PERFORMANCE EFFICIENCY ANALYSIS OF THIRTEEN POWER GENERATING CORPORATIONS FUNCTIONING IN INDIA – USING DATA ENVELOPMENT ANALYSIS

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Abstract:
Purpose: The aim of this research work is to investigate and examine the performance of the Power Plants of India individually and to identify the best operating plant.
Design / Methodology/ Approach: For this study, the researcher collected the data of the Power Plants of India for the financial years 2009 to 2013 by considering four input variables and two output variables. The Data Envelopment Analysis technique has been employed to study the performance of the power plants individually.
Findings
Our study reveals that
- ✓ Four power plants are relatively efficient based on the input oriented technical efficiency [CRS].
- ✓ Six power plants are efficient based on the input oriented technical efficiency [VRS].

Altogether only four Power Plants Are functioning effectively and efficiently and the remaining Power Plants are not functioning up to that expected level.

Keywords: Data Envelopment Analysis, Decision Making Unit, Performance, Efficiency, Constant Return to Scale, Variable Return to Scale.

Introduction: It is one of the main activities of any firm to monitor its efficiency. In the current scenario, there are a number of methods based either on the traditional approach or using IT to evaluate the efficiency of a system. Efficiency measurement methods can be divided into three main categories: ratio indicators, parametric and non-parametric methods. In selecting indicators to measure efficiency one can focus primarily on a firm's inputs and outputs.

In general, the term productive unit refers to a unit producing certain outputs by utilizing certain inputs. The evaluation of efficiency in production units and determining the sources of their inefficiency is a precondition to effectively improve the performance of any such unit in a competitive environment.

Power Plant[s] can be considered as production units too. In general, they are homogeneous units performing similar activities. All inputs and outputs have an impact on the efficient operation of such units, even though some are relatively considered to be more important or less important to each other.

Performance is normally referred to as the Power Plant's ability to generate electricity by effectively utilizing its resources. Based on the economical term, efficiency refers to the ratio of outputs to inputs.

Input refers to the scarce resource and output in terms of goods and services offered to the consumers. One can understand the notion of efficiency in terms of Power Plant as more beneficial as the Power sector is deemed to play a vital role in the financial division of a country. The Power sector of a country is one of the most important sectors of the country's economy. Hence, it is highly essential to measure its performance using the proper tool.

Usually, the performance is measured with the help of Financial Management tools like, Return on Assets [ROA], Return on Investments [ROI], Return on Equity [ROE], Equity to Assets [ETA] and Internal Growth of Equity [IGE], etc. These measures are lacking in the sense because they are not total productivity measures but are partial productivity measures. As a blessing in disguise, Data Envelopment Analysis (DEA) came as a rescuing tool. It is considered as a tool for measuring total productivity. That is, one can mix all the inputs and outputs to study the effectiveness of any type of organization.

The large numbers of Power Plants in India, their high branch density, the quick technological change and the increased competition have added more pressure to improve performance. Instead of studying a Power Plant partial productivity, with the available Financial Management Tool like Ratio Analysis, it is the need of the present decades to study the total productivity. In this context, the author has introduced the concept of the DEA model in this research paper. This system has the benefit of developing a data-driven technological frontier that necessitates no specification of any scrupulous functional shape or error structure. This study fills the gap in the literature by leaving from the traditional method of evaluating the efficiency of a Power Plant.

DEA was first introduced by (Charnes et al., 1978) as a Mathematical Programming Model with the help of the theoretical framework given by (Farrell, 1957), for computing the relative efficiencies of multiple Decision Making Units (DMUs), and it falls under the special category of Fractional Programming. DEA is a special technique which offers a comparative ratio for each unit in terms of output and input. The ratio is stated as efficiency scores for each unit. The measure of performance lies in the range 0 to 1. If the performance measure is 1 then the organization is considered to be highly efficient and if the measure is tending towards 0, the efficiency is otherwise. One of the significant roles of DEA is that the efficiency scores indicate the gap for potential improvements and developments for inefficient DMUs. DEA firstly applied by (Sherman and Gold, 1985) for assessing the efficiency of bank branches, is a tool for evaluating relative efficiency since it first identifies the bank's efficiency frontier and then compares it with other banks. It allows ranks to be awarded to the banks according to their technical efficiency scores and also to single out the driving forces for inefficiencies.

In the Power sector, the DEA model is preferable to an econometric approach of efficiency measurement because it has a number of advantages.

They are:

- ✓ It can simultaneously analyze several inputs and outputs, which is an alternative characteristic, because generation and distribution in the Power sectors often involves multiple inputs and outputs.
- ✓ It does not require any assumptions about the functional form of technology, and
- ✓ It calculates a maximal performance measure for each production unit relative to all other production units in the observed population with the sole condition that each production unit lies on or below the external.

This paper differs entirely from all other previous works by investigating and examining the current performance of the Power Plants in India individually, in terms of their efficiency for the period [2009 – 2013] using the Data Envelopment Analysis. This study classifies the Power Plants into two categories as efficient and inefficient. The remedial measures are discussed in order to improve the efficiency of the Power Plants.

Review of Literature: (Seiford and Zhu, 1999) examined the profitability and marketability of the top 55 U.S. commercial banks by applying the DEA model and concluded that large banks performed better with respect to profitability than small size banks, while small size banks have the better characteristic of marketability as compared to large size banks.

(Maudos et al, 2002) studied the cost and profit efficiency of 832 European banks based on ten European Union Countries (period 1993 – 1996). The return on assets (ROE) and return on equity (ROA) were acquired as performance measures to check profit efficiency of banks using DEA. This study was made based on the four dimensions, namely the market characteristics, differences in size, other bank characteristics and specialization. Variations in profit terms were found to be greater than the variations in cost terms.

(Park and Weber, 2006) tested the profitability of all Korean banks by testing with (traditional hypothesis approach) market structure hypothesis against efficient structure hypothesis applied after examination of the panel data (for the period of 1992-2002); with the help of (DEA) model. The outcome of this study shows that the performance measures significantly affects the profitability of banks.

(Pastor, Lovell and Tulkens, 2006) discussed the financial performance of branch offices. They studied 573 branch offices, for a six-month accounting period, of large European savings banks. Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH) programming, mathematical models were used to estimate financial performance with respect to their safeguard against expenses in giving customer services and building customer bases. They concluded that the financial performance evaluation factors can be reduced without statistical loss of significant information to the bank management.

(Sufian, 2009) studied the efficiency of the Malaysian banking sector during the Asian Crisis of 1997 for the period of 1995-1999. The efficiency of individual banks was computed by DEA technique. They considered the Profitability as the major ingredient which was used to evaluate the efficiency with other explanatory variables, like bank size and ownership. The outcome of this study indicated that as there is a positive association between the Efficiency of banks and loans intensity and the relationship is otherwise for the economic conditions and expense preference behavior.

(IzahMohdTahir, Nor Mazlina Abu Bakar and SudinHaron, 2009) evaluated the overall pure technical and scale efficiencies for Malaysian commercial banks during the period 2000-2006. The results suggest that domestic banks were relatively more efficient than foreign banks. They suggested that the domestic banks' inefficiency were attributed to the pure technical inefficiency rather than scale inefficiency. In contrast, foreign banks inefficiency was attributed to scale inefficiency rather than pure technical inefficiency.

(Khalid AlKhathlan and Syed Abdul Malik, 2010) analyzed the relative efficiency of Saudi Banks using annual data from 2003 through 2008 using DEA. The results show that, on a relative scale, Saudi banks were efficient in the management of their financial resources. In addition, the results would provide crucial information about the Saudi banks' financial conditions and management performance for the benefit of bank regulators, managers and bank stock investors.

(Nigmonov, 2010) studied the banks' performance and efficiency in Uzbekistan for the period of 2004-2006. The basic two DEA models were applied to analyze the data under the assumption of a constant and variable return to scale. The results have revealed that inefficiency occurs due to technical efficiency and overall banks average efficiency level decreased.

(Sufian and Habibullah, 2010) analyzed the efficiency of the Thailand banking sector covering the duration 1999-2008 with the help of DEA approach. The results have shown that inefficiency was offset during formulation of technical efficiency with respect to pure technical efficiency in the banking sector. The efficiency level of banks in data envelopment analysis is measured using a ratio of weighted sum of the outputs of the weighted sum of inputs.

(Joseph Magnus Frimpong, 2010) examined the relative efficiency of the banks in Ghana during the year 2007 based on the dataset provided by Ghana Banking.

(Mehmet HasanEken and Suleyman Kale, 2011) studied the performance model for measuring the relative efficiency and potential improvement capabilities of bank branches by identifying their strengths and weaknesses and the production and profitability aspects of the branches. Under both productivity and profitability approaches, efficiency characteristics of branches, which are grouped according to different sizes and regions, have similar tendencies. In both analyses, it is apparent that branch size and scale efficiency are related to each other. As branch size increases scale efficiency increases too, and after the most productive scale size, however, as size increases efficiency decreases. Too small and too large branches need special attention. Putting production and profit efficiency scores on two scales reveals the performing characteristics of branches. Each region needs different handling. Branches with low production-low profit efficiency should be evolved towards high production-high profit efficiency region.

(Tobias Olweny and Themba Mamba Shipho, 2011) studied to determine and evaluate the effects of bank-specific factors; Capital adequacy, Asset quality, liquidity, operational cost efficiency and income diversification on the profitability of commercial banks in Kenya. The second objective was to determine and evaluate the effects of market structure factors: foreign ownership and market concentration, on the profitability of commercial banks in Kenya. This study adopted an explanatory approach by using panel data research design to fulfill the above objectives. Annual financial statements of 38 Kenyan commercial banks from 2002 to 2008 were obtained from the CBK and Banking Survey.

(Pannu, Dinesh Kumar and Jamal A. Farooquie, 2011) In this paper, by using data envelopment analysis (DEA) models to analyze the relative efficiency and productivity change in Indian pharmaceutical industry (IPI) between 1998 and 2007 which covers the post-TRIPS (1995) and post Indian Patent Act Amendment (2005) period. BCC DEA model and Malmquist productivity index are used to estimate the relative efficiency and productivity change of Indian pharmaceutical companies over the 10 year period. This study proposed and tested several hypotheses on the average efficiency and the productivity change of IPI to check if the indigenous and multinational companies differ in their efficiency and productivity change over the aforementioned period and also, analyzed the effect of firm size on several performance measures. Exploring the relationship between DEA efficiency and innovation, the outcome this study shows that innovative firms with R & D and patents have higher efficiency than non-innovative firms.

(Mohammad RomelBhuia, AzizulBaten, AnatonAbdulbasahKamil and Nandini Deb, 2012) analyzed the relative efficiency of Bangladesh online banks during 2001 – 2007 by utilizing Data Envelopment Analysis. Based on the several online sampled banks, the findings reveal that the most efficient banks were AL-ArafahIslami Bank Limited, ShahajalalIslami Bank Limited, Eastern Bank Limited, and the less efficient banks over the study period were Janata Bank Limited, Uttara Bank Limited, United Commercial Bank Limited, Pubali Bank Limited, and AB Bank Limited. Among the three groups Group-1 (n=20), Group-2 (n=18), Group-3 (n=15) it was observed that the individual efficiency level of banks are increasing group by group. The efficiency level of Group-2 was slightly increased from the efficiency level of Group-1. The source of efficiency of the sampled banks was found to be lower for technical efficiency and scale efficiency rather than pure technical efficiency.

(Anastasios D. Varias and Stella Sofianopoulou, 2012) evaluated the efficiency of the biggest commercial banks that operated in Greece at the financial year 2009 by using DEA with multiple inputs and outputs. The innovation of the paper refers to the choice of data and the use of a combination of the intermediation approach. The results indicate several inefficiencies that may not have direct relation to the profitability of such institutions. But, these inefficiencies indicate the vulnerability of the Greek banking system and its potential to ask for help from the FSF (Financial Stability Fund).

(Aswini Kumar Mishra, Jigar, N., Gadhia, Bibhu Prasad Kar, BiswabasPatra and ShiviAnand, 2013) tested the soundness and the second is to measure the efficiency of 12 public and private sector banks based on market cap. As far as the first objective is concerned, CAMEL approach has been used over a period of twelve years (2000-2011), and it is established that private sector banks are at the top of the list, with their performances in terms of soundness being the best. Public sector banks like Union Bank and SBI have taken a back seat and display low economic soundness in comparison. On the other hand, the present study makes an attempt to measure the efficiency change of these selected banks operating in India during 2010-2012. By using frontier based non-parametric technique, Data Envelopment Analysis, provides significant insights on the efficiency of different banks and places the private sector ones at an advantageous position and thereby hints at the possibility of further improvisation of most of the public sector banks. DEA results exhibit that among the public sector banks, the performance of Bank of India, Canara Bank and Punjab National Bank got dampened in the last two years under study, whereas among the private sector banks, except the case of Axis Bank, which was not found to be satisfactory at all, the remaining private sector banks show marked consistency in their efficiency level during the period under study.

(SaâdBenbachir, Mohamed Abouch, Yassine El Haddad and AnasBenbachir, 2013) evaluated the relative efficiency for the bank branches of a Moroccan regional bank during the period 2007-2010 using DEA. As a result, they identified the inefficient bank branches with the help of identifying their strengths and weaknesses. (Karan S. Thagunna and ShashankPoudel, 2013) studied the relative efficiency and potential improvement capabilities of Nepali banks by scrutinizing intermediation aspects with the help of the DEA. The outcome of this study reveals that efficiency level is relatively stable and has increased overall. Additionally, it also breaks down the overall efficiency of banks into technical and scale efficiency.

(Sangeetha and Jain Mathew, 2013) studied banking companies in the service sector exhibiting the problem of distinct results in terms of efficiency. To measure the stability, sustainability and profitability of the banking system, it is therefore crucial to scale the operations of banks performing in India. A well-organized banking system will provide an extensive way to higher economic growth in any country. Thus, evaluating the technical efficiency is important to depositors, owners, potential investors, managers and to policy makers. The present study investigates the technical efficiency of public sector banks in India by considering the study period between 2008-09 and 2010-11. For this purpose, the data envelopment analysis was used with two input variables and two output variables. The efficiency scores were calculated for a sample of twenty-six public sector banks operating in India. The result shows that Corporation Bank, State Bank of India and IDBI were consistently performed efficiently in all the years under study.

(Mohammad and Kamaiah Bandi, 2013) This paper analyses the technical efficiency of Indian pharmaceutical industry using data envelopment analysis (DEA) for the period of 1997–2011 which covers both post TRIPS and post product patent period. The study finds that prior to 2005 (during the process patent regime) the sector has witnessed a gradual fall in its efficiency level and after 2005 i.e. the post product patent regime, the industry is witnessing an increasing trend in the level of efficiency of all the firms on an average. This study also indicates that the industry has experienced rapid pace of technological growth opening up new production possibilities. However, most of the firms have failed to appropriate the benefits of such technological change. The study also finds that installing capital-intensive techniques or imported technology has been a good strategy to accelerate the technological growth of firms.

(HeriBezić, TomislavGalović, and PetarMišević, 2013) This study constructs research and development (R & D) as a factor of productivity of European pharmaceutical industry. We introduce an empirical model derived from the Data Envelopment Analysis model to calculate R & D and efficiencies for selected European pharmaceutical companies. This research brings a mathematical view with Data Envelopment Analysis which is a mathematical modeling method of calculating relative efficiencies of Decision Making Units (DMUs), based on predetermined inputs and outputs. Performance evaluation of R & D activity is important for continuous improvement of performance of pharmaceutical companies. The model was used to obtain the overall level of exports with input factors of R & D activity. The subject of analysis is efficiency values and rank. After identifying relative efficiencies of the observed countries, the results are discussed.

Research Methodology:

Data Collection: For this study, the required data about the Power plants have been taken from the website Economic Times for the financial years 2009 – 2013.

Selection of Inputs and Outputs: Reviewing the literature on the application of data envelopment analysis (DEA), different studies have used different combination of inputs and outputs. In this study, the researcher considered four input variables and two output variables in order to have an elaborate study.

The variables under the study are listed below:

Variables which related to Power Sector are considered

Sl. No.	Input Variables	Output Variables
1	Manufacturing Expenses	Total Income
2	Material Consumed	Operating Profit
3	Personal Expenses	
4	Administrative Expenses	

CCR and BCC Model: The original CCR model was pertinent only to that expertise which is categorized by constant returns to scale. The major advancement was extended by Charnes, and Cooper (BCC) model to facilitate expertise that reveals variable returns to scale. This study has used input-oriented DEA model, which emphasizes on the minimization of inputs and the maximization of outputs held at their current levels. Also the BCC model with variable return to scale is considered.

General form of CCR Model: The general form Output Maximization DEA [CCR] model can be represented in the form of Fractional Programming Model as follows:

Here the general model is constructed to maximize the efficiency of the q[th] output variable:

v_{jq} - j^{th}output value of the q^{th} DMU

y_{jq} - j^{th}output variable of the q^{th} DMU

u_{iq} - i^{th} input value of the q^{th} DMU

x_{iq} - i^{th}input variable of the q^{th} DMU

E_q - Efficiency of the q^{th} DMU

$$\text{Max } E_q = \frac{\sum_{j=1}^{m} v_{jq} y_{jq}}{\sum_{i=1}^{s} u_{iq}\, x_{iq}}$$

Subject to the constraint

$$\frac{\sum_{j=1}^{m} v_{jq} y_{jq}}{\sum_{i=1}^{s} u_{iq}\, x_{iq}} \leq 1; \quad q = 1,2, \ldots, n$$

$$v_{jq}, y_{jq}, u_{iq}, x_{iq} \geq 0 \; for \; all \; i = 1,2, .. s; j = 1,2, .. m, q = 1,2, \ldots n$$

Solving this fractional programming problem directly is so tedious; hence the fractional programming model is converted into regular linear programming model as described below:

$$Max \;\; E_q = \sum_{j=1}^{m} v_{jq} y_{jq}$$

Subject to the constraints

$$\sum_{i=1}^{s} u_{iq} x_{iq} = 1$$

$$\sum_{j=1}^{m} v_{jq} y_{jq} - \sum_{j=1}^{m} u_{iq} x_{iq} \leq 0; \quad q = 1,2, \ldots n$$

$$v_{jq}, y_{jq}, u_{iq}, x_{iq} \geq 0 \; for \; all \; i = 1,2, .. s; \; j = 1,2, .. m, \;\; q = 1,2, \ldots n$$

The general form of input minimization DEA [CCR] linear programming model can be represented as follows:

$$Min \; E_q = \sum_{i=1}^{s} u_{iq} x_{iq}$$

Subject to the constraints

$$\sum_{j=1}^{m} v_{iq} y_{iq} = 1;$$

$$\sum_{j=1}^{m} v_{jq} y_{jq} - \sum_{i=1}^{s} u_{iq} x_{iq} \leq 0; \quad q = 1,2, \ldots n$$

$$v_{jq}, y_{jq}, u_{iq}, x_{iq} \geq 0 \; for \; all \; i = 1,2, .. s; j = 1,2, .. m, q = 1,2, \ldots n$$

General form of BCC Model: The DEA envelopment program for considering variables return to scale is as follows:

$$Min \; \theta_m$$

Subject to the Constraints

$$Y\lambda \;\; \geq \;\; Y_m; \; X\,\lambda \;\; \leq \;\; \theta X_m$$

$$\sum_{n=1}^{N} \lambda_n = \; 1$$

$$\lambda \geq \;\; 0 \;\; ; \theta_m \; free \; variable$$

Empirical Results

Input-Oriented Technical Efficiency (Constant Return to Scale): Table 1communicates that the DEA efficiency score based input oriented technical efficiency [Constant return to scale] under the CCR Model. The Analysis report strongly communicates only is relatively efficient based on the input oriented technical efficiency [CRS] for the year 2009 – 2013.

It is observed that there is a varying trend in their mean of technical efficiency of power plants of India from 2009 - 2013, the score lies in the interval [0.33563, 1.0000]. The average efficiency of all the plants for the entire period is less than 1.

Input-Oriented Pure Technical Efficiency (Variable Return to Scale): Table 2 communicates that the DEA efficiency score based input oriented technical efficiency [Variable Return to Scale] under the BCC Model. In BCC Model there is an increase in the number of plants which show the consistency in their performance. The Analysis report strongly communicates that six power plants attained maximum efficiency score 1 for the year 2009 – 2013. It is observed that there is a varying trend in their mean of technical efficiency of power plants of India from 2009 to 2013, the score lies in the interval [0.69163, 1.00000]. The average efficiency of all the plants for the entire period is less than 1.

Input-Oriented Scale Efficiency (Variable Return to Scale): Table 3 shows the mean efficiency each year by decomposing technical efficiency into pure technical efficiency and scale efficiency. Decomposing technical efficiency into pure technical efficiency and scale efficiency allows us to gain insight into the main sources of inefficiencies. The average index of technical efficiency during the study period varies in between 33.56% to 100%, pure technical efficiency varying at 69.16% to 100%, and of scale efficiency varying at 36.3% to 100%.

Overall Mean Efficiency: Among all the thirteen power plants considered for this study, there are only four power plants (NTPC Ltd, KSK Energy Ventures Ltd, Jaiprakash Power Ventures Ltd and JSW Energy Ltd) which are highly consistent with the efficiency score of 1 and stand first. The rank of all the thirteen power plants is given in the Table 4.

Summary and concluding remarks: This research analysis is based on the application of Data Envelopment Analysis to compute the relative efficiency of Thirteen Power plants functioning in India. The outcome of this research study reveals certain constructive managerial insights into evaluating and advancing Power plant industry operations. The resulting analysis shows that NTPC Ltd, KSK Energy Ventures Ltd, Jaiprakash Power Ventures Ltd and JSW Energy Ltd are relatively efficient with the maximum efficiency score 1 throughout the study period. That is the remaining nine Power Plants are less efficient and the same can successfully endorse their resource utilization efficiency by improved, efficient handling of all the input and output variables.

References:

1. Al-Faraj, T.N., Alidi, A.S and Bu-Bhsait, K.A. (1993), "Evaluation of bank branches by means of data envelopment analysis", *International Journal of Operations & Production Management*, Vol. 13 No. 9, pp. 45-52.
2. Al Khathlan, K. and Malik, S. A. (2010), "Are Saudi Banks Efficient? Evidence Using Data Envelopment Analysis (DEA)", *International Journal of Economics and Finance*, Vol. 2 No. 2, pp. 53-58.
3. AnastasiosVarias, D and Stella Sofianopoulou (2012), "Efficiency evaluation of Greek commercial banks using DEA", Journal of Applied Operational Research, Vol. 4 No. 4, pp. 183–193.
4. Aswini Kumar Mishra, Jigar, N., Gadhia, Bibhu Prasad Kar, BiswabasPatra and ShiviAnand (2013), "Are Private Sector Banks More Sound and Efficient than Public Sector Banks? Assessments Based on Camel and Data Envelopment Analysis Approaches", *Research Journal of Recent Sciences,* Vol. 2 No. 4, pp. 28-35.
5. Banker, R.D. (1984), "Estimating most productive scale size using data envelopment analysis", *European Journal of Operational Research*, Vol. 3 No. 5, pp. 262-226.
6. Charnes, A., Cooper, W.W and Rhodes, E (1978), "Measuring the efficiency of decision making units", European Journal of Operation Research, Vol. 2, pp. 429-444.
7. Farrel, M.J. (1957), "The measurement of Productivity efficiency", *Journal of Royal Statistical Society (A)*, 120, pp. 253 – 281.

8. HeriBezić, TomislavGalović, and PetarMišević, (2013) "R & D Efficiency for Pharmaceutical Companies in the EU", *International Journal of Economics and Statistics*, Vol. 1, Issue 4, pp. 209 – 215.
9. IzahMohdTahir, Nor Mazlina Abu Bakar and SudinHaron (2009), "Evaluating Efficiency of Malaysian Banks Using Data Envelopment Analysis", *European Journal of Scientific Research*, Vol. 4 No. 8, pp. 96 – 106.
10. Joseph Magnus Frimpong (2010), "Investigating Efficiency of Ghana Banks: A Non-Parametric Approach", *American Journal of Scientific Research*, Issue 7, pp. 64-76.
11. Karan Thagunna, S. and ShashankPoudel (2013), "Measuring Bank Performance of Nepali Banks: A Data Envelopment Analysis (DEA) Perspective", *International Journal of Economics and Financial Issues*, Vol. 3 No. 1, pp.54-65.
12. Mariappan, P. (2010), "Operations Research Methods and Application", *New Century Publication*.
13. Maudos, J., Pastor, J. M., Perez, F. and Quesada, J. (2002), "Cost and profit efficiency in European banks", *Journal of International Financial Markets, Institutions and Money*, Vol. 12, pp. 33-58.
14. Mester, L.J. (1996), "A study of bank efficiency taking into account risk-preferences", *Journal of Banking and Finance*, Vol. 20 No. 6, pp. 1025-1045.
15. Mohammad, A.A.S. and Kamaiah Bandi, (2013) "The Technical Efficiency of the Pharmaceutical Industry in India: A Firm Level Analysis", *Asian Journal of Research in Business Economics and Management*, Vol. 3, No. 12, pp. 98 – 11.
16. Mohammad RomelBhuia, AzizulBaten, AnatonAbdulbasahKamil and Nandini Deb (2012), "Evaluation of Online Bank Efficiency in Bangladesh: A Data Envelopment Analysis (DEA) Approach", *Journal of Internet Banking and Commerce*, Vol. 17 No.2, pp. 1-17.
17. Nigmonov, A. (2010), "Bank Performance and Efficiency in Uzbekistan", *Eurasian Journal of Business and Economics 2010*, Vol. 3 No. 5, pp. 1-25.
18. Pannu, H.S., Dinesh Kumar, U. and Jamal A. Farooquie, (2011) "Efficiency and productivity analysis of Indian pharmaceutical industry using data envelopment analysis", *International Journal of Operational Research*, Vol. 10 No. 1, pp. 121 – 136.
19. Park, K. H. and Weber, W. L. (2006), "Profitability of Korean banks: Test of market structure versus efficient structure", *Journal of Economics and Business*, Vol. 58, pp. 222–239.
20. Pastor, J., Lovell, C. A. and Tulkens, H. (2006), "Evaluating the financial performance of bank branches", *Annals of Operations Research*, Vol. 145, pp. 321–337.
21. Ramanathan, R. (2003), "An Introduction to Data Envelopment Analysis: A Tool for Performance Measurement", *Sage Publications*, New Delhi.
22. Sangeetha R. and Jain Mathew (2013), "A study on technical efficiency of public sector banks in India", *International Journal of Business and Economics Research*, Vol. 2 No. 2, pp.15-21.
23. SaâdBenbachir, Mohamed Abouch, Yassine El Haddad, AnasBenbachir (2013), "Evaluation of Bank-Branches Technical and Scale Efficiency using Data Envelopment Analysis: Case of a Moroccan Regional Bank", *International Research Journal of Finance and Economics*, Issue 104, pp. 6-34.
24. Seiford, L. M. and Zhu, J. (1999), "Profitability and Marketability of the Top 55 U.S. Commercial Banks", *Management Science*, Vol. 45 No. 9, pp. 1270-1288.
25. Sufian, F. (2009), "Determinants of bank efficiency during unstable macroeconomic environment: Empirical evidence from Malaysia", *Research in International Business and Finance*, Vol. 23, pp. 54–77.
26. Tobias Olweny and Themba Mamba Shipho (2011), "Effects of Banking Sectoral Factors on The Profitability of Commercial Banks In Kenya", *Economics and Finance Review*, Vol. 1 No. 5, pp. 01 – 30
27. Profit and Loss account for Pharmaceutical Industries, (2009–2013) from http://economictimes.indiatimes.com

Table 1 Input-Oriented Technical Efficiency (Constant Return to Scale)

Sl.No.	Name of the Power plant	2009	2010	2011	2012	2013	Mean efficiency of individual Plants
1	**Torrent Power Ltd.**	1	0.5030	0.62460	0.75203	0.62568	**0.70106**
2	**NLC Ltd.**	0.26896	0.42062	0.33852	0.32362	0.32641	**0.33563**
3	**Adani Power Ltd.**	0	1	1	1	0.82085	**0.76417**
4	**NTPC Ltd.**	1	1	1	1	1	**1**
5	**Reliance Infrastructure Ltd.**	0.53945	0.39816	0.37274	0.48920	0.42497	**0.44491**
6	**KSK Energy Ventures Ltd.**	1	1	1	1	1	**1**
7	**SJVN Ltd.**	1	0.99992	1	1	1	**0.99998**
8	**Tata Power company Ltd.**	0.88487	0.43656	0.69665	0.75685	0.44429	**0.64384**
9	**HPC Ltd.**	0.36844	0.64091	0.47542	0.75560	1	**0.64807**
10	**CESC Ltd.**	0.23696	0.29710	0.47542	0.42059	0.54215	**0.39444**
11	**Jaiprakash Power Ventures Ltd.**	1	1	1	1	1	**1**
12	**JSW Energy Ltd.**	1	1	1	1	1	**1**
13	**Reliance power Ltd.**	0.49171	1	0.20683	0.22282	0.72042	**0.52836**
	Mean efficiencyof overall plants	**0.67618**	**0.74587**	**0.70694**	**0.74775**	**0.76191**	

Table 2 Input-Oriented Technical Efficiency (Variable Return to Scale)

Sl. No.	Name of the Power plant	2009	2010	2011	2012	2013	Mean efficiency of individual plant
1	**Torrent Power Ltd.**	1	0.90277	1	1	0.83908	**0.94837**
2	**NLC Ltd.**	0.87102	1	0.95673	0.87373	1	**0.9403**
3	**Adani Power Ltd.**	1	1	1	1	0.85448	**0.9709**
4	**NTPC Ltd.**	1	1	1	1	1	**1**
5	**Reliance Infrastructure Ltd.**	0.98017	0.84647	0.89102	1	0.95447	**0.96513**
6	**KSK Energy Ventures Ltd.**	1	1	1	1	1	**1**
7	**SJVN Ltd.**	1	1	1	1	1	**1**

8	**Tata Power company Ltd.**	1	1	1	1	0.89123	**0.97825**
9	**HPC Ltd.**	1	1	1	1	1	**1**
10	**CESC Ltd.**	0.52512	0.51641	0.68207	0.73454	1	**0.69163**
11	**Jaiprakash Power Ventures Ltd.**	1	1	1	1	1	**1**
12	**JSW Energy Ltd.**	1	1	1	1	1	**1**
13	**Reliance power Ltd.**	1	1	0.21928	0.3959	1	**0.72304**
	Mean efficiency of overall plants	**0.95202**	**0.94351**	**0.90378**	**0.9234**	**0.96456**	

Table 3 Input-Oriented Scale Efficiency (Variable Return to Scale)

Sl.No.	Name of the Power plant	2009	2010	2011	2012	2013	Mean efficiency of individual plant
1	**Torrent Power Ltd.**	1	0.558	0.643	0.752	0.746	**0.740**
2	**NLC Ltd.**	0.309	0.421	0.387	0.370	0.326	**0.363**
3	**Adani Power Ltd.**	0.000	1	1	1	0.961	**0.792**
4	**NTPC Ltd.**	1	1	1	1	1	**1**
5	**Reliance Infrastructure Ltd.**	0.550	0.472	0.559	0.489	0.445	**0.503**
6	**KSK Energy Ventures Ltd.**	1	1	1	1	1	**1**
7	**SJVN Ltd.**	1	1	1	1	1	**1**
8	**Tata Power company Ltd.**	0.885	0.437	1	0.757	0.499	**0.716**
9	**HPC Ltd.**	0.368	0.641	0.475	0.756	1	**0.648**
10	**CESC Ltd.**	0.451	0.576	0.684	0.573	0.542	**0.565**
11	**Jaiprakash Power Ventures Ltd.**	1	1	1	1	1	**1**
12	**JSW Energy Ltd.**	1	1	1	1	1	**1**
13	**Reliance power Ltd.**	0.492	1	0.943	0.563	0.720	**0.744**
	Mean efficiency of Overall plant	**0.697**	**0.777**	**0.822**	**0.789**	**0.788**	

Table 4 Overall mean efficiency of all the measures put together

Sl.No.	Name of the Power plant	Mean efficiency of the individual plant [input-CRS]	Mean efficiency of the individual plant [input-VRS]	Mean of mean efficiency	Rank based on Mean efficiency
1	**Torrent Power Ltd.**	0.70106	0.94837	0.824715	**4**
2	**NLC Ltd.**	0.33563	0.9403	0.637965	**8**
3	**Adani Power Ltd.**	0.76417	0.9709	0.867535	**3**
4	**NTPC Ltd.**	1	1	1	**1**
5	**Reliance Infrastructure Ltd.**	0.44491	0.96513	0.70502	**7**
6	**KSK Energy Ventures Ltd.**	1	1	1	**1**
7	**SJVN Ltd.**	0.99998	1	0.99999	**2**
8	**Tata Power company Ltd.**	0.64384	0.97825	0.81105	**6**
9	**HPC Ltd.**	0.64807	1	0.82404	**5**
10	**CESC Ltd.**	0.39444	0.69163	0.54304	**10**
11	**Jaiprakash Power Ventures Ltd.**	1	1	1	**1**
12	**JSW Energy Ltd.**	1	1	1	**1**
13	**Reliance power Ltd.**	0.52836	0.72304	0.62570	**9**

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