Efficiency Measurement of Indian Sugar Manufacturing Firms: A DEA Approach

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Abstract

Data Envelopment analysis (DEA) has been used to calculate the technical and scale efficiency measures of the public and private sugar manufacturing firms of the Indian Sugar Industry (2006 to 2010). Within DEA framework, the input & Output oriented Variable Returns to Scale (VRS) & Constant Return to Scale (CRS) model is employed for the study of Decision making units (DMUs). A representative sample of 43 firms which account for a major portion of the total market share is studied. The selection criterion for the inclusion of a firm in the analysis was the total sales of INR 5,000 million or more in the year 2010. After reviewing the literature, it is found that no study has been conducted in the context of Indian sugar manufacturing firms in the Post-liberalization era which motivates us to initiate the study.

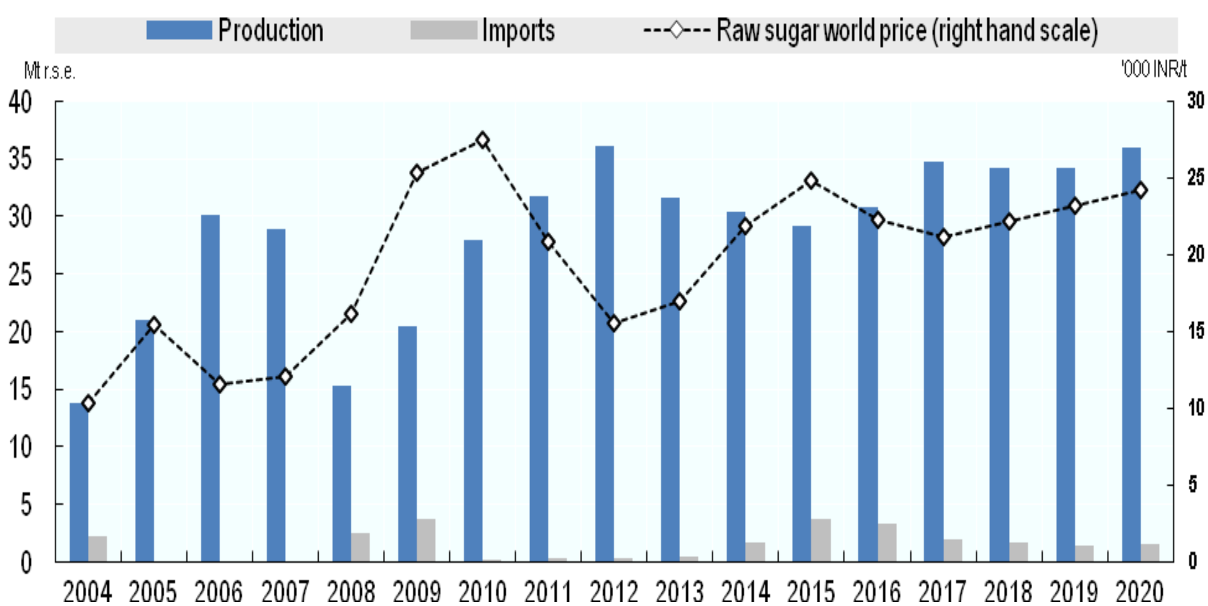
Keywords: Technical Efficiency, Indian Sugar Manufacturing Units, DEA, Input /Output oriented.

Sugar Industry was part of the structured Industrial Development Policy in the five year plans, introduced in 1951 and has always been under the direct control of the Government ever since. It is highly politicized and closely controlled by authorities set by the Governments (State & Central). The authorities control the minimum prices for sugar canes as well as rate of sugar both as commercial and domestic uses. They also control the licensing of sugar manufacturing business and Imports and exports.

The country has a dual sugar pricing policy. It is a peculiar situation where raw material price is fixed by the Government, which goes up every year. Sugar price for the levy sugar (40% of production) is fixed without taking into consideration of all factors that go into production, i.e. 40% of the sugar is sold below cost of production. Thus Government, for all its valid reasons, has protected the farmer and the household consumer who gets levied sugar. The quantity is determined based on historical data on past plus to keep the prices under check - who uses this sugar. 80% of free sale is used by Institutional users who are free to charge for their product.

Besides the controls on sales, are such that mills are forced to sell its product fortnightly basis due to fear of the quantity short-sold getting converted into levy. The advantage is taken by the trade, i.e. the retailer. A retailer adjusts the price upwards when the mill rate goes up but does not drop when the mill is forced to sell at lower prices.

Figure 1: A Projection of India's Sugar Production, Consumption and Imports



Source: OECD and FAO Secretariats.

As per OECD-FAO (Agricultural Outlook 2011-2020), "India, the second largest global producer and the world's leading consumer, is expected to boost production substantially to 32 Mt of sugar per year, on average, in the coming decade, or some 50% higher than in 2008-10, when production fell sharply. The annual sugar output will continue to be subject to periodic large swings in response to the longstanding production cycle. Some other countries of Asia, such as China and Pakistan, are also expected to continue to experience milder forms of production cycles, which contribute to fluctuations in production and their import volumes. Outside this group, an expansion drive underway in Thailand is expected to continue as investment projects currently in the pipeline come on stream, lifting production to around 8.7 Mt by 2020-21, and maintaining its position as the world's third largest producer".

Table 1: Sugar Production, Supply and Distribution of Sugar in India

(1,000 metric tons, raw value)

Year	Production	Imports	Total Supply	Exports	Domestic Consumption
2008-09	15,950	1,358	29,604	224	23,500
2009-10	20,637	2,431	28,429	225	23,000
2010-11	26,650	405	32,259	3,200	23,000
2011-12	28,300	0	34,359	2,500	25,000

Source: USDA, Foreign Agriculture Service, PSD online

http://www.fas.usda.gov/psdonline/psdHome.aspx.

The sector also has a significant standing in the global sugar space as an Indian domestic sugar market it is one of the largest markets in the world, in volume terms. The country is also the second largest sugar producing geography and remains a key growth driver for world sugar, growing above the Asian and world consumption growth average.

Indian Sugar Mills Association (ISMA) which is the body of Sugar Producers of India declared that around 16.59 million tons of sugar have been produced till February which is almost 2.70% higher than the same period last year's production. According to ISMA, the recovery rate is 9.8%, which a significant across the globe. The sugar cane growers' data suggest that the country the world's second-largest sugar producer and biggest consumer may produce around 24.5 million tonnes in year 2012-13. India typically needs around 21.5 million to 22 million tonnes of annual consumption, which means the country will still have surplus stocks to export for a third year in a row in 2012-13 and prices may subdue for another year.

Research Methodology

For last few decades, firms are interested to evaluate their performances over their competitors in terms of 'efficiency'. According to Farrell (1957) efficiency can be decomposed into two parts, Technical Efficiency (TE) and Allocative Efficiency (AE). TE considers attaining the maximal output of a Decision Making Units (DMU) given a set of inputs whereas AE considers optimal allocations of inputs given the set of prices of the products. Total Economic Efficiency can be computed from these two efficiency measures. Efficiency can be viewed from input and output orientation.

Suppose a firm operates on two inputs (X_1 and X_2) to produce a single output Y. So the production function can be given as below

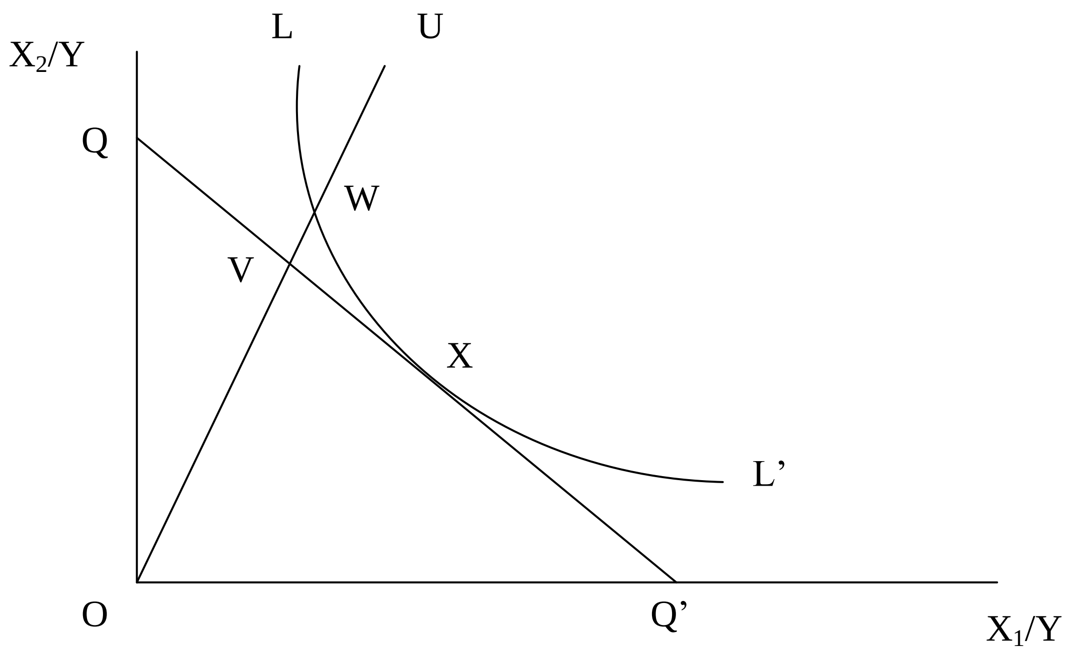
$$Y = f(X_1, X_2)$$

This equation can be rewritten as follows

$$1 = f(X_1/Y, X_2/Y) \quad \text{(Assuming constant returns to scale)}$$

In an input oriented measure the basic principle is to reduce inputs without changing the amount of output. In the following figure LL' is the efficient unit isoquant with a given level of input level OU.

Figure 2: Efficient Unit Isoquant with a given Level of Input Level

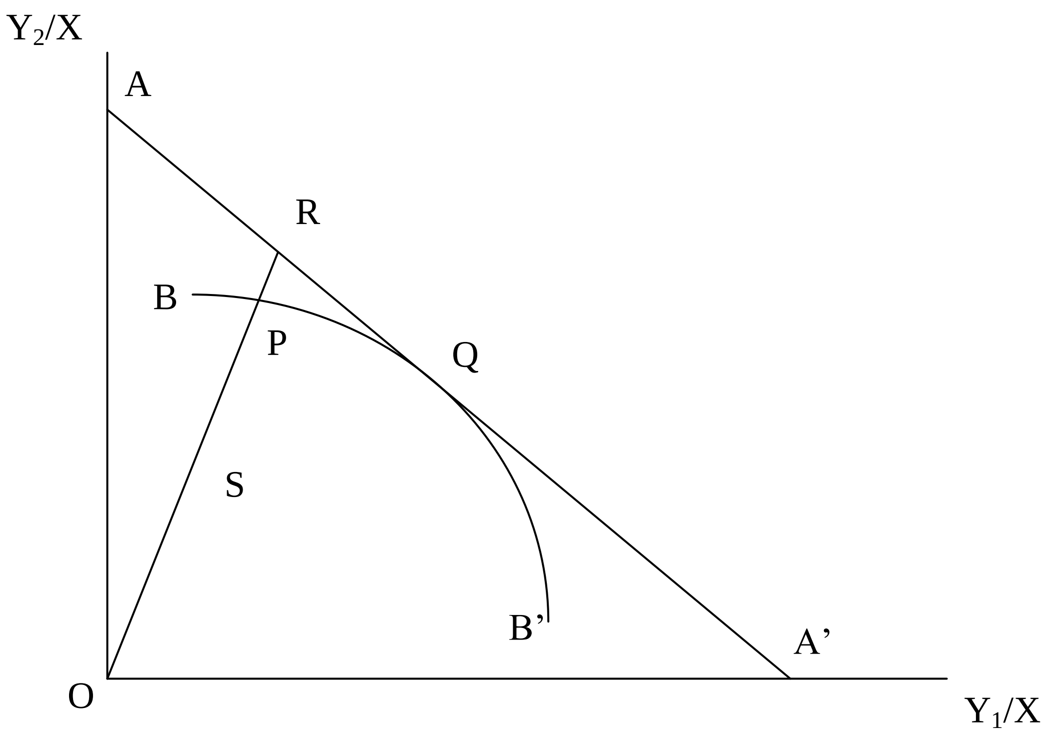


Suppose a firm operates at the U level of input and W is an efficient point as it lies on the efficient unit isoquant. The UW level of input can be reduced without reducing the amount of output. This amount is the measurement of inefficiency. The amount of efficiency must be one minus the level of inefficiency. So from the diagram Technical Efficiency can be measured by the ratio of OW/OU which is one minus the level of inefficiency. If input prices are known that is shown by the line QQ' a firm can reduce its production cost by the amount of WV such that it can operate on X which is efficient both technically and allocatively rather than W which is only technically efficient. So Allocative Efficiency is given by the ratio OV/OW.

Total Economic Efficiency can be given by E = OV/OU = OV/OW * OW/OU = Technical Efficiency * Allocative Efficiency……………………(i)

As all efficiency measures are ratio, they range between zero and one. In output oriented measure expansion of output without changing the level of inputs was evaluated (Hua, Z. & Bian, Y., 2008). It is assumed that firm produces two outputs (Y_1 and Y_2) using one input (X). In the following figure BB' is the production possibility curve where each and every firm is technically efficient.

Figure 3: Production Possibility Curve



Suppose a firm operates at point S which is an inefficient condition as it lies below the production frontier. So SP is the level of technical inefficiency and efficiency can be derived by one minus level of inefficiency. So Technical Efficiency is given by the ratio OS/OP. If it is incorporated price information which is represented by the isoprofit curve AA' Allocative Efficiency is given by OP/OR.

Total Economic Efficiency is given by E = OS/OR = OS/OP * OP/OR =Technical Efficiency * Allocative Efficiency. …………………………….(ii)

The input and output oriented measures of efficiency are same under the assumption of constant returns to scale and differ when increasing and decreasing returns to scale exist (Fare and Lovell, 1978).

Farrell's (1957) frontier function technique is limited in the sense of constant returns to scale and non parametric nature. Later these assumptions are relaxed. The efficiency estimation technique can be divided into two categories.

(1) Econometric techniques
(2) Mathematical programming techniques

Econometric Techniques

These methods involve estimation of production function (primal) or cost or profit function (dual) to derive the frontier. There are two types of frontiers, deterministic and stochastic. The Ordinary Least Square technique is used to estimate the deterministic frontier. The major drawback of this method is that it does not capture the possible effects of the uncontrollable factors of the producer which results an overestimation of efficiency (Meeusen and van den Broeck, 1977).

Stochastic frontier model carefully handles this problem. Maximum likelihood methods estimate a stochastic frontier model which comprises an error term that incorporates the possible effects of uncontrollable factors of the producer. But this methodology needs specific functional form to estimate efficiency and is limited with respect to the distributional assumptions of the error term.

Mathematical Programming Techniques

Farrell's non parametric piecewise convex isoquant is recognized as mathematical programming technique. His work was strengthened by Charnes, Cooper and Rhodes (1978), Fare, Grosskopf and Lovell (1983), Banker, Charnes and Cooper (1984), and Byrens, Fare and Grosskopf (1984), Pannu, H.S. This approach is widely known as Data Envelopment Analysis (DEA). The major advantage of DEA is that it does not demand any specification about the functional form or does not assume any distributional form of the error term. DEA works smoothly under the assumption of VRS.

Analytical Model

Data Envelopment Analysis (DEA) is a non parametric mathematical programming to estimate the frontier function. DEA provides the efficiency of different firms operating on same input output variable. We illustrate the DEA method from both input and output orientation. Let us consider P number of DMU producing Q number of outputs using R number of inputs. Inputs are denoted as x_{ip} (i =1,2,… R) and outputs are denoted as y_{jp} (j =1,2,… Q) for each farm p (p =1,2,… P).

It was liked to find out the efficiency for each farm and hence its better to get a ratio of all outputs over all inputs. So we are interested to find out the ratio of $u_j y_{jp} / v_i x_{ip}$, where y_{jp} is the quantity of j^{th} output produced by p^{th} farm, x_{ip} is the quantity of i^{th} input used by p^{th} farm, u_j and v_i are the output and input weights respectively.

So efficiency can be represented as $TE_P = \sum_{j=1}^{Q} u_j y_{jp} \Big/ \sum_{i=1}^{R} v_i x_{ip}$ (Coelli,1998; Worthington, 1999).

DMU is interested to maximize their efficiency where efficiency must be less than one which plays the role of constraint.

The optimization problem becomes

Max TE_p

subject to $\sum_{j=1}^{Q} u_j y_{jp} \Big/ \sum_{i=1}^{R} v_i x_{ip}$ ≤ 1. ……………………………………………………(a)

where u_j and $v_i \geq 0$.

The constraint restricts the efficiency less than one and confirms that weights are positive. The weights are chosen in such a way that efficiency will be maximized. From an output oriented viewpoint the mathematical programming can be formulated as below (Coelli, 1998; Worthington, 1999; Shiu, 2002)

Max TE_p

subject to $\sum_{j=1}^{Q} u_j y_{jp}$ - x_{ip} $+ w \leq 0$ p =1,2,… P ……………………………(b)

$v_i x_{ip}$ - $\sum_{i=1}^{R} u_i x_{ip}$

u_j and v_i ≥ 0.

From input orientation method the mathematical programming can be formulated as follows (Banker and Thrall, 1992; Coelli, 1998; Worthington, 1999; Shiu, 2002; Topuz et al, 2005).

Min TE_p

subject to $\sum_{j=1}^{Q} u_j y_{jp}$ - y_{jp} + w ≥ 0 p =1,2,… P ……………………(c)

x_{ip} - $\sum_{i=1}^{R} u_i x_{ip}$ ≥ 0

and u_j and v_i ≥ 0.

If $w = 0$ then the above model follows CRS and if w is unconstrained then it follows VRS. We get technical efficiency in the first case and pure technical efficiency in the second case.

Selection of Inputs and Outputs

DEA approach can be applied to revenue producing DMUs. This can be done by converting the financial performance measures to the DMU's technical efficiency equivalents. While using input and output variables, the methodology of Feroz et. al. (2003) and Wang (2006) was followed, who have converted the financial performance measures to the firm's technical efficiency equivalent using DuPont Model[2]. This process of measuring financial performance indicators can be converted into output and input variables. Where, sales revenue and Profit after Tax (PAT) can be used as output variable while cost of goods sold (COGS), selling and Administration expenses, and total assets as input variables. The indicators are defined as follows:

1. Input (X_1): Total Cost of Goods Sold (COGS)
2. Input(X_2): Total Selling and Administration Expenses (or Cost)
3. Input (X_3): Total Assets hold by firm during the year
4. Output (Y_1): Total Sales of the Firm during the Year
5. Output (Y_2): Total Profit after Tax (PAT) of the Firm during the Financial Year.

The above methodology helps to logically convert performance ratios into efficiency. In this way long term resources total assets and short term resources, cost of goods sold and selling and Administration expenses are used to produce output in the form of sales revenue and PAT.

Selection of Data

A representative sample of 43 firms which have accounted for a major portion of the total market share is studied considering the imitates of DEA only those firms are included in an analysis which have their equity in positive and their annual reports were available for all the five years from 2006 to 2010. The selection criterion for the inclusion of a firm in the analysis has been total sales of INR 500 crores or more. Data for the study is obtained from secondary sources (www.capitaline.com) in the form of annual reports of the steel firms for the period 2006 to 2010.

Results and Discussions

We have analyzed the efficiency for different DMUs from both input and output oriented measures. In input oriented measures DMUs operate on same isoquant and in output oriented measures DMUs operate on same PPF. The objective is to attain maximum efficiency given the constraints. Detail mathematical formulation is given in the Research Methodology section. Input and output oriented measures can be calculated for CRS as well as VRS. So we have four different combinations of efficiency measures;

1. Input oriented CRS: Operate at the best point of isoquant under CRS
2. Input oriented VRS: Operate at the best point of isoquant under VRS
3. Output oriented CRS: Operate at the best point of PPF under CRS
4. Output oriented VRS: Operate at the best point of PPF under VRS

We have implemented our model in Data Envelopment Analysis software and compare the mean of efficiency from different measures. We have presented our two outputs and three inputs efficiency for different DMUs in the table. Data of the five year period of 43 sugar firms are taken for this study.

We calculate the efficiency using the DEA approach for both constant and variable returns to scale. We consider both input and output oriented measures and present the analysis in the following table. We take 43 sugar manufacturing firms of India and measure the efficiency for a five year period.

We conduct DEA analysis for sugar firms in Indian context. We compute the efficiency for 43 firms from input and output orientation for last five year period.

Table 2: Two Outputs-Three Inputs DEA Efficiency of Indian Sugar Manufacturing Firms (2006-2010)

S. No.	DMUs	Input Oriented		Output Oriented	
		CRS	VRS	CRS	VRS
1.	Bajaj Hindusthan	0.5288	0.9230	0.5288	0.9932
2.	Balrampur Chini Mills	0.0960	0.3888	0.0960	0.7902
3.	Dalmia Bharat	0.0850	0.4640	0.0850	0.7792
4.	Dhampur Sugar	0.0948	0.1018	0.0948	0.4576
5.	EID Parry	0.1280	0.2906	0.128	0.6090
6.	Sakthi Sugars	0.0844	0.0982	0.0844	0.5160
7.	Shree Renuka Sugar	0.1358	0.4584	0.1358	0.6688
8.	Triveni Engineering India	0.1120	0.4714	0.1120	0.8050
9.	Simbhaoli Sugars Ltd.	0.0880	0.0880	0.0880	0.3130
10.	Bannari Amm. Sugar	0.1074	0.1076	0.1074	0.4786
11.	DCM Shriram Inds	0.1478	0.1478	0.1478	0.4564
12.	Dharani Sugars	0.1484	0.1484	0.1484	0.3312
13.	Jeypore Sugar Co.	0.1368	0.1368	0.1368	0.3296
14.	J.K. Sugar	0.3246	0.3246	0.3246	0.3554
15.	Kesar Enterprise	0.1954	0.1954	0.1954	0.3222
16.	Kothari Sugars	0.1658	0.1658	0.1658	0.3482
17.	Parrys Sugar	0.1952	0.1952	0.1952	0.3570
18.	Ponni Sug.Erode	0.3950	0.3950	0.3950	0.4410
19.	Rajshree Sugars	0.1124	0.1124	0.1124	0.3446
20.	Thiru Aroor Sugar	0.1150	0.1150	0.1150	0.3108
21.	Ugar Sugar Works	0.0994	0.0994	0.0994	0.2936
22.	Dwarikesh Sugar Industries Ltd.	0.1302	0.1302	0.1302	0.3182
23.	Eastern Sugar & Industries Ltd.	1	1	1	1
24.	Empee Sugars & Chemicals Ltd.	0.4434	0.4434	0.4434	0.4704
25.	Gayatri Sugars Ltd.	0.4036	0.4036	0.4036	0.4252
26.	Gobind Sugar Mills Ltd.	0.2662	0.2662	0.2662	0.3576

27.	Indian Sucrose Ltd.	0.2836	0.2836	0.2836	0.3626
28.	Kashipur Sugar Mills Ltd.	0.7674	0.7686	0.7674	0.7744
29.	KCP Sugar & Industries Corporation Ltd.	0.1710	0.1710	0.1710	0.3900
30.	K. M. Sugar Mills Ltd.	0.2936	0.2936	0.2936	0.3650
31.	Naraingarh Sugar Mills Ltd.	0.6072	0.6072	0.6072	0.6224
32.	Oswal Overseas Ltd.	0.6764	0.6764	0.6764	0.6786
33.	Oudh Sugar Mills Ltd.	0.0864	0.0864	0.0864	0.3184
34.	Piccadilly Agro Industries Ltd.	0.3120	0.3120	0.3120	0.3800
35.	Prudential Sugar Corporation Ltd.	0.4862	0.4862	0.4862	0.4956
36.	Rana Sugars Ltd.	0.1526	0.1526	0.1526	0.3022
37.	SBEC Sugar Ltd.	0.2358	0.2358	0.2358	0.3356
38.	Shree Chamundeswari Sugars Ltd.	0.1854	0.1854	0.1854	0.3302
39.	United Provinces Sugar Co Ltd.	0.2674	0.2674	0.2674	0.3478
40.	Upper Ganges Sugar & Industries Ltd.	0.0896	0.0896	0.0896	0.2762
41.	Uttam Sugar Mills Ltd.	0.1210	0.1210	0.1210	0.2986
42.	Vishnu Sugar Mills Ltd.	0.5266	0.5266	0.5266	0.5464
43.	Piccadilly Sugar & Allied Inds Ltd.	0.8590	0.8590	0.8590	0.8616
	Mean	**0.27582**	**0.32077**	**0.27582**	**0.47808**

From input oriented point of view, industry average efficiency is 0.2758 and 0.3207 for CRS and VRS respectively. Among 43 firms 15 and 16 firms have efficiency more than the industry average for CRS and VRS respectively from input orientation. From output oriented view 15 firms perform better than the industry average efficiency for both CRS and VRS. Average industry efficiency for CRS is same either from both measures.

In Annexure 2 we provide year wise efficiency of 43 firms for CRS and VRS from input and output oriented point of view. We got the same results from both the measures. In CRS efficient firms are Bajaj Hindusthan (2006,2007), Eastern Sugar & Industries Ltd (2006,2007,2008,2009,2010), Kashipur Sugar Mills Ltd (2010) and Piccadilly Sugar & Allied Industries Ltd (2006,2010). As per VRS efficient firms are Bajaj Hindusthan (2006, 2007,2008,2009), Balrampur Chini

(2007), Dalmia Bharat (2010), EID Parry (2009), Sh. Renuka Sugar (2010), Eastern Sugar & Industries Ltd (2006,2007,2008,2009,2010), Kashipur Sugar Mills Ltd (2010) and Piccadilly Sugar & Allied Industries Ltd (2006, 2010). So Eastern Sugar & Industries Ltd performs better than other DMUs from both input and output oriented measures for last five years.

Summary & Comments

DEA is one of the most popular techniques to assess the efficiency level of DMUs. It is a non parametric method and need not to assume the distributional form of the production possibility curve, which gives it a comparative advantage than other modeling techniques. Studying the exhaustive literature we found that DEA is one of the most suitable tools to measure the efficiency of various DMUs and no study has been done in the context of Indian sugar industry in post-liberalization era which motivates us to initiate the study.

Empirical analysis using the panel data of five years (2006-2010) from 43 Indian sugar manufacturing firms demonstrates that Indian firms have achieved, on an average technical efficiency, about 86-90 per cent. From both input and output orientation industry efficiency average in a CRS is same while it is different for VRS and showing better efficiency in case of output orientation.

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