq 3(m+s)$ .Each efficient frontier or evaluation context $E^{l}\ (l = 1,..., L)$ provides to measure attractiveness score which can be obtained from the following model:

$$\max_{\lambda_j, \phi} \phi_p^{la} = \phi$$

$$\textbf{s.t} \sum_{j \in E^{la}} \lambda_i x_{ji} - x_{jp} \leq 0 \qquad \forall j$$

$$\sum_{i \in J^{la}} \lambda_i y_{ki} - \phi y_{kp} \geq 0 \qquad \forall k$$

$$\lambda_i \geq 0, \quad i \in E^{la} \quad \textbf{(2)}$$

Where $E^{la} \Rightarrow E^{l} \cap E^{a}$

Then $A_p^{la} \equiv 1/\phi_p^{la}$ is called the output-oriented attractiveness of DMU$_p$ from a specific level E^{la} . In model (2), each efficient frontier represents an evaluation context for evaluating the relative attractiveness of DMUs in E^{la} .

When $A_p^{la} > 1$ or larger the value of A_p^{la} , the more attractive DMU$_p$, because DMU$_p$ clearly appears as the attractive option in E^{la} . Eventually, thebest DMU can be identified in E^{la} based upon their attractiveness.

To obtain relative progress score for a specific DMU$_p$ $\in E^{l^\circ}$, $l^\circ \in \{2,..., L\}$, the following model is used:

$$\max_{\lambda_j, \phi} \phi_p^{\lg} = \phi$$

$$\textbf{s.t.} \sum_{j \in E^{\lg}} \lambda_i x_{ji} - x_{jp} \leq 0 \qquad \forall j$$

$$\sum_{i \in E^{\lg}} \lambda_i y_{ki} - \phi y_{kp} \geq 0 \qquad \forall k$$

$$\lambda_i \geq 0, \quad i \in E^{lg} \qquad \textbf{(3)}$$

Each efficient frontier, E^{lg} , contains a possible projection for a specific DMU in E^{l° to improve its performance. For larger $\phi_p^{\lg}$ value more progress is required in contrast to smaller $\phi_p^{\lg}$ value.

The R software was used to program the LP model and analyze the data.

	TGA	FacA	OffA	TotArea	Labour	LabWag	Equipments	Throughput
Max	942.5	10	5.2	1672	3814	89	73	2718173
Min	80	0.3	0.02	81	326	89	5	181487
Average	497.68	3.99	0.57	826.07	1800.68	89	23.86	1175269
SD	226.48	2.19	0.80	409.73	809.58	0	21.46	563556.3

Table 2: Statistics on input-output data

The input data includes TGA (tea garden area), Fac A (factory area), OffA (Office area), number of labours, labour wage, number of equipments and throughput as output. Maximum tea garden area out of 38 gardens was 942.5 hectare. Maximum factory area was 10 sq. m., office are 5.2 sq. m., total area of the garden was 1672 sq. m. Maximum number of labour among the gardens were 3814. Their maximum wage was Rs. 89. Maximum number of equipments used among the gardens were 73 with maximum output of 2718173…..

Minimum tea garden area out of 38 gardens was 80 hectare. Minimum factory area was 0.3 sq.m., office are 0.02 sq. m., total area of the garden was 81 sq. m. Minimum number of labour among the gardens were 326. Their minimum wage was Rs. 89. Minimum number of equipments used among the gardens was 5 with maximum output of 181487 kgs.

Average tea garden area out of 38 gardens was 497.68 sq. m. Average factory area was 3.99 sq. m., office are 0.57 sq. m., total area of the garden was 826.07 sq. m. Minimum number of labour among the gardens were 1800. Their minimum wage was Rs. 89. Minimum number of equipments used among the gardens were 24 with maximum output of 1175269 kgs.

Standard deviation of tea garden area out of 38 gardens was 226.48 sq. m. Average factory area was 2.19 sq. m., office are 0.80 sq. m., total area of the garden was 409.73 sq. m. Minimum number of labour among the gardens were 810. Their minimum wage was Rs.0. Minimum number of equipments used among the gardens was 21 with maximum output of 563556.3 kgs.

In table 3 according to the correlation analysis we find that there is a high positive correlation between TGA (tea garden area) and TotArea (total area), number of labours, equipments and throughput.

	TGA	FacA	OffA	TotArea	Labour	LabWag	Equipments	Throughput
TGA	1	0.51	0.03	0.88	0.71	0	0.74	0.69
FacA	0.51	1	-0.17	0.54	0.57	0	0.39	0.30
OffA	0.03	-0.17	1	0.08	0.05	0	-0.01	0.17
TotArea	0.88	0.54	0.08	1	0.70	0	0.78	0.57
Labour	0.71	0.57	0.05	0.70	1	0	0.42	0.43
LabWag	0	0	0	0	0	1	0	0
Equipments	0.74	0.39	-0.01	0.78	0.42	0	1	0.55
Throughput	0.69	0.30	0.17	0.57	0.43	0	0.55	1

Table 3: Correlation analysis between inputs and output variables

However, there is no correlation between TGA and OffA (office area) and LabWag (labour wage). For the second variable FacA(factory area) we find a mild positive correlation between TGA, TotArea, Labour and equipments. However, there is a negative weak correlation between FacA and OffA. Again there is no correlation between FacA and LabWag. For the third variable OffA, we do not find any significant correlation with any of the variables. For the fourth variable TotArea (total area), we find there is a high positive correlation with TGA, OffA, and equipments. There is mild positive correlation with FacA and throughput. There is no correlation with LabWag. Labour variable has got positive correlation with TGA and TotArea. It has mild correlation with FacA, equipments and throughput. However, no correlation with LabWag. LabWag has no correlation with any of the input and output variables. Equipments have got positive relationship with TGA and TotArea. Mild positive correlation with throughput and low positive correlation with FacA and labour. However, no correlation with LabWag. Throughput variable has got positive relationship with TGA and mild positive correlation with TotArea, Equipment and labour. There is low positive correlation with FacA and no correlation with OffA and LabWag.

No.	DMU	Score	Rank	Reference set (lambda)							
1	Lattakoojan	1	1	Lattakoojan	1						
2	Borjan	0.44	30	Khagorijan	0.4	Dheodaam	0.32	Dehing	0.26		
3	Khagorijan	1	1	Khagorijan	1						
4	Maud	0.15	38	Khagorijan	1						
5	Thanai	0.62	20	Khagorijan	0.5	Dheodaam	0.12	Dehing	0.36		
6	Dikom	0.53	23	Dehing	0.34	Khowang	0.25	Powai	0.39		
7	Sealkotee	0.44	29	Lattakoojan	0.006	Khagorijan	0.66	Dheodaam	0.2	Dehing	0.12
8	Sessa	0.62	21	Khagorijan	0.7	Dehing	0.24	Namroop	0.007		
9	Cornhill	0.37	35	Khagorijan	0.56	Namroop	0.005				
10	Anandbag	0.26	37	Khagorijan	0.72	Dheodaam	0.11	Dehing	0.16		
11	Dheodaam	1	1	Dheodaam	1						
12	Tarajulie	0.73	14	Khagorijan	0.58	Dehing	0.008	Khowang	0.21	Powai	0.19
13	Jamirah	0.45	28	Khagorijan	0.64	Dehing	0.26	Powai	0.004		
14	Ganeshbari	0.43	32	Khagorijan	0.77	Dheodaam	0.003	Dehing	0.21		
15	Dehing	1	1	Dehing	1						
16	Khowang	1	1	Khowang	1						

17	Dilli	0.85	10	Khagorijan	1						
18	Tengpani	0.34	36	Khagorijan	0.74	Dehing	0.006	Khowang	0.16	Powai	0.005
19	Batabari	0.43	33	Khagorijan	0.64	Dheodaam	0.1	Dehing	0.18	Khowang	0.002
20	Teok	0.72	16	Khagorijan	0.51	Dheodaam	0.29	Dehing	0.19		
21	Sagmootea	0.68	19	Khagorijan	0.43	Dheodaam	0.002	Dehing	0.52		
22	Nonoi	0.99	8	Khagorijan	0.14	Dheodaam	0.25	Dehing	0.58	Khowang	0.007
23	Namroop	1	1	Namroop	1						
24	Nahorkutia	0.83	12	Khagorijan	0.79	Dheodaam	0.005	Khowang	0.06	Powai	0.12
25	Nahartoli	0.51	26	Khagorijan	0.5	Dehing	0.5				
26	Nahorani	0.78	13	Khowang	0.43	Powai	0.56				
27	Chabua	0.84	11	Khowang	0.44	Powai	0.55				
28	Rungamuttee	0.72	15	Dheodaam	0.42	Dehing	0.34	Khowang	0.007	Powai	0.21
29	Diffloo	0.52	24	Khagorijan	0.49	Dheodaam	0.23	Dehing	0.27		
30	Kellyden	0.58	22	Khowang	0.12	Powai	0.87				
31	Kakajan	0.49	27	Khowang	0.13	Powai	0.86				
32	Borhat	0.44	31	Khowang	0.79	Powai	0.2				
33	Lamabari	0.52	25	Khagorijan	0.12	Khowang	0.85	Powai	0.007		
34	Hattigor	0.71	18	Dheodaam	0.006	Dehing	0.1	Powai	0.86		
35	Hathikuli	0.39	34	Khagorijan	0.68	Dheodaam	0.16	Dehing	0.15		
36	Achabam	0.87	9	Khagorijan	0.55	Dheodaam	0.006	Dehing	0.36		
37	Bhelaguri	0.71	17	Khagorijan	0.3	Dheodaam	0.006	Dehing	0.62		
38	Powai	1	1	Powai	1						

Table 4: DEA efficiency scores of various tea gardens

Table 4 displays the efficiency scores of various DMUs i.e. the tea gardens. Out of 38 tea gardens 7 tea gardens namely Powai, Laatokojan, Namrup, Khagorijan, Khowang, Dehing, and Dheodam are found to be on the efficient frontier. The most inefficient tea estate is found to be Maud with an efficiency score of 0.15 followed by Anandbaug with a score of 0.26.

The 7 efficient tea estates become the reference set for the rest inefficient tea estates. For instance Nonoi which has an efficiency score of 0.99 has reference set of Khagorjan, Deodham, Dehing and Khowang. It means if Nonoi has to increase its efficiency score to 1 it has to utilize resources similar to the four reference set in order to reach the frontier of score 1.

The graphical representation of the tea estates are shown in fig.1. It can be seen from the figure that the most inefficient tea estate is Ananadbag with a score of 0.26 and refers to Khagorijan, Deodham, and Dehing tea estates.

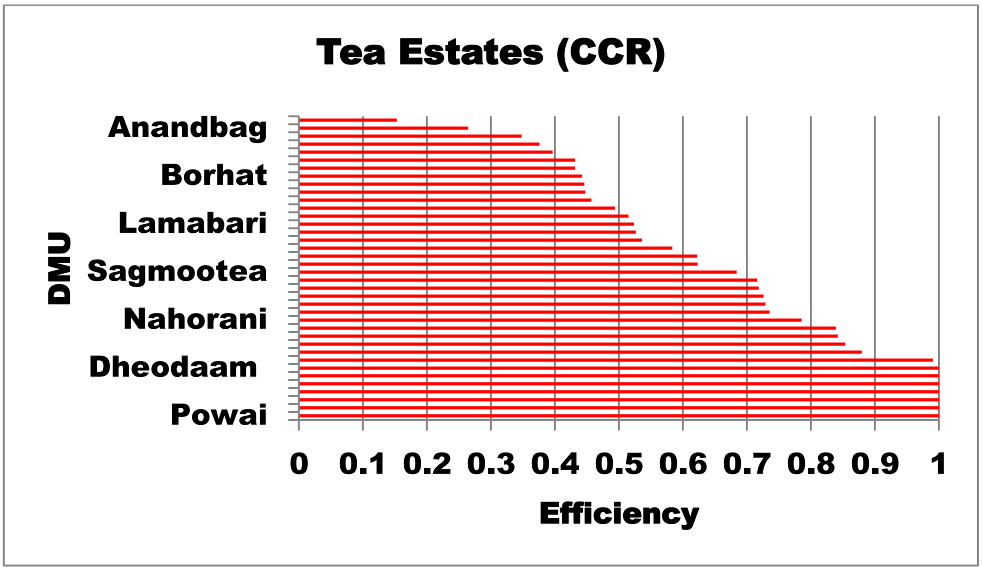

Figure 1: Graphical representation of efficiency scores of the tea estates

Conclusion

The developed methodology will serve as a standard tool to measure efficiency and identify priority variables in a cross sectional point of time. The ability to identify the sources of inefficiency will be useful to tea estate managers of inefficient estates, acting as a guide to focusing efforts at improving estate performance. Identification of scale inefficiency and slacks will help the government to focus on their policy of regulated commodity to improve efficiency.

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