

APPLICATIONS OF DATA ENVELOPMENT ANALYSIS AS A BENCHMARKING TOOL - CASE STUDY

Karthik Vignesh SS
Srinivasan Balan
Koilkuntla Maddulety
Sankar TS
Sumit Guha
Vibhu Ganesan

*National Institute of Industrial Engineering, Vihar Lake
Mumbai 400087, India*

Abstract

DEA is a multi factor productivity model for measuring the relative efficiencies of a homogenous set of decision making units (DMU's). This paper deals with the application of DEA model to determine the benchmarked DMU among the list of certain DMU's with certain inputs and outputs parameters. Two different areas were identified for the application of DEA for benchmarking. Pharmaceutical Industries and Indian State wise performance were analysed. The model is explained with the Linear programming mathematical model and its impact in the sensitivity analysis. Results indicate the efficiency of all DMU's and scope of improvement for different DMU's.

Keywords: *DEA, Multi Factor Productivity, Decision Making Unit, Benchmarking, Linear Programming, Mathematical model, Sensitivity analysis*

1. Introduction

Benchmarking is the method commonly used by industries to compare one's business practises and processes with the "best practises" within the sector, so that one can identify the potential areas of improvement and improve based on the results. One of the important steps in benchmarking is the use of decision making tools, in order to classify the "best in class" units from the rest. DEA as a tool is useful in analysing the various units and identifying the best performing units, as well as in providing actionable measures that is to be taken by the other units, in order to improve their performance. In this paper, we apply the DEA tool for benchmarking in two different cases. In case one, we have made a study among the pharmaceutical companies in India. In the second case, we have done a benchmark study among the top 10 Indian states, chosen on the basis of the Net Industrial Value Added in the year 2007-2008. The DEA analysis of both the cases provides valuable information regarding the best practises, as

well as giving insights on the inefficient units, by showing the scope of improvements to be made.

2. Literature Review

Data envelopment Analysis(DEA) is a technique to measure and compare the efficiencies of various Decision Making Units(DMU) with common inputs and outputs. In DEA literature, any entity whose efficiency is being evaluated is usually referred to as "Decision Making Unit(DMU)". This technique was first proposed by Charnes, Cooper and Rhodes (CCR) (1978) when they provided a linear programming formulation to measure the productive efficiency(CCR Efficiency) of a DMU relative to a set of referant DMUs. To measure the technical efficiency and the returns to scale, the CCR model can be modified via addition of convexity constraint. Banker, Charnes and Cooper introduced a new separate variable which makes it possible to operations where conducted in regions of increasing, constant or decreasing return to scale. DEA is receiving importance as a tool for evaluating the performance of manufacturing and service operations.

2.1 CCR Model of Data Envelopment Analysis:

The CCR model proposed that the efficiency of any DMU is obtained as the maximum of a ratio of weighted outputs to weighted inputs subject to the condition that the similar ratios of every DMU should be less than or equal to unity. The efficiency of one member of the reference set of DMUs is rated relative to the others. The above problem is run 'n' times, 'n' being the number of DMUs, identifying the relative efficiency scores of all DMUs. Each DMU selects the input and output weights that maximize its efficiency score. In general, a score of 1 means the DMU under consideration is efficient and a score of less than 1 is considered to inefficient. For every inefficient DMU, DEA defines an a set of corresponding efficient units that can be used as a

benchmark for improvement. The benchmarks can be obtained using the dual of the given primal problem. A test DMU is inefficient if a composite DMU (linear combination of the units in the set) can be identified which uses less input than the test DMU while maintaining at least the same output levels. The units involved in the construction of the composite DMU can be used as benchmarks to improve the inefficient DMUs. Although benchmarking in DEA allows for the identification of targets for improvements, it has certain limitations. A difficulty addressed in the literature regarding this process is that an inefficient DMU and its benchmarks may not be inherently similar in their operating practices. This is primarily due to the fact that the composite DMU that dominates the inefficient DMU does not exist in reality. To overcome these problems researchers have utilized performance-based clustering methods for identifying more appropriate benchmarks (Doyle & Green, 1994; Talluri, May 2000)

These methods cluster inherently similar DMUs into groups, and the best performer in a particular cluster is utilized as a benchmark by other DMUs in the same cluster. (Talluri, May 2000)

2.2 Unrestricted weight flexibility problem in DEA:

Traditional DEA models do not allow for ranking DMUs, specifically the efficient ones. Also, it is possible in DEA that some of the inefficient DMUs are in fact better overall performers than certain efficient ones. This is because of the unrestricted weight flexibility problem in DEA. A DMU can achieve a high relative efficiency score by being involved in an unreasonable weight scheme (Dyson & Thannassoulis, 1988; Wong & Beasley, 1990). Such DMUs heavily weigh few favorable measures and completely ignore other inputs and outputs. These DMUs can be considered as niche members and are not good overall performers. Cross-efficiencies in DEA are one method that could be utilized to identify good overall performers and effectively rank DMUs (Sexton et al., 1986).

2.3 BCC Model of Data Envelopment Analysis:

The BCC model examines the links between the returns to scale and most productive scale size in multiple-output-multiple-input production environments. It also considers the possibility that the production frontier is not differentiable and provides a generalized approach which considers a range of values of returns to scale measure to determine whether increasing or decreasing returns prevail at non-differentiable points on the production frontier. While these ideas are developed in the

context of the production possibility set used in Data Envelopment Analysis, the concepts apply to any convex production possibility set. First, the concept of returns to scale is well defined only for production possibilities that are boundary points (i.e., radial technical efficient points). For points in the interior of the production possibility set, productivity changes due to returns to scale are confounded with productivity changes due to inefficiency elimination. Second, the concept of returns to scale is directly related to the concepts of most productive scale size. Consider a point A on the boundary of a convex production possibility set. The ray from the origin to the point A intersects the production possibility set in two points in general, (at least) one of which is the point A itself. If A is the first of these points (closer to the origin), then A is smaller than the mpss for its mix of inputs and outputs, and increasing returns to scale prevail at A. If A is the second point (farther from the origin) then it is larger than the mpss and decreasing returns to scale obtain. The exception to the situations involving two points of intersection occurs when the ray from the origin intersects the production possibility set at a unique point, viz. A, or at an infinity of points in a line segment which includes A. In these cases, A is itself an mpss and constant returns to scale prevail at A (i.e., the return to scale interval includes the number 1). The BCC model developed the ideas of returns to scale and mpss with reference to an input oriented efficiency model.

2.4 Strengths of DEA

The DEA is a very powerful tool that can be used in several situations. The following are a few strengths of DEA:

- a) It doesn't require an assumption of a functional form relating inputs to outputs.
- b) DMUs are directly compared against a peer or combination of peers.
- c) Inputs and outputs can have very different units.

2.5 Limitations of DEA

The same characteristics that make DEA a powerful tool can also create problems. These limitations should be kept in mind when choosing whether or not to use DEA.

- a) Since DEA is an extreme point technique, noise (even symmetrical noise with zero mean) such as measurement error can cause significant problems.
- b) DEA is good at estimating "relative" efficiency of a DMU but it converges very slowly to

“absolute” efficiency. In other words, it can tell you how well you are doing compared to your peers but not compared to a “theoretical maximum.”

- c) Since DEA is a nonparametric technique, statistical hypothesis tests are difficult and are the focus of ongoing research.
- d) Since a standard formulation of DEA creates a separate linear program for each DMU, large problems can be computationally intensive.

2.6 Evolution of DEA

DEA is a linear programming technique for measuring relative efficiency of decision making units (DMUs). This method was proposed by Charnes, Cooper, and Rhodes (1978) and developed by Banker, Charnes, and Cooper (1984). In the past years, many applications were in practice for evaluation of many different kinds of DMU's. (Cooper, Seiford & Tone 2007; Emrouznejad, Parker, & Tavares 2008). For instance, in benchmarking applications, use of DEA was analysed and identified for activity based management as proposed by Carsten Homburg (Homburg, 2001). DEA models were used for identifying and benchmarking the best health care systems as proposed by James, Aysun and Mehmet (James C Benneyan, 2008). DEA in conjunction with Goal Programming were applied for performance benchmarking that extends performance measurement technique to incorporate the interactive decision making (Thierry Post, 1999). DEA as a benchmarking tool for electricity distribution companies was proposed by Lassila, Viljainen, Honkapuro and Partanen (2003).

3. Mathematical Programming of DEA

Let us assume, there are certain inputs i to represent certain DMU's. As a multi factor weight allocation model, it is written as follows.

4. Numerical Cases:

For the analysis, appropriate inputs and outputs are selected and modelled in the form of fractional DEA. As per model proposed by Banker et al (Banker R D, 1984), the fractional DEA is converted into linear programming models. LP functions are then modelled in Microsoft Excel 2007 and solved using Solver addins

4.1 Case: Pharmaceutical sector analysis

Major players in the Indian Pharmaceutical sector are selected as DMU's as shown in the table. Inputs selected for the analysis is Raw material cost, Employee cost and Selling & Distribution expenses and Sales, growth rate are correspondingly chosen as outputs. These inputs directly affect the sales

generated which are the output. Also these inputs contribute around 90% of the cost structure and directly the operating efficiency of the industry. (Refer table 1 in the appendix)

These inputs and outputs are modelled using Output Maximisation model at Constant Returns to Scale for each DMU. Considering the model proposed by Charnes & Cooper (Banker R D, 1984). Substituting values for Primal DMU in equation 1

Objective function,

$$\text{Max } Z = 2\,654.5V_1 + 14.32V_2$$

Subject to constraints,

$$1) \quad 2\,654.5V_1 + 14.32V_2 = 1$$

$$2) \quad 1\,139.24u_1 + 303.74u_2 + 461.93u_3 = 1$$

$$3) \quad (878.46u_1 + 174.71u_2 + 439.11u_3) - (1\,845.09v_1 + 4.7v_2) = 1$$

$$4) \quad (2\,083.29u_1 + 728.4u_2 + 884.89u_3) - (4\,781.59v_1 + 2.78v_2) = 1$$

$$5) \quad (1\,599.4u_1 + 516.4u_2 + 1\,036.6u_3) - (4\,395.6v_1 + 9.9v_2) = 1$$

$$6) \quad (2\,687.54u_1 + 318.87u_2 + 867.98u_3) - (4\,781.59v_1 + 2.78v_2) = 1$$

$$7) \quad (728.65u_1 + 209.71u_2 + 182.82u_3) - (1\,884.14v_1 + 12.39v_2) = 1$$

$$8) \quad (806.2u_1 + 266.9u_2 + 554u_3) - (1\,885.6v_1 + 8.1v_2) = 1$$

$$9) \quad (288.66u_1 + 115.01u_2 + 279.59u_3) - (1\,029.56v_1 + 19.01v_2) = 1$$

$$10) \quad (410.06u_1 + 93.22u_2 + 37.51u_3) - (931.63v_1 + 11.41v_2) = 1$$

Where

u_i and v_i are the input and output weights respectively (Where $0 = u_i, v_i = 1$)

Constraints (1) & (2) are for the DMU under consideration whose output is to be maximised. Remaining constraints (3) to (10) are for the other DMU's. Similarly for Other DMU's this procedure is repeated and the corresponding efficiencies are calculated. (Refer table 2 in the appendix)

The outputs show that DMU's such as Cipla, Divi's Labs, GSK and Glenmark Pharmaceuticals can be taken as benchmarks for the other DMU's. Although the above DMU's are not 100% efficient, they are considered for the formation of Frontiers with which the other DMU's can be compared. But according to the column sum maximization, Glenmark is having the highest score of 9 out of 9 and is considered to be the best performing DMU among the existing DMU's.

4.1.1 Sensitivity analysis

To show the potential improvements for the other DMU's, the primal problem is converted into a dual

problem and the potential improvements are calculated and listed below.

The dual for the model can be formulated as mentioned in equation 2. The dual is seeking the efficiency rating, minimize θ , subject to the constraint (a) that the weighted sum of inputs of the other service units is less than or equal to the inputs of the DMU being evaluated and (b) that the weighted sum of the outputs of the other DMU is greater than or equal to the service unit being evaluated. The weights are the u_i values. The other DMU with non zero v_j values are the units in the efficiency reference set (ERS).

The dual equations for the 1st DMU is as follows

Minimize

subject to constraints

$$1) \quad 1 \ 139.24 \ u_1 + 878.46 \ u_2 + 2 \ 083.29 \ u_3 + 1 \ 599.4 \ u_4 + 2 \ 687.54 \ u_5 + 728.65 \ u_6 + 806.2 \ u_7 + 288.66 \ u_8 + 410.06 \ u_9 \leq 1 \ 139.24 \ ;$$

$$2) \quad 303.74 \ u_1 + 174.71 \ u_2 + 728.4 \ u_3 + 516.4 \ u_4 + 318.87 \ u_5 + 209.71 \ u_6 + 266.9 \ u_7 + 115.01 \ u_8 + 93.22 \ u_9 \geq 303.74 \ ;$$

$$3) \quad 461.93 \ u_1 + 439.11 \ u_2 + 884.89 \ u_3 + 1 \ 036.6 \ u_4 + 867.98 \ u_5 + 182.82 \ u_6 + 554 \ u_7 + 279.59 \ u_8 + 37.51 \ u_9 \geq 461.93 \ ;$$

$$4) \quad 2 \ 654.5 \ u_1 + 1 \ 845.09 \ u_2 + 4 \ 781.59 \ u_3 + 4 \ 395.6 \ u_4 + 5 \ 605.69 \ u_5 + 1 \ 884.14 \ u_6 + 1 \ 885.6 \ u_7 + 1 \ 029.56 \ u_8 + 931.63 \ u_9 = 2 \ 654.5;$$

$$5) \quad 14.32 \ u_1 + 0 \ u_2 + 2.784 \ u_3 + 9.9 \ u_4 + 7.1 \ u_5 + 12.39 \ u_6 + 8.1 \ u_7 + 19.01 \ u_8 + 11.41 \ u_9 = 14.32;$$

$$u_i = 0 \quad i=1 \dots 9;$$

Solving this we get $\theta = 0.8759$

Solving similarly for other DMUs we get the results. (Refer table 3 in the Appendix)

As the above table shows 5 out of 9 companies are operating below their maximum efficiency. One way for these inefficient units to improve their efficiency is to change their input. In order to find out the Efficiency reference Set (ERS) we need to multiply the u_i values obtained for a particular inefficient DMU with the input of all the DMUs.

The u_i values obtained for the different DMUs and is mentioned in the table 4 (Refer table 4 in the Appendix)

For DMU Piramal the target raw materials can be calculated as

$$0.053 \times 2 \ 687.54 + 1.107 \times 288.66 + 1.307 \times 421.06 = 997.9$$

Similarly target values for other inefficient DMUs

can be calculated. (Refer table 5 in the Appendix)

4.2 Case: Performance analysis of different states of India

For the second case, we have compared a few of the states of India on the basis of various industrial parameters. The data was obtained from the Annual Survey of Industries (ASI) conducted in 2007-2008, which provides the various data related to industrial productivity in the various states. For the purpose of our evaluation, we considered 3 inputs – No: of factories, Total no: of people involved and Total investments and 3 outputs – Value of output, wages per worker and Profits. (Refer table 6 in the Appendix)

The data was then analysed using the CCR output-oriented model with constant Returns-to-Scale, where the outputs as maximised and the inputs are considered as 1, as given in Equation 1. For each DMU, the objective function and the constraints were modelled using the CCR model, and for each, the efficiency values were obtained. As an example, for Maharashtra,

Objective function

$$\text{Max } Z = 151 \ 614v_1 + 7 \ 549 \ 581v_2 + 51 \ 993 \ 933v_3$$

subject to constraints

$$1) \quad 18 \ 304u_1 + 21 \ 476 \ 750u_2 + 1 \ 354 \ 827u_3 = 1$$

$$2) \quad 151 \ 614v_1 + 7 \ 549 \ 581v_2 + 51 \ 993 \ 933v_3 = 1$$

$$3) \quad (105 \ 605v_1 + 4 \ 234 \ 836v_2 + 44 \ 824 \ 316v_3) = (15 \ 107u_1 + 20 \ 955 \ 836u_2 + 1 \ 045 \ 475u_3)$$

$$4) \quad (78 \ 832v_1 + 1 \ 762 \ 741v_2 + 26 \ 543 \ 807v_3) = (21 \ 042u_1 + 12 \ 952 \ 311u_2 + 1 \ 549 \ 761u_3)$$

$$5) \quad (115 \ 440v_1 + 2 \ 107 \ 909v_2 + 18 \ 425 \ 766v_3) = (8 \ 443u_1 + 8 \ 622 \ 398u_2 + 724 \ 075u_3)$$

$$6) \quad (74 \ 998v_1 + 1 \ 786 \ 942v_2 + 18 \ 253 \ 326v_3) = (16 \ 741u_1 + 9 \ 583 \ 545u_2 + 1 \ 041 \ 265u_3)$$

$$7) \quad (91 \ 103v_1 + 1 \ 362 \ 613v_2 + 19 \ 381 \ 502v_3) = (10 \ 717u_1 + 9 \ 195 \ 910u_2 + 751 \ 165u_3)$$

$$8) \quad (119 \ 197v_1 + 1 \ 540 \ 724v_2 + 6 \ 033 \ 835v_3) = (1 \ 615u_1 + 2 \ 976 \ 122u_2 + 152 \ 668u_3)$$

$$9) \quad (49 \ 791v_1 + 937 \ 881v_2 + 12 \ 488 \ 415v_3) = (4 \ 707u_1 + 4 \ 785 \ 642u_2 + 5 \ 096 \ 17u_3)$$

$$10) \quad (55 \ 785v_1 + 1 \ 002 \ 611v_2 + 5 \ 795 \ 018v_3) = (1 \ 854u_1 + 3 \ 086 \ 215u_2 + 155 \ 819u_3)$$

$$11) \quad (48 \ 438v_1 + 941 \ 124v_2 + 7 \ 872 \ 158v_3) = (3 \ 165u_1 + 3 \ 643 \ 168u_2 + 255 \ 293u_3)$$

Using the excel solver, the above L.P model was solved and the value of Z was obtained as 1, which meant that the self-efficiency of Maharashtra was 1. Similarly, for all the 10 states, the L.P model was formulated any analysed using the solver. As per this basic analysis, 4 states, Maharashtra, Gujarat, Haryana and Jharkand obtained a self-efficiency

score of 1, while the other 6 states came out as inefficient.

The self-efficiency score is not sufficient to classify the performance of the states and ranking them. So, the data is to be then analysed using any of the ranking methods which are used along with DEA. One of the first methods of ranking, the cross-evaluation matrix was developed by Sexton et al. (Sexton T R, 1986), inaugurating the subject of ranking in DEA. This method provides sufficient information regarding the ranking of the various DMU's (Nicole Adler, 2002). The cross efficiency matrix provides the values of self-efficiencies as well as the efficiencies evaluated using the optimal weights of the other DMU's. It is a square matrix where the diagonal elements represent the self-efficiency scores. For all the other elements in the matrix, the E_{ij} values represent the score given to unit j in the DEA run of the unit I, i.e. unit j evaluated using the optimal weights of unit i. Table 7 shows the cross-efficiency matrix obtained after the analysis.

According to Adler and Friedman (Nicole Adler, 2002), the average cross-efficiency score \bar{e}_j , which is the average of the efficiency scores of unit j, is a better measure than the self-efficiency score E_{jj} . Considering this condition, out of the 4 efficient states, 2 states Maharashtra and Jharkhand stand out with average values of 0.984 and 0.977, while Gujarat and Haryana manage 0.914 and 0.930 respectively.

Apart from finding out the inefficient DMU's, DEA allows us to measure the amount by which the inputs have to be reduced, keeping the outputs at the same level, so that the DMU becomes efficient. Alternately, we can also measure the level by which the outputs have to be increased, keeping the same level of inputs

This is done using the dual L.P model of the basic CCR model. As an example, the dual L.P for Tamil Nadu would be

Minimise

subject to constraints

1) Aswaptappa. K, Human Resource Management, Tata McGraw Hills publications.

- 1) $18\ 304\ x_1 + 15\ 107\ x_2 + 21\ 042\ x_3 + 8\ 443\ x_4 + 16\ 741\ x_5 + 10\ 717\ x_6 + 1\ 615\ x_7 + 4\ 707\ x_8 + 1\ 854\ x_9 + 3\ 165\ x_{10} = 21\ 402$;
- 2) $21\ 476\ 750\ x_1 + 20\ 955\ 836\ x_2 + 12\ 952\ 311\ x_3 + 622\ 398\ x_4 + 9\ 583\ 545\ x_5 + 9\ 195\ 910\ x_6 + 2\ 976\ 122\ x_7 + 4\ 785\ 642\ x_8 + 3\ 086\ 215\ x_9 + 3\ 643\ 168\ x_{10} = 12\ 952\ 311$;

- 3) $1\ 354\ 827\ x_1 + 1\ 045\ 475\ x_2 + 1\ 549\ 761\ x_3 + 724\ 075\ x_4 + 1\ 041\ 265\ x_5 + 751\ 165\ x_6 + 152\ 668\ x_7 + 509\ 617\ x_8 + 155\ 819\ x_9 + 255\ 293\ x_{10} = 1\ 549\ 761$;
- 4) $151\ 614\ x_1 + 105\ 605\ x_2 + 78\ 832\ x_3 + 115\ 440\ x_4 + 74\ 998\ x_5 + 91\ 103\ x_6 + 11\ 919\ x_7 + 49\ 792\ x_8 + 55\ 785\ x_9 + 48\ 438\ x_{10} = 78\ 832$;
- 5) $7\ 549\ 581\ x_1 + 4\ 234\ 836\ x_2 + 1\ 762\ 741\ x_3 + 2\ 107\ 909\ x_4 + 1\ 786\ 942\ x_5 + 1\ 362\ 613\ x_6 + 1\ 540\ 724\ x_7 + 937\ 881\ x_8 + 1\ 002\ 611\ x_9 + 941\ 124\ x_{10} = 1\ 762\ 741$;
- 6) $51\ 993\ 933\ x_1 + 44\ 824\ 316\ x_2 + 26\ 543\ 807\ x_3 + 18\ 425\ 766\ x_4 + 18\ 253\ 326\ x_5 + 19\ 381\ 502\ x_6 + 6\ 033\ 835\ x_7 + 12\ 488\ 415\ x_8 + 5\ 795\ 018\ x_9 + 7\ 872\ 158\ x_{10} = 26\ 543\ 807$;

On solving the above set of equations, we get to be 0.7853 which is the efficiency as found out by the primal problem. Also, we get the values of x_1 to x_{10} . For Tamil Nadu, x_8 comes to 2.125, while all the other x_i values are 0. The values for all the DMU's are found out similarly and are shown in Table 8.

The x_8 values for Tamil Nadu indicates that the peer state for Tamil Nadu is DMU 8 (Haryana) and also that the optimal values of input and output for Tamil Nadu can be obtained by multiplying the corresponding values of Haryana by a factor of 2.125. For example, the ideal number of factories is Tamil Nadu will be $4704 \times 2.125 = 10004$, where 4704 is the number of factories in Haryana. Comparing this with the current value of 21402, we get that the number of factories in Tamil Nadu have to be reduced 52.45%. Similarly, the percentage changes of all the input and output parameters for the different states have been found out and are shown in the table 9 (Talluri, May 2000).

5. Conclusion

This case study represents of the performances of Indian Pharmaceutical industry and various states of the country. With the help of available financial data of the pharmaceutical sector and the outputs of the various states, their efficiencies are compared using DEA. This empirical analysis is used for benchmarking of the various DMU's against the best performing DMU in their respective sectors.

In the Pharmaceutical sector Glenmark Pharmaceuticals is identified as the best performing DMU. However for the formation of efficiency frontiers which helps in the benchmarking of the other DMU's, companies such as Cipla, GSK

Pharmaceuticals and Divi's labs are considered. Above mentioned DMU's along with Glenmark are considered as Reference DMU's for comparing the other DMU's (Peers). The potential improvements that can be achieved for the peer DMU's are also estimated. Similarly among the states, Maharashtra is identified as the best performing DMU and the reference DMU's are Gujarat, Jharkhand and Hararyana along with the best performing DMU.

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Table 1: Performance of Pharmaceutical industries for the year 2009*All data is in million rupees**(Source: www.moneycontrol.com)*

DMU	Inputs			Outputs	
	Raw Materials	Employee Cost	Selling & Admin Expenses	Net Sales	Growth rate
Piramal	1 139.24	303.74	461.93	2 654.5	14.32
Sun Pharma	878.46	174.71	439.11	1 845.09	4.7
Ranbaxy	2 083.29	728.4	884.89	4 781.59	2.78
Dr Reddys	1 599.4	516.4	1 036.6	4 395.6	9.9
Cipla	2 687.54	318.87	867.98	5 605.69	7.1
GSK	7 28.65	209.71	182.82	1 884.14	12.39
Cadilla	806.2	266.9	554	1 885.6	8.1
Glenmark	288.66	115.01	279.59	1 029.56	19.01
Divi's Labs	410.06	93.22	37.51	931.63	11.41

Table 2: Relative Efficiencies of the DMU's

DMU	Piramal	Sun	Ranbaxy	Dr Reddy	Cipla	GSK	Cadilla	Glen	Divi's
Piramal	0.876	0.839	0.775	0.901	1	0.991	0.752	1	1
Sun	0.876	0.839	0.775	0.901	1	0.991	0.752	1	1
Ranbaxy	0.833	0.718	0.813	0.878	0.777	1	0.735	1	0.959
DrReddy	0.876	0.839	0.775	0.901	1	0.991	0.752	1	1
Cipla	0.876	0.839	0.775	0.901	1	0.991	0.752	1	1
GSK	0.870	0.812	0.787	0.898	0.947	1	0.750	1	1
Cadilla	0.876	0.839	0.775	0.901	1	0.991	0.752	1	1
Glenmark	0.876	0.839	0.775	0.901	1	0.991	0.752	1	1
Divi's	0.876	0.839	0.775	0.901	1	0.991	0.752	1	1

Table 3: Efficiencies of different DMU's using Dual model

DMU Name	Efficiency
Piramal	0.876
Sun Pharma	0.839
Ranbaxy	0.813
Dr Reddys	0.901
Cipla	1.000
GSK	1.000
Cadilla	0.752
Glenmark	1.000
Divi's Labs	1.000

Table 4: Contributions of slack variables towards the DMU's

	1	2	3	4	5	6	7	8	9
Piramal	0.000	0.000	0.000	0.000	0.053	0.000	0.000	1.107	1.307
Sun Pharma	0.000	0.000	0.000	0.000	0.193	0.000	0.000	0.715	0.031
Ranbaxy	0.000	0.000	0.000	0.000	0.000	1.761	0.000	1.421	0.000
Dr Reddys	0.000	0.000	0.000	0.000	0.045	0.000	0.000	3.058	1.065
Cipla	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
GSK	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
Cadilla	0.000	0.000	0.000	0.000	0.018	0.000	0.000	1.382	0.386
Glenmark	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
Divi's Labs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

Table 5: Potential improvements for the various DMU's

DMU Name	Target Raw Materials	Target Employee Cost	Target Selling and Admin Expenses	Target Net Sales	Target Growth rate
Cadilla	606.6	200.82	416.84	1 885.6	30.81
Dr Reddys	1 441.71	465.49	934.4	4 395.6	70.61
Piramal	997.9	266.06	404.62	2 654.5	36.33
Ranbaxy	1 693.55	532.8	719.35	4 781.59	48.84
Sun Pharma	736.91	146.56	368.35	1 845.09	15.31

Table 6: List of DMU's with outputs and inputs*(Source: Annual survey of Industries 2007-2008)*

State	No. of Factories	Invested capital (lakhs)	Total Labour	Emoluments per worker (per year)	Profits (lakhs)	Value of output (lakhs)
Maharashtra	18 304	21 476 750	1 354 827	151 614	7 549 581	51 993 933
Gujarat	15 107	20 955 836	1 045 475	105 605	4 234 836	44 824 316
Tamil Nadu	21 042	12 952 311	1 549 761	78 832	1 762 741	26 543 807
Karnataka	8 443	8 622 398	724 075	115 440	2 107 909	18 425 766
Andhra Pradesh	16 741	9 583 545	1 041 265	74 998	1 786 942	18 253 326
Uttar Pradesh	10 717	9 195 910	751 165	91 103	1 362 613	19 381 502
Jharkhand	1 615	2 976 122	152 668	119 197	1 540 724	6 033 835
Haryana	4 707	4 785 642	509 617	49 792	937 881	12 488 415
Chhattisgarh	1 854	3 086 215	155 819	55 786	1 002 611	5 795 018
Madhya Pradesh	3 165	3 643 168	255 293	48 439	941 124	7 872 158

(Source: Annual survey of Industries 2007-2008)

Table 7: Cross-efficiency Matrix

	Maharashtra	Gujarat	Tamil Nadu	Karnataka	Andhra Pradesh	Uttar Pradesh	Jharkhand	Haryana	Chhattisgarh	Madhya Pradesh
Maharashtra	1.000	0.951	0.600	0.825	0.534	0.747	1.000	1.000	0.894	0.884
Gujarat	1.000	1.000	0.542	0.761	0.512	0.724	1.000	0.835	0.912	0.854
Tamil Nadu	0.928	0.820	0.785	0.819	0.730	0.808	0.777	1.000	0.720	0.828
Karnataka	1.000	0.903	0.759	0.874	0.728	0.853	1.000	1.000	0.849	0.908
Andhra Pradesh	1.000	0.832	0.774	0.866	0.750	0.806	1.000	1.000	0.822	0.880
Uttar Pradesh	1.000	0.903	0.759	0.874	0.728	0.853	1.000	1.000	0.849	0.908
Jharkhand	1.000	1.000	0.542	0.761	0.512	0.724	1.000	0.835	0.912	0.854
Haryana	1.000	0.832	0.774	0.866	0.750	0.806	1.000	1.000	0.822	0.880
Chhattisgarh	0.912	1.000	0.407	0.629	0.396	0.604	1.000	0.639	0.915	0.750
Madhya Pradesh	1.000	0.903	0.759	0.874	0.728	0.853	1.000	1.000	0.849	0.908

Table 8: Contribution of slack values for all the DMU's

	1	2	3	4	5	6	7	8	9	10
Maharashtra	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gujarat	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tamil Nadu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.125	0.000	0.000
Karnataka	0.095	0.000	0.000	0.000	0.000	0.000	0.497	0.842	0.000	0.000
Andhra Pradesh	0.091	0.000	0.000	0.000	0.000	0.000	0.077	1.045	0.000	0.000
Uttar Pradesh	0.166	0.000	0.000	0.000	0.000	0.000	0.243	0.744	0.000	0.000
Jharkhand	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
Haryana	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000
Chhattisgarh	0.000	0.046	0.000	0.000	0.000	0.000	0.615	0.000	0.000	0.000
Madhya Pradesh	0.088	0.000	0.000	0.000	0.000	0.000	0.231	0.150	0.000	0.000

Table 9: Potential Improvements of Inefficient DMU's.

	No: of Factories (%)	Invested capital (%)	Total labour (%)	Emoluments per worker (%)	Profits (%)	Value of output (%)
Tamil Nadu	-52.45	-21.47	-30.11	34.25	13.09	0
Karnataka	-23.07	-12.58	-12.58	0	7.61	0
Andhra Pradesh	-59.91	-25	-35.88	0	0	0
Uttar Pradesh	-35.33	-14.69	-14.69	0	70.59	0
Chhattisgarh	-8.54	-9.12	-8.54	40.24	14.17	0
Madhya Pradesh	-14.68	-9.22	-9.22	0	23.79	0