

# AN EMPIRICAL STUDY ON RISK-RETURN ANALYSIS TO COMPUTE EFFICIENCY OF INDIAN CEMENT COMPANIES DURING PRE- AND POST-RECESSION PERIODS

Arindam Banerjee\*

**Abstract** *The study aims at computing the efficiency of the cement companies in Indian scenario during the Pre- and Post period of recession by utilising Data Envelopment analysis. Linear program has been formulated by taking Risk (namely financial risk and business Risk) as inputs and Return (namely return on equity and return on assets) as outputs during the Pre- and Post- period of recession. The cement companies have been ranked according to their efficiency scores computed through the linear program. A further endeavour has been made in this paper to investigate whether the risk (namely financial risk or business risk) is having any impact on the efficiency score of the cement companies during the Pre and Post recession period by utilising multiple regression analysis. The study has also utilised the Spearman rank correlation to investigate if there is a significant difference between the ranks obtained by the cement companies during the pre and post period of recession. It is a very unique work in itself where the relationship between the risk and return has been explored to compute the efficiency score and to investigate whether risk is having any impact on the efficiency scores of the cement companies.*

**Keywords:** Risk, Return, Data Envelopment Analysis, Efficiency, Cement, India

**JEL Classification:** C61, C67.

## INTRODUCTION

Every investment has element of risk involved with it. Risk can be defined as the variability in return. Risk can be classified into a systematic risk and an unsystematic risk. Systematic risks are those types of risk, which cannot be controlled and diversified like market risk, inflation risk and interest rate risk. But unsystematic risk can be controlled and diversified. Two basic types of unsystematic risks associated with a company's functioning can be considered as 'Business Risk' and 'Financial Risk'. While business risk is related to the operating environment of the business, financial risk is associated with capital structure decisions of the company.

After reviewing a number of past literatures, none of the articles was found to explore the relationship between risk and return to investigate the efficiency of the companies. It was one of the main reasons for motivation of present study. Operating leverage was taken as the proxy of the 'Business Risk' and 'Financial Leverage' as the proxy of the financial risk. Data envelopment analysis has been utilised to compute the efficiency of the organisation.

The entire period of our study was segregated into pre-recession period (1999-00 to 2006-07) and post-recession period (2007-08 to 2014-15).

The outputs, which have been taken into consideration for the present study, relate to profitability of the firms. Return on Assets and Return on Equity have been taken the proxies for the profitability. The first ratio is very important from manager's point of view while the second ratio is important from equity shareholders' point of view. The first ratio takes into consideration earning before interest and tax while the second ratio takes into consideration the profit after tax.

The post-recession period includes the recession period also. As per the report of NBER, the recession started in the second half of 2007 and ended in mid of 2009. It started with subprime crisis, which originated in the United States. In India the effect of recession was also felt. Some of the important effects felt in the Indian economy were the plunging of BSE Sensex in December 2007 (around 20000) to March 2009 (around 8000), withdrawal of funds by Foreign Institutional investors, and adverse effect on GDP and Index of Industrial Production (IIP). The recession also had an adverse effect on IT and IT-enabled services like BPOs, KPOs, etc.

\* Assistant Professor, J.D. Birla Institute (Department of Management), Kolkata, West Bengal, India.  
Email: [arindamresearch790@gmail.com](mailto:arindamresearch790@gmail.com)

Hence, an effort has been made in this paper so as to measure the efficiency of the Indian cement companies during the pre and post period of recession taking 'Financial Risk' and 'Business Risk' as inputs and 'Return on Equity' and 'Return on Assets' as outputs.

## LITERATURE REVIEW

Data envelopment analysis is an operation research technique utilised to compute the efficiency of the decision-making units (DMUs). It is a very useful technique if there is more than one input and output. Charnes et al. in 1978 have defined efficiency as the ratio between weighted sum of inputs and weighted sum of outputs.

A number of past literatures has been surveyed for the present study:

Fred et al. (1994) utilised data envelopment analysis on financial data of U.S. computer industry with six input variables and three output variables to evaluate and make a comparison between three alternative sets of input-output variables.

Sunil et al. (2011) applied data envelopment analysis on the financial data of selected Indian pharmaceutical firms taking three input variables related to cost and three output variables related to profitability.

Malhotra et al. (2008) applied data envelopment analysis on financial data of sixteen pharmaceutical firms with three input variables and nine output variables.

Subramanyam et al. (2008) in their paper proposes model utilising data envelopment analysis to measure and assess the risk in Indian commercial banks. The empirical results reveal that exogenous risk is menace more to the public sector banks than foreign and private sector banks.

Narayanaswamy et al. (2014) in their paper examined the relative efficiency of the private sector banks by utilising data envelopment analysis and negative relationship was observed between non-performing assets and different type of efficiency during the period of study.

Bodla (2013) in his paper reviews and summarises the various researches done around the world on the subject of financial risk management so as to know about risk-management practices and to identify further scope of research. The review of the past study indicates that most of the previous studies concentrated on management of the financial risk but not on the measurement of these risks.

Hemrit et al. (2012) in their paper emphasis to identify the main sources of operational risk and to explain the potential benefits of managing such risk.

Alipour et al. (2011) in their paper investigate into the effect of business risk on bank's outsourcing process and their rankings in Iranian scenario.

Ozturk et al. (2016) in their paper have tried to statistically measure the effects of financial risk and business risk on firm values of logistics companies' BRICS-T countries that are listed on the stock exchange. It was concluded from the study that while business risk made an impact on firm values in countries like Turkey, China and India, it was found that financial risk affected Firm value in Russia, Brazil and South Africa.

Ferus (2014) in his paper has tried to develop a new procedure to forecast credit risk of companies in Polish economic environment by utilising data envelopment analysis. In order to verify and compare the efficiency of various methods of company credit risk estimation, the efficiency of classification of companies has also been examined.

Anthony et al. (2019) in their paper has investigated into the financial aspects and financial ratios of seven Indian chemical companies and have applied data envelopment analysis to find out the efficiency of the chemical companies in Indian scenario.

Siew et al. (2018) in their paper have proposed a DEA model by incorporating the financial ratios and risk factors by evaluating and comparing the efficiency of financial companies in Malaysian scenario. The study has helped to identify the efficient financial companies as well as to determine the optimal input and output combination to maximise the efficiency of the financial companies in Indian scenario.

Sin (2019) in his paper have tried to measure the financial efficiency of firms by considering inputs and procurement capital. The study concluded that the management performance in terms of inputs was inefficient but was efficient in terms of procurement capital. The study also analyses current financial positions in terms of each DMUs and suggest means to improve financial positions.

Kohl (2019) in their paper reviewed the work of around 262 past papers with special focus of the application of data envelopment analysis on the healthcare sector with an emphasis on hospitals. The work also analyses on the inputs and outputs and well as the methodological settings of the different papers analysed.

Charnes, Cooper and Rhodes (1978) were the first to introduce to the concept of DEA. They made a scalar measure of efficiency of each participating unit known as decision-making units (DMUs). The paper developed methods for objectively determining weights by taking into consideration multiple inputs and outputs similar to ordinary

linear programming. Initially, the efficiency was measured for non-profit organisations.

Banker, Charnes and Cooper (1984) in their paper developed mathematical programming to measure the operational efficiency of the DMUs.

Anderson and Peterson (1993) developed the super efficiency analysis. In their paper, they developed guidelines to rank the efficient units and proposed a super-efficient DEA model to replace the traditional DEA approach. The paper also formulated techniques to compare the ranks computed on basis of parametric methods.

Golany and Roll (1989) in their paper established a thumb rule that the number of decision-making units taken for the study should be at least twice the number of inputs and outputs considered for the study.

Bowlin (1998) mentioned that the number of decision-making units should be thrice the number of inputs and outputs taken for the study.

Thus, the past seminal works of Charnes, Cooper and Rhodes (1978), Banker, Charnes, Cooper (1984), Anderson and Peterson (1993), Golany and Roll (1989) and Bowlin (1998) have also been referred to while formulating the linear programming to compute the efficiency and super efficiency scores of the cement companies as well choosing the appropriate number of decision-making units for the present study. This has been further discussed in the research methodology section regarding the number of decision-making units that has been taken for the study.

## RESEARCH METHODOLOGY

The present study has been conducted on the cement industry in Indian scenario. An endeavour has been made in this study to find out the efficiency of the different companies of the cement industry.

The entire period of study has been segregated into pre- and post-recession period. Pre-recession period has been taken from the time period of 1999-00 to 2006-07. Post-recession period has been taken from 2007-08 to 2014-15. Lingo 11.0 and SPSS 20.0 software has been used for analysis purpose.

Two inputs related to risk namely 'Financial Risk' and 'Business Risk' and two outputs related to profitability namely 'Return on Equity' and 'Return on Assets' have been taken into consideration for the study.

Data envelopment analysis is an operation research technique utilised to compute the efficiency of the decision-making units (DMUs). In this paper, a linear program has been formulated to compute the efficiency of the decision-making units, i.e. the cement companies.

A further endeavour has been made in this research paper to observe whether 'Business risk' and 'Financial risk' are having any influence on the efficiency scores during the Pre and Post period of recession. This has been investigated utilising multiple regression analysis.

Further, in this paper, Spearman rank correlation technique has been utilised to investigate if there is significant difference between the ranks obtained by the Indian cement companies during the pre and post period of recession.

Golany and Roll (1989) and Bowlin (1998) [referred to in literature review section] has been utilised to calculate the number of decision-making units for the present study. According to the two literatures taken into consideration,  $n \geq \max \{2*m*s; 3(m + s)\}$  where  $n$  denotes the number of sample decision making unit, 's' for number of outputs and 'm' is number of Inputs. The present study takes into consideration two (2) inputs and two (2) outputs. Hence, the number of decision-making units will be  $\geq \max \{8; 12\}$  i.e. 12.  $[2*2*2 = 8; 3(2+2) = 12]$

A total of 12 cement companies in form of decision-making units has been taken into consideration for the present study.

The data related to the all four variables, i.e. 2 inputs (Business Risk and Financial Risk) and 2 outputs (Return on Equity and Return on Assets) related to the 12 cement companies has been derived from CMIE Prowess database software. These cement companies were selected on basis of their turnover.

The list of Indian cement companies taken into consideration for the present study has been given in Annexure 1 under the list of cement companies.

## OBJECTIVES OF THE STUDY

The major objectives of the present study can be stated as below:

- To compute the efficiency scores of the Indian cement companies during the pre and post period of recession taking "Business Risk" and "Financial Risk" as the inputs and "Return on Equity" and "Return on Assets" as the outputs.
- To rank the Indian cement companies on basis of the efficiency scores obtained during the pre and post period of recession.
- To investigate whether "Financial risk" and "Business risk" are significantly influencing the efficiency scores of the Indian cement companies during the pre and post period of recession utilising multiple regression technique.

- To investigate if there had been a significant difference between the ranks obtained by the Indian cement companies during the pre and post period of recession utilising Spearman rank correlation technique.

## DEFINITION OF THE VARIABLES TAKEN FOR THE STUDY

### Inputs

Two inputs namely Business Risk and Financial risk has been taken for the study.

*Business Risk:* Operating Leverage has been taken as the proxy for Business Risk. Business Risk is basically caused due to the operating environment and presence of fixed cost in the cost structure. Degree of Operating Leverage can be defined as the percentage change in EBIT (Earnings before Interest and Tax) due to percentage change in Sales.

Business Risk = Percentage change in EBIT/Percentage change in Sales

$$= \{EBIT_t - EBIT_{t-1}/EBIT_{t-1}\} / \{Sales_t - Sales_{t-1}/Sales_{t-1}\}$$

In the above formula, EBIT = Average EBIT from 1999-00 to 2006-07 for Pre-Recession period and from 2007-08 to 2014-15 for Post-recession period.

Also, the Sales figures includes Average Sales from 1999-00 to 2006-07 for Pre-Recession period and from 2007-08 to 2014-15 for Post-recession period.

*Financial Risk:* Financial Leverage has been taken as the proxy for Financial Risk. Financial Risk is caused due to inclusion of more debt in the capital structure. Hence, the risk related to capital structure decisions is known as financial risk. When we introduce more debt in capital structure, the financial risk increases due to increase in the fixed rate of interest amount that has to be paid on the debt component. Even if a company does not earn profit, the company has to pay the fixed interest amount on the debt component. It is a kind of unsystematic risk, which can be controlled and diversified.

Financial Risk has been defined as the ratio of debt and equity in this paper.

Hence, Financial Risk = Debt/Equity.

### Outputs

Two outputs related to profitability taken into consideration for the study relates to:

*Return on Equity:* ROE is a very important ratio from the equity shareholders' point of view. It is observed that with the increase of debt component in the capital structure results in trading on equity which increases the return to the equity shareholders. Hence, though from the company's point of view, the financial risk increases with the increase of debt component in the capital structure, the return to equity shareholders also increases.

ROE = Average PAT (Profit after Tax)/ Average Net worth

*Return on Assets:* ROA is a very important ratio from manager's point of view. It indicates if the managers of the company are able to efficiently utilise its assets to generate revenue for the company.

ROA = Average EBIT (Earnings before Interest and Tax)/ Average Total Assets

## RESULTS AND FINDING

Two inputs related to risk namely 'Business Risk' and 'Financial Risk' and two outputs related to profitability namely 'Return on Equity (ROE)' and 'Return on Assets (ROA)' have been taken into consideration for the present study.

The present study has been segregated into pre-recession period (1999-00 to 2006-2007) and post-recession period (2007-08 to 2014-2015). It has been an endeavour in this study to understand if there is a change in the efficiency score obtained by the cement companies in Indian scenario during the post-recession period in comparison to the pre-recession period.

To compute the efficiency score, data envelopment analysis has been utilised in this study. Linear program has been developed taking the inputs and outputs in the study so as to measure the efficiency of the firms belonging to the cement industry.

Business Risk has been computed through operating leverage and Debt/Equity ratio has been taken as the proxy of Financial Risk.

The 12 Indian cement companies have been taken as decision making units (DMUs) for the present paper.

The proxy for profitability taken into consideration for the study includes ROE (Return on Equity) and ROA (Return on Assets).

### Pre-Recession Period (1999-00 to 2006-07)

The efficiency scores for 12 cement companies in India have been computed for the pre-recession period from 1999-00



to 2006-07 utilising data envelopment analysis. The list of the 12 cement companies taken into consideration for the present study has been provided in Annexure 1.

Linear program has been developed to compute the efficiency scores of the cement companies. Two inputs related to risk ('Business Risk' and 'Financial Risk') and two outputs related to profitability ('Return on Assets' and 'Return on equity') have been taken into consideration for the present study.

The sample linear program for ACC Ltd to compute the efficiency score has been given in Annexure 2.

The efficiency score computed for the Indian cement companies are given in Table 1 for the pre-recession period. The ranks obtained by the companies as per their efficiency scores have also been given in Table 1. The result of Table 1 is given below:

**Table 1: Efficiency Scores and the Ranks of the Indian Cement Companies (Pre-Recession Period)**

Companies	Efficiency Scores	Rank
A C C Ltd.	0.67	3
Ambuja Cements Ltd.	0.726	2
Birla Corporation Ltd.	0.784	1
Century Textiles & Inds. Ltd.	0.59	6
Chettinad Cement Corpn. Pvt	0.635	4
India Cements Ltd.	0.257	11
J K Lakshmi Cement Ltd.	0.14	12
My Home Inds. Pvt. Ltd.	0.378	10
O C L India Ltd. [Merged]	0.562	7
Prism Johnson Ltd.	0.456	9
Ramco Cements Ltd.	0.6	5
Shree Cement Ltd.	0.514	8

Source: Computed by the Author

It can be observed from Table 1 that Birla Corporation Ltd has been ranked as number 1 (one) company as per its efficiency score followed by Ambuja Cement Limited and ACC Ltd during the Pre-recession period (1999-00 to 2006-07).

A further endeavour has been made in this paper to investigate whether 'Financial Risk' or 'Business Risk' is influencing the efficiency scores of the Indian cement companies during the pre-recession period. To attain this objective, multiple regression analysis has been conducted by utilising SPSS 20.0 by taking "Efficiency score" as the dependent variable and "Financial Risk" and "Business Risk" as the independent variables.

It can be observed from Table 2 that the R square (Coefficient of Determination) is .806. It means that "Financial Risk" and "Business Risk" is explaining the dependent variable, i.e. efficiency score to the extent of 80.6%. The result of Table 2 is given below:

**Table 2: Regression Result (R Square) Pre-Recession Period**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.898 <sup>a</sup>	.806	.763	.09256

a. Predictors: (Constant), Business Risk, Financial Risk

Source: Computed by the Author

The regression results from Table 3 further indicates that "Financial Risk" with t value of -5.182 and p value of .001 is significantly but negatively influencing the efficiency score during the pre-recession period. "Business Risk" with t value of -.968 and p value of .358 is insignificant. The result of Table 3 is given below:

**Table 3: Regression Results (t Value and p Values) Pre-Recession Period**

Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.815	.057		14.315	.000
	Financial Risk	-.126	.024	-.826	-5.182	.001
	Business Risk	-.010	.010	-.154	-.968	.358

a. Dependent Variable: Efficiency Score.

Source: Computed by the author

## Post-Recession Period (2007-08 to 2014-15)

Like the pre-recession period, efficiency scores of the Indian cement companies have been computed for the post-recession period for 8 years i.e. from 2007-08 to 2014-15. Linear program has been formulated utilising data envelopment analysis. Two inputs related to risk i.e. "Financial Risk" and "Business Risk" and two outputs related to Profitability namely "Return on equity" and "Return on assets" have been taken into consideration for the study. The sample linear program for ACC Ltd. has been provided in Annexure 3.

The efficiency scores computed for post-recession period has been given in Table 4. The companies are also ranked according to efficiency score in Table 4. The result of Table 4 is given below:

**Table 4: Efficiency Scores and the Ranks of the Indian Cement Companies (Post Recession Period)**

Companies	Efficiency Score	Rank
A C C Ltd.	0.5303	1
Ambuja Cements Ltd.	0.1243	2
Birla Corporation Ltd.	0.0521	5
Century Textiles & Inds. Ltd.	0.0102	12
Chettinad Cement Corpn. Pvt. Ltd.	0.0196	10
India Cements Ltd.	0.0276	6
J K Lakshmi Cement Ltd.	0.0197	9
My Home Inds. Pvt. Ltd.	0.1164	3
O C L India Ltd. [Merged]	0.0232	7
Prism Johnson Ltd.	0.0212	8
Ramco Cements Ltd.	0.0146	11
Shree Cement Ltd.	0.0522	4

Source: Computed by the author

It can be observed from Table 4 that ACC Ltd has been ranked a number one as per its efficiency score followed by Ambuja Cements Ltd and My Home Inds. Pvt. Ltd.

Multiple regression analysis has been conducted through SPSS 20.0 taking the “efficiency score” as the dependent variable and “Financial Risk” and “Business Risk” as the independent variables. It is observed from the regression results the R square is .380 in case of post-recession period. It means that 38% of the variation in dependent variable (Efficiency score) is explained by the independent variables (Financial Risk and Business Risk). The result of Table 5 is given below:

**Table 5: Regression Results R<sup>2</sup> Post Recession Period**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.617 <sup>a</sup>	.380	.243	.12672

Predictors: (Constant), Operating Risk, Financial Risk

Source: Computed by the author

It is further observed from the regression results in Table 6 that “Financial Risk” with t value of -2.161 and p value of .029 is significantly and negatively influencing the efficiency score of the firms belonging to the cement industry in Indian scenario during the post-recession period. Business Risk with t value of -.683 and p value of .512 is insignificant. The

result of Table 6 is given below:

**Table 6: Regression Results (t Value and p Values) Post-Recession Period**

Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.211	.065		3.235	.010
	Financial Risk	-.139	.064	-.570	-2.161	.029
	Business Risk	-.008	.012	-.180	-.683	.512

a. Dependent Variable: Efficiency Score

Source: Computed by the author

## Spearman Rank Correlation

Spearman rank correlation technique has been utilised to investigate if there is significant difference between the ranks obtained by the Indian cement companies during the Pre and Post period of recession. SPSS 20.0 has been used for the purpose.

It is observed from Table 7 that the Spearman rank correlation is .203. As the Spearman rank correlation is .203 which is less than .500, it can be safely deduced that there is a significant difference between the ranks obtained by the Indian cement companies during the Pre and Post period of recession. The result of Table 7 is given below:

**Table 7: Spearman Rank Correlation**

Correlations				
			Rank Pre	Rank Post
Spearman's rho	Rank Pre	Correlation Coefficient	1.000	.203
		Sig. (2-tailed)	.	.527
		N	12	12
	Rank Post	Correlation Coefficient	.203	1.000
		Sig. (2-tailed)	.527	.
		N	12	12

Source: Computed by the author

## CONCLUSIONS

It has been observed from the results of the present study that Birla Corporation Ltd has been ranked as number 1 (one) company as per its efficiency score followed by Ambuja Cement Limited and ACC Ltd during the pre-recession period. While during the post-recession period ACC Ltd has

been ranked a number one as per its efficiency score followed by Ambuja Cements Ltd and My Home Inds. Pvt. Ltd.

It is further observed that during both the pre and post-recession periods, financial risk is a very important and significant variable influencing the efficiency scores of the Indian cement companies.

From the Spearman rank correlation, it can be deduced that there is a significant difference between the ranks obtained by the companies during the pre and post period of recession. Hence, it can be safely deduced that recession did have an impact on the efficiency of the cement companies in Indian scenario. The main reason for such significant decrease may further be investigated into calculating the mean (average) of the four inputs and outputs during the pre and post period of recession. It is observed from Table 8 that the return on equity and return on assets have decreased by 11.01% and 1.60%, respectively, while the inputs in form of Operating risk and Financial risk have decreased by 64.65% and 58.12%, respectively, which is large in terms of decrease in post-recession period compared to pre-recession period. It may explain the reason behind the significant difference between the ranks obtained by the cement companies during the pre and post period of recession.

The result of Table 8 is given below:

**Table 8**

	N	Pre Mean	Post Mean	% increase/ Decrease
Return on Equity	12	.1516	.1349	(11.01)
Return on Assets	12	.1120	.1102	(1.60)
Operating Risk	12	4.3481	1.5368	(64.65)
Financial Risk	12	1.9649	.8228	(58.12)
Valid N (listwise)	12			

Source: Computed by the author

It is observed that financial risk is significantly and negatively influencing the efficiency score of the cement companies. It may indicate that with the increase of financial risk, the efficiency scores are decreasing of the cement companies. Hence, the cement companies should be cautious while designing the capital structure so as to minimise the financial risk to increase its efficiency.

## IMPLICATION OF THE STUDY AND SCOPE OF FUTURE RESEARCH

One of the important motivations for doing this study was that previously no such work has been conducted. The study mainly focussed on measuring the efficiency of the

cement companies in Indian scenario taking risk as input and profitability as output during the pre and post period of recession. It was observed from the study that recession did have an impact on the efficiency of the cement companies. Financial risk was found to be significantly influencing the efficiency scores of the cement companies during the pre and post recession period. The cement companies should try to minimise the financial risk so as to maximise the efficiency of the companies by designing its capital structure appropriately.

The present study has been conducted on the cement companies in Indian scenario. The future research can encompass other industries. The study has been conducted by taking two inputs (related to risk) and two outputs (related to profitability) to measure the efficiency of the companies. The future scope can take into consideration other risks apart from financial and business risk and other profitability parameter other than return on equity and return of assets for their future study.

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## ANNEXURE 1: LIST OF CEMENT COMPANIES

A C C Ltd.	J K Lakshmi Cement Ltd.
Ambuja Cements Ltd.	My Home Inds. Pvt. Ltd.
Birla Corporation Ltd.	O C L India Ltd. [Merged]
Century Textiles & Inds. Ltd.	Prism Johnson Ltd.
Chettinad Cement Corpn. Pvt. Ltd.	Ramco Cements Ltd.
India Cements Ltd.	Shree Cement Ltd.

Source: Compiled by the Author

## ANNEXURE 2: LINEAR PROGRAM FOR ACC LTD TO COMPUTE THE EFFICIENCY SCORE (PRE-RECESSION PERIOD)

Min = Theta;

$$1.095 * w_1 + 0.73375 * w_2 + 0.935 * w_3 + 1.59375 * w_4 + 2.05375 * w_5 + 3.55375 * w_6 + 5.2125 * w_7 +$$

$$1.93625 * w_8 + 1.3075 * w_9 + 1.6075 * w_{10} + 1.945 * w_{11} + 1.605 * w_{12} \leq 1.095 * \theta;$$

$$3.518923151 * w_1 + 1.147889986 * w_2 + 7.770423668 * w_3 + 1.942861194 * w_4 + 1.805707337 * w_5 + 4.457857081 * w_6 + 8.63477934 * w_7 + 7.680808119 * w_8 + 2.04145123 * w_9 + 9.034393687 * w_{10} + 1.911535826 * w_{11} + 2.230793557 * w_{12} \leq 3.518923151 * \theta;$$

$$0.12774428 * w_1 + 0.205600273 * w_2 + 0.137470593 * w_3 + 0.085518222 * w_4 + 0.110957195 * w_5 + 0.061062392 * w_6 + 0.046595365 * w_7 + 0.157458718 * w_8 + 0.099949918 * w_9 + 0.122897898 * w_{10} + 0.117298725 * w_{11} + 0.07200344 * w_{12} \geq 0.12774428;$$

$$0.210784 * w_1 + 0.27954 * w_2 + 0.222295 * w_3 + 0.122236 * w_4 + 0.157007 * w_5 + 0.056085 * w_6 + 0.05966 * w_7 + 0.236866 * w_8 + 0.141245 * w_9 + 0.117345 * w_{10} + 0.201014 * w_{11} + 0.134031 * w_{12} \geq 0.210784;$$

$$w_1 + w_2 + w_3 + w_4 + w_5 + w_6 + w_7 + w_8 + w_9 + w_{10} + w_{11} + w_{12} = 1;$$

$$w_1 \geq 0; w_2 \geq 0; w_3 \geq 0; w_4 \geq 0; w_5 \geq 0; w_6 \geq 0; w_7 \geq 0; w_8 \geq 0; w_9 \geq 0; w_{10} \geq 0; w_{11} \geq 0; w_{12} \geq 0;$$

## ANNEXURE 3: LINEAR PROGRAM FOR ACC LTD TO COMPUTE THE EFFICIENCY SCORE (POST-RECESSION PERIOD)

Min = Theta;

$$0.05375 * w_1 + 0.02125 * w_2 + 0.4075 * w_3 + 2.07 * w_4 + 1.07875 * w_5 + 0.7675 * w_6 + 1.075 * w_7 + 0.1825 * w_8 + 0.915 * w_9 + 1 * w_{10} + 1.45375 * w_{11} + 0.84875 * w_{12} \leq 0.05375 * \theta;$$

$$-0.295438 * w_1 - 0.305799808 * w_2 - 0.257884827 * w_3 + 0.518368701 * w_4 + 3.968890532 * w_5 + 11.09643407 * w_6 + 0.296285158 * w_7 - 0.092949934 * w_8 + 1.018749325 * w_9 + 0.385418585 * w_{10} + 0.604785839 * w_{11} + 1.505173763 * w_{12} \leq -0.295438 * \theta;$$

$$0.16521279 * w_1 + 0.18799763 * w_2 + 0.12315479 * w_3 + 0.05044396 * w_4 + 0.10200902 * w_5 + 0.06266577 * w_6 + 0.0922105 * w_7 + 0.12095085 * w_8 + 0.100216 * w_9 + 0.06668651 * w_{10} + 0.10482944 * w_{11} + 0.14593877 * w_{12} \geq 0.16521279;$$

$$0.192106498 * w_1 + 0.181097986 * w_2 + 0.151658001 * w_3 + 0.080650323 * w_4 + 0.130347631 * w_5 + 0.068021215 * w_6 + 0.140013482 * w_7 + 0.108970128 * w_8 + 0.127411111 * w_9 + 0.066946098 * w_{10} + 0.166877488 * w_{11} + 0.205167036 * w_{12} \geq 0.192106498;$$

$$w_1 + w_2 + w_3 + w_4 + w_5 + w_6 + w_7 + w_8 + w_9 + w_{10} + w_{11} + w_{12} = 1;$$

$$w_1 \geq 0; w_2 \geq 0; w_3 \geq 0; w_4 \geq 0; w_5 \geq 0; w_6 \geq 0; w_7 \geq 0; w_8 \geq 0; w_9 \geq 0; w_{10} \geq 0; w_{11} \geq 0; w_{12} \geq 0;$$