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Evaluation of Efficiency of Automobile Manufacturing Companies in India Using Data Envelopment Analysis

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Abstract : This study seeks to measure and evaluate the efficiency of Automobile manufacturing companies in India using Data Envelopment Analysis (DEA) methodology. DEA is a methodology for evaluating and measuring the relative efficiencies of a set of decision making units (DMUs) that use multiple inputs and outputs. DEA provides management with information regarding the most efficient Automobile manufacturing companies in the observation set and identifies the relatively inefficient companies by comparison with the most efficient ones. Also, it indicates the magnitude of these inefficiencies.

Keywords: DEA; Efficiency; DMU; CCR model

INTRODUCTION

Automobile industry has been called as locomotive industry, as it is an industry with intensive technology and capital and presenting large industry linkage effects. Developing nations, therefore, regard it as the leading industry. It is the "world's largest manufacturing activity". The automobile industry, as a customer, motivates the development of iron–steel, petrochemical and tire industries. As a producer, it provides all types of motor vehicles for tourism, infrastructure maintenance, transportation, and agriculture. Therefore, any changes in the automobile industry will affect the entire economy. The quantity of automobiles in a country could be treated as an indicator of living standards. The Role of Automobile Industry in India GDP has been phenomenon. The rising productivity levels, which are associated to lower costs and increased production play a crucial role in the economic growth of a nation and also ensure sustained competitiveness at global front. Scarcity of resources has been recognized as a limiting factor on the process of economic growth. It is relevant to mention here that output expansion based on increased use of resources may be feasible but it cannot be sustainable. Therefore, efficiency or productivity of resources becomes a critical factor in economic growth.

Data Envelopment Analysis (DEA) is a relatively new data-oriented approach for evaluating the technical efficiency of a set of peer entities called Decision Making Units (DMUs). DEA provides a single measure and easily deals with multiple inputs and multiple outputs. Since the DEA technique was first developed, it has been widely applied to industries as diverse as health care (Bhat, Verma, & Reuben, 2001; Jacobs, Smith, & Street, 2006), Banking (Hassan & Sanchez, 2007), and transportation (Pathomsiri, 2006) and many other industries and organizations.

CCR-Model was introduced by Charnes, Cooper and Rhodes (1978). This model measures the efficiency of each DMU which is obtained as a maximum of the ratio of total sum of weighted outputs to total sum of weighted inputs. Consequently, the efficiency can be defined as follow.

$$\text{Efficiency}=\frac{Weighted\ Sum\ of\ Outputs}{Weighted\ Sum\ of\ Inputs}$$

The weights for the ratio are determined by the restriction that the similar ratios for every DMU have to be less than or equal to unity, thus reducing multiple inputs and outputs to a single "virtual" input and single "virtual" output without requiring pre-assigned weights. Therefore, the efficiency score is a function of the weights or the "virtual" input-output combination.

This study uses a CCR model to measure the relative efficiency of Seven Automobile Manufacturing Firms in India for the period 2011-16. It uses Two inputs (Total Expenses and Employees Benefits Expenses) and Two Outputs (Gross Asset and Total Operating Income). Using these inputs and outputs, technical efficiency of these firms is evaluated.

LITERATURE REVIEW

DEA involves an alternative principle for extracting information about a population of observations. In contrast to parametric approaches whose object is to optimize a single regression plane through the data, DEA optimizes on each individual observation with an objective of calculating a discrete piecewise frontier determined by the set of Pareto-efficient DMUs. Both the parametric and non-parametric (mathematical-programming) approaches use all the

information contained in the data. In parametric analysis, the single optimized regression equation is assumed to apply to each DMU. DEA, in contrast, optimizes the performance measure of each DMU. This results in a revealed understanding about each DMU instead of the mythical "average" DMU. In other words, the focus of DEA in on the individual observations as represented by the n optimizations (one for each observation) required in DEA analysis, in contrast to the focus on the averages and estimation of parameters that are associated with single-optimization statistical approaches.

The parametric approach requires the imposition of a specific functional form (e.g., a regression equation, a production function, etc.) relating the independent variables to the dependent variables(s). The functional form selected also requires specific assumptions about the distribution of error terms (e.g., independently and identically normally distributed) and many other restrictions, such as factors earning the value of their marginal product. In contrast, DEA does not require any assumption about the functional form. DEA calculates a maximal performance measure for each DMU relative to all other DMUs in the observed population with the sole requirement that each DMU lie on or below the extremal frontier. Each DMU not on the frontier is scaled against a convex combination of the DMUs on the frontier facet closest to it.
Charnes, Cooper, and Rhodes (1978) extended Farrell's (1957) idea linking the estimation of technical efficiency and production frontiers. Their CCR model generalized the single-output/input ration measure of efficiency for a single DMU in terms of a fractional linear-programming formulation transforming the multiple input/output characterization of each DMU to that of a single "virtual" output and virtual input. The relative technical efficiency of any DMU is calculated by forming the ratio of a weighted sum of outputs to a weighted sum of inputs, where the weights (multipliers) for both outputs and inputs are to be selected in a manner that calculates the Pareto efficiency measure of each DMU subject to the constraint that no DMU can have relative efficiency score greater than unity.

For each inefficient DMU (one that lies below the frontier), DEA identifies the sources and level of inefficiency for each of the inputs and outputs. The level of inefficiency is determined by comparison to a single referent DMU or a convex combination of other referent DMUs located on the efficiency frontier that utilize the same level of inputs and produce the same or higher level of outputs. This is achieved by requiring solutions to satisfy inequality constraints that can increase some outputs (or decrease some inputs) without worsening the other inputs or outputs. The calculation of potential improvement for each inefficient DMU does not necessarily correspond to the observed performance of any actual DMU making up the piece wise production frontier or to a deterministic projection of an inefficient DMU onto the efficient frontier. The calculated improvements (in each of the inputs and outputs) for inefficient DMUs are indicative of potential improvements obtainable because the projections are based on the revealed best practice performance of "comparable" DMUs that are located on the efficient frontier.

RESEARCH METHODOLOGY

DEA is a methodology for evaluating and measuring the relative efficiencies of a set of DMU's that use multiple inputs and outputs. The relative efficiency of p^{th} DMU can be obtained by using the following linear programming (LP) model (Charnes et al., 1978).

- *CCR- Model*

$$\text{Max } \theta_p = \sum_{r=1}^{s}(u_r\, y_{rp})$$

Such that

$$\sum_{i=1}^{m}(v_i\, x_{ip}) = 1$$

$$\sum_{r=1}^{s}(u_r\, y_{rj}) - \sum_{i=1}^{m}(v_i\, x_{ij}) <= 0;$$

$$U_r, v_j >= 0$$

Where

θ_p is the measure of relative efficiency of p^{th} DMU

i=1, 2, …., m denotes the no. of input
j=1, 2, …., p, .., n denotes the no. of DMUs
r=1, 2, …, s denotes the no. of output
x is the input.
y is the output.

CASE ILLUSTRATION AND DISCUSSION

This study incorporates seven Automobile Manufacturing firms as Decision Making Units (DMUs). The data set for this study has been divided into five Indian financial years i.e. from 2011-12 to 2015-16.
The inputs used for this study includes: - Total Expenses and Employees Benefits Expenses
The Outputs includes: - Gross Asset and Total Operating Income

The DMUs are enlisted below:

Table 1: List of DMUs

DMUs	Decision Making Units(DMUs)
1.	Bajaj Auto Ltd.
2.	Hero Motocorp Ltd.
3.	Force Motors Ltd.
4.	Mahindra & Mahindra Ltd.
5.	Maruti Suzuki India Ltd.
6.	Tata Motors Ltd.
7.	TVS Motor Company

A. The data set used for evaluating efficiencies is described below: -

- *DATA SET*

Table 2: Data set for FY 2011-12

Serial Number	Firm	Employee Benefits expenses (in crores)	Total Expenses (in crores)	Gross Asset (in crores)	Total Operating Income(in crores)
1.	Bajaj Auto Ltd.	540.11	15,976.85	11,081.07	20,137.02
2.	Hero Motocorp Ltd.	735.52	21,078.89	9,888.92	23,943.60
3.	Force Motors Ltd.	258.87	2,059.01	1,664.36	2,109.60
4.	Mahindra & Mahindra Ltd.	1,701.78	28,680.13	23,911.98	33,024.91
5.	Maruti Suzuki India Ltd.	843.8	34,267.70	22,302.20	36,413.90
6.	Tata Motors Ltd.	2,691.45	52,954.37	54,519.28	54,880.64
7.	TVS Motor Company	370.11	6,831.45	3,140.50	7,147.91

Table 3: Data Set for FY 2012-13

Serial Number	Firm	Employee Benefits expenses (in crores)	Total Expenses (in crores)	Gross Asset (in crores)	Total Operating Income (in crores)
1.	Bajaj Auto Ltd.	639.48	16,526.51	12,478.62	20,792.74
2.	Hero Motocorp Ltd.	820.92	21,637.29	9,641.65	24,166.49
3.	Force Motors Ltd.	262.32	1,997.24	1,707.83	2,016.37
4.	Mahindra & Mahindra Ltd.	1,866.45	35,819.17	27,453.59	41,168.26
5.	Maruti Suzuki India Ltd.	1,069.60	41,409.30	26,737.20	44,400.30
6.	Tata Motors Ltd.	2,837	46,262.79	52,184.77	46,853.92
7.	TVS Motor Company	407.13	6,938.67	3,135.60	7,193.09

Table 4: Data Set for FY 2013-14

Serial Number	Firm	Employee Benefits expenses (in crores)	Total Expenses (in crores)	Gross Asset (in crores)	Total Operating Income (in crores)
1.	Bajaj Auto Ltd.	726.58	16,223.87	14,747.60	20,855.92
2.	Hero Motocorp Ltd.	930.04	22,854.60	10,097.30	25,721.85
3.	Force Motors Ltd.	240.55	2018.93	1771.87	2081.56
4.	Mahindra & Mahindra Ltd.	2,163.72	36,909.85	31,288.65	41,266.49
5.	Maruti Suzuki India Ltd.	1,368.10	40,865.00	30,535.70	44,523.50
6.	Tata Motors Ltd.	2,877.69	38,607.08	49,734.42	38,121.14
7.	TVS Motor Company	476.11	7,640.80	3,564.70	7,992.06

Table 5: Data Set for FY 2014-15

Serial Number	Firm	Employee Benefits expenses (in crores)	Total Expenses (in crores)	Gross Asset (in crores)	Total Operating Income (in crores)
1.	Bajaj Auto Ltd.	897.3	17,769.35	15,562.32	22,194.43
2.	Hero Motocorp Ltd.	1,172.87	24,594.18	10,521.70	28,078.04
3.	Force Motors Ltd.	277.73	2,304.55	1,971.68	2429.49
4.	Mahindra & Mahindra Ltd.	2,316.93	35,460.60	32,944.87	39293.77
5.	Maruti Suzuki India Ltd.	1,606.60	45,934.00	33,549.30	50802.2
6.	Tata Motors Ltd.	3,091.46	41,754.01	49,943.17	38,183.04
7.	TVS Motor Company	592.42	9,616.46	4,604.65	10,073

Table 6: Data Set for FY 2015-16

Serial Number	Firm	Employee Benefits expenses (in crores)	Total Expenses (in crores)	Gross Asset (in crores)	Total Operating Income (in crores)
1.	Bajaj Auto Ltd.	918.44	17,820	15,672.76	23,600.86
2.	Hero Motocorp Ltd.	1319.56	24,595.84	12,340.69	28,990
3.	Force Motors Ltd.	303.7	2,881.94	2,293.85	3,131.23
4.	Mahindra & Mahindra Ltd.	2342.15	37,578.67	36,412.34	41,739.83
5.	Maruti Suzuki India Ltd.	1988.7	51,673.20	39,195.60	58,208.20
6.	Tata Motors Ltd.	3026.75	43,989.14	52,426.25	44,502.74
7.	TVS Motor Company	664.23	10,729.21	4,962.57	11,295.18

B. *The efficiency for the firms is calculated using Linear Programming (LP) Model.*

C. *The efficiency of various DMUs obtained using the CCR model is as follows:*

Table 7: Efficiency Score from 2011-16

DMUs / Year	1	2	3	4	5	6	7
2011-12	100	90.8	90.1	99.1	100	100	83.0
2012-13	100	89.6	89.5	94.2	100	100	82.4
2013-14	100	86.0	92.7	89.2	100	100	81.4
2014-15	100	90.0	93.3	96.1	100	100	83.9
2015-16	100	85.4	89.0	94.4	100	100	79.5
Average	100	88.36	90.92	94.6	100	100	82.04
Standard Deviation	0	2.47	1.95	3.6	0	0	1.68

Table 8: Average Efficiency scores of Automobile Companies

Serial No.	Financial Year	Efficiency Score
1	2011-12	94.71428571
2	2012-13	93.67142857
3	2013-14	92.75714286
4	2014-15	94.75714286
5	2015-16	92.61428571

- *Potential Improvements*

Although, there is always space for improvement but DMUs 1, 5 and 6 are the relatively most efficient DMUs. The potential improvements in other DMUs for each Financial Year and how it changed over the years is given below:

1. Force Motors Ltd.(DMU 2)

Financial Year	Potential Improvement	
	Employee B. Expenses (%)	Total Expenses (%)
2011-12	68.39	9.25
2012-13	65.35	10.41
2013-14	61.37	13.96
2014-15	58.18	9.98
2015-16	48.35	8.65

There is a decline in potential improvement of Employee Benefit expenses which means steps were taken to improve the efficiency. Further steps can be taken to improve efficiency and as of Financial Year 2015-16 48.35% reduction in employee benefit expenses would improve efficiency of the firm. A reduction of 8.65% in total expenses would lead to better efficient system.

2. Hero Motocorp Ltd. (DMU 3)

Year	Potential Improvements	
	Employee B. Expenses (%)	Total Expenses (%)
2011-12	12.69	9.88
2012-13	10.45	10.45
2013-14	7.34	7.34
2014-15	6.66	6.66
2015-16	3.93	2.75

There is a decline in improvements required to attain maximum efficiency which shows that steps were taken to improve it. As of financial Year 2015-16, 3.93% and 2.75% reduction in employee benefits expenses and total expenses respectively is essential for maximum efficiency.

3. Mahindra and Mahindra Ltd.(DMU 4)

Year	Potential Improvements	
	Employee B. Expenses (%)	Total Expenses (%)
2011-12	31.04	0.9
2012-13	23.63	5.77
2013-14	26.93	10.78
2014-15	15.89	3.94
2015-16	4.25	1.6

Following the trend, there is a decline in improvements required over the years to attain maximum efficiency which implies that necessary steps were taken in the past. As of financial Year

2015-16, 4.25% and 1.6% reduction in employee benefits expenses and total expenses respectively is essential for maximum efficiency.

4. TVS Motor Company (DMU 6)

Year	Potential Improvements	
	Employee B. Expenses (%)	Total Expenses (%)
2011-12	48.20	16.98
2012-13	45.60	17.60
2013-14	41.52	18.63
2014-15	31.26	16.14
2015-16	16.75	12.25

There is a small decrement in the potential improvements over the years which indicates that not many effective steps were taken to counter inefficiency. As of financial Year 2015-16, 16.75%and 12.25% reduction in employee benefits expenses and total expenses respectively is required to achieve maximum efficiency.

CONCLUSIONS

This study attempts to investigate the technical efficiency of Automobile Manufacturing firms from Financial Year 2011-12 to 2015-16.

The results suggest that the mean technical efficiency declined from 2011-12 to 2013-14 and then technical efficiency improved during the period 2013-14 to 2014-15. The result shows that Automobile Manufacturing Firms like Baja Auto Ltd., Maruti Suzuki India Ltd. and Tata Motors Ltd. are the most Efficient during the period and they have consistency in their performance.

Automobile Manufacturing Firms like Force Motors Ltd. and TVS Motor Company can be a matter of concern as their efficiency scores are below satisfactory level. The major factor leading to their poor performance is the excess expenditure on employees. Either they should let off some of the employees or reduce the employee benefits expenses. Firms like Hero Motocorp Ltd. and Mahindra & Mahindra Ltd. didn't perform either very well or poor. They can improve their efficiency by reducing the employee benefits expenses and their total expenses.

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