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PERFORMANCE EVALUATION OF MANUFACTURE OF DAIRY PRODUCTS IN INDIA - DEA APPROACH

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Abstract

Performance Evaluation of a set of peer entities/organizations is a vital issue in the modern world. In fact there are many tools for the performance measurement of similar type of organizations out of which Data Envelopment Analysis (DEA) is a most powerful tool. DEA is a non-parametric method for evaluating the relative efficiency of Decision Making Units (DMUs) on the basis of multiple inputs and outputs. In this study we attempted basic models of DEA, namely CCR (Charnes Cooper and Rhodes) and BCC Banker, Charnes and Cooper), for measuring technical efficiency of industrial units relating to manufacture of dairy products in India.

1. Introduction

Data Envelopment Analysis is a non-parametric technique based on linear programming problem used for measuring the relative efficiency of a homogenous set of decision making units in the presence of multiple inputs and multiple outputs. Decision Making Units generally refers to similar type of organizations such as Banks, Hospitals, Schools, Industries etc., which consumes identical inputs and produce identical outputs.

It may be noted that in recent years there has been a lot of interest for

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applying DEA in various fields like Agriculture, Banking, Education, Energy, Marketing etc. DEA also supplies information that warrant the comparison of each in efficient DMU with its "peer group", that is, a group of effificient units that are similar to the units under analysis.

India is the world's largest producer of dairy products and has the world's largest dairy herd. The country contributes to 13% of world's total milk production but consumes almost all of its own milk production hence is the world's largest consumer of dairy products. In the drought-prone and rain-fed areas, dairying has been the activity that alleviates the poverty and unemployment. About three-fourth of the Indian population live in rural areas and in which 38% are poor. Dairy products are a critical source of nutrition and animal protein to millions of people in India. As India was neither an active importer nor an exporter of dairy products, it was hardly noticed by most international dairy companies.

After 2000, Indian dairy products occupied a place in global markets. Milk production in India has developed significantly in the past few decades. A demand supply gap has become imminent in the dairy industry due to the changing consumption habits, dynamic demographic patterns, and the rapid urbanization of rural India despite the increase in production. To match the rapidly growing Indian economy, there is an urgent need for the growth rate of the dairy sector.

Based on the above facts, the author in this study applied DEA for measuring the relative efficiency of manufacturing units of dairy products in India. The paper is organized as follows. In Section 2, the review of literature has been presented. Section 3 and Section 4 deals with the Methodology and Data Structure employed in the study. Empirical Investigations are discussed in Section 5 and the conclusion is given in Section 6.

2. Review of Literature

The basic measure of efficiency in the case of single input and single output was proposed by M. J. Farrel [5]. To deal with the multiple input and multiple output situation, A. Charnes, W. W. Cooper and E. Rhodes [3] developed a model to evaluate the relative efficiency of decision making units based on constant returns to scale (CRS) assumption. Further, R. D. Banker,

A. Charnes, W. W. Cooper [1] extended the CCR model by allowing variable returns to scale assumption. The above research contributed more to the development of basic ideas of DEA. Thanassoulis et al. [11] studied the potential usefulness of DEA involving multiple inputs and multiple outputs. Kornbluth [7] analysed the policy effectiveness of player teams in a business game. Yue [12] discussed the applications of DEA in engineering and the natural sciences.

Many researchers have made significant contributions in the applications of DEA in the various fields. A study measuring the efficiency of higher education institutions from UK universities using DEA was done by J. Johnes [6]. Bassam Adeseit [2] used DEA to study the performance of 120 dairy farms in Jordan using Constant Return to Scale (CRS) and Variable Return to Scale (VRS) DEA models. Elena Toma et al. [4] applied DEA at regional level by using various inputs and outputs to analyse the performance of agriculture practiced in plain, hill and mountain areas. Using DEA, Mostafa Mardani et al. [8] analysed the technical and scale efficiency of potato production in 23 Iranian provinces. The technical efficiency and efficiency differences among 19 Minority Technical Institutions under JNTUH of Telangana in India was measured by R. P. Sreedevi [10] using BCC in DEA. S. Jasmine Rathi et al. [9] analyses the efficiency of rice production in India through DEA.

3. Methodology

Assume that there are n units each consuming m inputs to produce s outputs. Let y_{rj} denote the level of the r^{th} output $(r = 1, 2, \ldots, s)$ from unit $j (j = 1, 2, \ldots, n)$ and x_{ij} denotes the level of the i^{th} input $(i = 1, 2, \ldots, m)$ to the j^{th} unit. Charnes et al. [3] initially developed the following output maximization model with the formation of virtual input (weighted sum of inputs) and virtual output (weighted sum of outputs)

$$Max\ z = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}$$

Subject to

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{irj}} \leq 1; \; j = 1, 2, \ldots, n$$

$$u_r, v_i \geq 0; \; r = 1, 2, \ldots, s; \; i = 1, 2, \ldots, m,$$

where

u_r is the weight of that output

v_i is the weight of that input.

When the above model runs for each DMU it gives the efficiency score and the weights u_r and v_i which leads to efficiency. Charnes et al. [3] brought modifications on the non-negativity constraints $u_r, v_i \geq 0$ through ε and changed it as $u_r, v_i \geq \varepsilon$ where $\varepsilon > 0$ is a non-Archimedean infinitesimal constant.

The above is a fractional linear programming problem and it is difficult to solve. So a transformation proposed by Charnes and Cooper (1962) for fractional programming, converted the above fractional program into following linear programming problem.

$$Max\ z = \sum_{r=1}^{s} u_r y_{rj}$$

Subject to

$$\sum_{i=1}^{m} v_i x_{ij} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0; \; j = 1, 2, \ldots, n$$

$$u_r, v_i \geq \varepsilon; \; r = 1, 2, \ldots, s; \; i = 1, 2, \ldots, m.$$

When the above problem is solved for n times, once for each unit in the sample, it gives the optimal solution (z^*, u^*, v^*). The evaluated DMU is said to be CCR efficient if $z^* = 1$ and there exists at least one optimal (u^*, v^*) with $u^*, v^* > 0$. Otherwise the evaluated DMU is CCR inefficient. This problem is known as a primal problem.

The concept of LPP states that every primal has its own dual. Thus the dual of CCR DEA known as input oriented DEA model is given below

$$Min\ \theta_0$$

Subject to

$$\sum_{j=1}^{n} y_{rj}\lambda_j \geq y_{r0};\ r = 1, 2, \dots, s$$

$$\sum_{j=1}^{n} x_{ij}\lambda_j \leq \theta_0 x_{i0};\ i = 1, 2, \dots, m$$

$$\lambda_j \geq 0;\ j = 1, 2, \dots, n$$

$$\theta_0 \text{ unrestricted (free)}$$

where θ_0 is a scalar λ_j is the weight of the j^{th} DMU.

By solving the above model it gives the efficient score θ^* and DMU weights λ. The evaluated DMU is efficient iff $\theta^* = 1$, $\lambda_j = 1$ for $\lambda_j \neq \lambda_0$ and $\lambda_j = 0$ for all other DMUs. Otherwise the evaluated DMU is inefficient.

The above CCR model has a very strong assumption of constant returns to scale. Many economies viewed this assumption as over-restrictive and so DEA has not received widespread attention for the analysis of production process. By this Banker, Charnes and Cooper [1] introduced another model with the assumption of variable returns to scale known as BCC model. Banker et al. [1] modified the CCR model with the introduction of convexity constraint. This model evaluates the efficiency DMU $j\,(j = 1, 2, \dots, n)$ by solving the following model.

$$Min\ \theta_0$$

Subject to

$$\sum_{j=1}^{n} y_{rj}\lambda_j \geq y_{r0};\ r = 1, 2, \ldots, s$$

$$\sum_{j=1}^{n} x_{ij}\lambda_j \leq \theta_0 x_{i0};\ i = 1, 2, \ldots, m$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0;\ j = 1, 2 \ldots, n$$

θ_0 unrestricted (free) where λ_j is the weight of the j^{th} DMU.

The BCC model is differing from CCR model by the convexity constraint $\sum_{j=1}^{n} \lambda_j = 1$. The convexity constraint gives the frontiers piece-wise linear and concave characteristics which lead to variable returns to scale characterisations.

4. Data Structure

The present study consider the data relating to manufacture of dairy products in India. It is a secondary data taken from Annual Survey of Industries report (ASI) during the period 2016-17. The data matrix includes 26 states in India. Each state is considered as a decision making unit with 3 inputs and 2 outputs pertaining to manufacturing industries of dairy products. Number of factories, number of employees and gross value of addition to fixed capital are treated as input variables, total output and profit are treated as output variables.

The Descriptive Statistics of the input and the output variables are given below

Table 1. Descriptive Statistics.

	N	Mean	Standard Deviation	Minimum	Maximum
IP1	26	72.6154	94.62181	3	339
1P2	26	6584.0000	8181.57819	108	26801
1P3	26	80140.0000	323860.21041	1	1664057
OP1	26	590012.3000	837293.12961	1969	3597116
OP2	26	16240.4200	21615.02773	88	76745

5. Empirical Investigation

Both CCR and BCC models are applied to the data considered in this study and the results are presented in the following table.

Table 2. Efficiency Scores and Peers.

S.No.	DMUs	CRS TE	CRS PEERS AND WEIGHTS	VRS TE	VRS PEERS AND WEIGHTS
1	Andhra Pradesh	0.171	5(1.08) 9(0.62) 25(0.43)	0.831	5(0.57) 15(0.16) 25(0.27)
2	Assam	0.141	5(0.02) 23(0.38) 25(0.01)	0.334	5(0.05) 23(0.94) 25(0.01)
3	Bihar	0.093	5(0.42) 23(0.12) 25(0.04)	0.102	5(0.42) 9(0.05) 23(0.51) 25(0.03)
4	Chattisgarh	0.116	5(0.03) 9(0.13) 25(0.01)	0.374	5(0.35) 9(0.09) 23(0.57)
5	Delhi	1.000	22	1.000	15
6	Goa	0.157	5(0.03) 23(0.08) 25(0.01)	0.950	5(0.20) 23(0.80)
7	Gujarat	0.224	5(6.19) 25(0.75)	1.000	0
8	Haryana	0.249	5(1.50) 9(0.31) 25(0.35)	1.000	0
9	Himachal Pradesh	1.000	13	1.000	7
10	Jammu and Kashmir	0.183	5(0.03) 23(0.50) 25(0.02)	0.256	5(0.03) 9(0.02) 23(0.94) 25(0.01)
11	Jharkhand	0.177	5(0.08) 9(0.22) 25(0.00)	0.381	5(0.35) 9(0.17) 23(0.48)
12	Karnataka	0.260	5(1.78) 9(3.28) 25(0.32)	1.000	0

13	Kerala	0.166	5(0.54) 9(0.77) 25(0.05)	0.177	5(0.54) 9(0.27) 25(0.19)
14	Madhya Pradesh	0.474	5(0.45) 9(4.68) 25(0.15)	1.000	1
15	Maharashtra	0.204	5(3.24) 9(7.43) 25(0.08)	1.000	3
16	Odisha	0.269	5(0.18) 9(0.07) 25(0.29)	0.285	5(0.17) 9(0.09) 23(0.45) 25(0.28)
17	Puduchery	0.075	5(0.05) 25(0.02)	0.605	5(0.98) 23(0.02)
18	Punjab	0.107	5(1.07) 23(0.35) 25(0.13)	0.345	5(0.92) 15(0.05) 25(0.03)
19	Rajasthan	0.219	5(1.16) 9(1.28) 25(0.02)	0.659	5(0.77) 14(0.01) 15(0.12) 25(0.10)
20	Sikkim	0.608	5(0.01) 23(0.69) 25(0.02)	0.827	5(0.01) 23(0.97) 25(0.02)
21	TamilNadu	0.204	5(2.26) 9(8.48) 25(0.03)	1.000	0
22	Telegana	0.073	5(0.63) 9(0.13)	0.077	5(0.63) 9(0.13) 23(0.25)
23	Tripura	1.000	7	1.000	11
24	Uttar Pradesh	0.164	5(2.87) 9(1.78)	1.000	0
25	Uttarkhand	1.000	20	1.000	10
26	West Bengal	0.117	5(0.21) 23 (0.19) 25(0.11)	0.152	5(0.30) 23(0.60) 25(0.11)

From the above table, it may be observed that four DMUs are efficient under CCR model and eleven DMUs are efficient under BCC model. Four states namely Delhi, Himachal Pradesh, Tripura and Uttarakhand have been identified as efficient DMUs by CRS model and 11 states namely Delhi, Gujarat, Haryana, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Tamil Nadu, Tripura, Uttar Pradesh and Uttarakhand are efficient under VRS model.

Further the above table indicates that efficient DMUs forms the reference set (peers) and it fixes the input and output target for the inefficient DMUs. The inefficient DMUs can improve their efficiency by comparing its inputs and outputs with efficient DMUs in the reference set. For instance, the efficient DMUs Delhi, Himachal Pradesh and Uttarakhand forms the reference set for the inefficient DMU Andhra Pradesh under CCR model. Similarly the efficient DMUs Delhi, Maharashtra and Uttarkhand form the reference set for the inefficient DMU Andhra Pradesh under BCC model.

The state Telangana is found to be only 7% efficient in both CRS and VRS assumption. The state secures least percentage of efficiency among all the states included in the study. To attain efficiency the state Telangana has to reduce approximately 93% of all its input.

The efficiency of 10 states lie between 10-20% under CRS assumption but only 3 states lie in the same range of efficiency under VRS assumption. It can also be observed that under CRS assumption none of the inefficient DMUs have secured efficiency score between 60-100% whereas 5 inefficient DMUs have efficiency scores lying in that range under VRS assumption.

The state Goa attains marginal efficiency (95%) under VRS assumption whereas it gets the efficiency score of 15% under CRS assumption.

Peer count summary based on the peers and ranking of DMUs based on the peer counts for both CCR and BCC model is carried out and presented in the following table.

Table 3. Peer Counts and Ranking.

CRS			VRS		
Efficient DMUs	Peer Count	Ranking	Efficient DMUs	Peer Count	Ranking
5	22	1	5	15	1
9	14	3	9	7	4
23	8	4	14	1	6
25	21	2	15	3	5
			23	11	2
			25	10	3

From the above table, it may be observed that fifth DMU stood Rank 1 and twenty fifth DMU receives Rank 2 and so on in CRS model. In VRS model, fifth DMU receives Rank 1 and twenty third DMU receives Rank 2 and so on.

6. Conclusion

It may be observed that the number of efficient DMUs is more in BCC model comparatively with CCR model. This is because of the VRS assumption which is inbuilt in BCC model. It is interesting to note that with respect to Goa, there is a big difference in efficiency score between the CRS and VRS assumption. It clearly indicates that as far as the manufacture of dairy products is concerned, the decision maker may be suggested to adopt only VRS assumption. Thus, we may infer that the scale assumption plays a vital role in DEA.

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