Regulatory Effect on Performance Measurement of Electricity Generation: Evidence from India

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Abstract- The objective of study is to develop a framework for measuring the performance of the Indian electricity generation industry by evaluating the relative efficiency and productivity improvement trend of 30 electricity generating companies (GENCOs) including 28 states and 2 union territories (UTs) for the panel data of 6 years from the time period 2002-03 to 2007-08 by estimating a parametric and non parametric production function so as to maximize the electricity production. Such a performance appraisal will identify the best operating parameters for GENCOs and trace the degree and causes of inefficiencies (technical or random error) amongst them. The performance benchmarks can be created for inefficient utilities by identifying and gathering best practices in Indian power generation industry which can be then suitably used by the inefficient companies so that they can proceed to progress towards achieving the benchmarking figures. The results make out scope for efficiency improvement in terms of output (electricity generated) maximization of electricity generation or scale of operation and set up target for performance improvement for the individual power generating company

Keywords – Generation Company (GENCO), Data envelopment analysis (DEA), Stochastic frontier analysis (SFA), Total factor productivity (TFP) change, Regulation, Privatization.

I. Introduction

At present India is the world's fifth largest consumer of energy and by 2030 it is expected to become the third largest, overtaking Japan and Russia. The electricity scenario in India since independence has been passed through a crucial phase as it has to cope with the rapid increase in demand due to growing economy. This has resulted in massive spending in the power sector resulting in phenomenal increase in the installed generating capacity, and the demand for electricity (Sharma, 2010). Today the power status of Indian power sector is that though the installed generating capacity has increased from nearly a thousand MW at the time of independence to a level of approximately hundred sixty thousand MW but there is not much improvement in bridging the demand-supply gap.

Different models for reforming the power sector have been adopted across the country to meet the challenges of growing demand for electricity. These reforms have sought to transform the state–owned and centralized electricity sector into decentralized, market oriented industries with private sector participation (Saleem 2007). Before going for further changes it is necessary to have empirical analysis of the extent to which the structural change of Indian electric power industry is working. Such analysis can be carried out by in-depth study of performance of generation utilities in India by employing benchmarking techniques for evaluating the efficiencies. There have not been serious efforts to improve the efficiency levels to the international best practice levels, which alone would have eliminated the deficits completely (Sharma 2010).

II. Methodology

The two methodologies namely: non-parametric deterministic approach known as Data envelopment analysis (DEA) and econometric approach known as stochastic frontier analysis (SFA) have been described which are used for performance evaluation of generation industry in India. DEA is a non-stochastic method that uses piecewise linear programming to calculate (rather than estimate) the efficient or best-practice frontier of a sample of firms whereas SFA is stochastic method used to estimate the efficient frontier and efficiency scores.

A. Data Envelopment Analysis –

The DEA is a mathematical programming approach which characterizes the relationship among multiple inputs and multiple outputs by envelopment of the observed data to determine a best practice frontier for production (Charnes et al. 1978, Banker et al.1984, Fare et al.1985, Fare et al. 1994). The data envelopment analysis (DEA) involves the use of linear programming methods to construct a non-parametric piecewise surface or frontier over the data. Efficiency measures are then calculated relative to this surface. DEA can be used to calculate the allocative and technical efficiency of the firms and the latter measure can be decomposed into scale, congestion, and pure technical inefficiency (Mortimer 2002).

4.1.1 The Constant Returns to Scale (CRS) DEA Model

The CCR model was suggested by Charnes et al. in 1978 and hence is named as CCR model and assumes constant returns to scale (CRS) assumption (Charnes et al. 1978). If assuming data on K inputs and M outputs for each of N firms, then for the i_{th} firm these are represented by the column vectors x_i and y_i respectively. The $K \times N$ input matrix, X , and the $M \times N$ output matrix, Y , represent the data for all N firms. A measure of the ratio of all outputs over all inputs would be obtained for each firm, such as $u' y_i / v' x_i$, where u is a $M \times 1$ vector of output weights and v is a $K \times 1$ vector of input weights. The input and output matrices X and Y respectively are given as:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdot & \cdot & \cdots & \cdots \\ x_{k1} & x_{k2} & \cdots & x_{kn} \end{bmatrix} \qquad (1)$$

$$Y = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \cdot & \cdot & \cdots & \cdots \\ y_{m1} & y_{m2} & \cdots & y_{mn} \end{bmatrix} \qquad (2)$$

The optimal weights are obtained by solving the mathematical programming problem:

$$\max_{u,v} (u' y_i / v' x_i),$$

$$st\ (u' y_j / v' x_j) \le 1,\ j = 1,2,\ldots N$$

$$u, v \ge 0 \qquad (3)$$

It is required to calculate values of u and v , such that the efficiency measure for the i_{th} firm is maximized, subject to the constraints that all efficiency measures must be less than or equal to one. The difficulty in this ratio formulation is that it has an infinite number of solutions. This can be avoided by imposing the constraint $v' x_i$, which provides:

$$\max_{\mu,v}(\mu' y_i),$$

$$st\ v' x_i = 1,$$

$$\mu' y_j - v' x_j \leq 0,\ j = 1,2,\ldots N$$

$$\mu, v \geq 0, \qquad (4)$$

where the notation is changed from u and v to μ and v, to stress that this is a different linear programming problem. Equation (4) is known as the multiplier form of the DEA linear programming problem. By the duality in linear programming, equivalent envelopment form of this problem can be derived as:

$$\min_{\theta,\lambda} \theta,$$

$$st\ -y_i + Y\lambda \geq 0,$$

$$-\theta x_i + X\lambda \geq 0,$$

$$\lambda \geq 0, \qquad (5)$$

where θ is a scalar and λ is a $N \times 1$ vector of constants. This envelopment form involves fewer constraints than the multiplier form $(K+M<N+1)$. The efficiency score for the i_{th} firm will be the value of θ. According to the Farell definition, it will satisfy: $\theta \leq 1,$ with a value of 1 indicating a point on the frontier and hence the firm is technically efficient firm (Farrell 1957). Note that linear programming must be solved N times, once for each utility in the sample. A value of θ is then obtained for each utility.

The Variable Returns to Scale (VRS) DEA Model and Calculation of Scale Effciencies

If the utilities do not perform at optimal scales, this CCR model can be modified to take into account variable returnsto scale (VRS) conditions by adding a convexity constraint. BCC model was suggested by Banker, Charnes and Cooper investigates whether the performance of each DMU was conducted in region of increasing, constant or decreasing returns to scale in multiple outputs and multiple inputs situations (Banker 1984). The CRS linear programming problem can be easily modified to account for VRS by adding the convexity constraint: N1´λ=1 to equation (4) to provide:

$$\min_{\theta,\lambda} \theta,$$

$$st\ -y_i + Y\lambda \geq 0,$$

$$-\theta x_i + X\lambda \geq 0,$$

$$N1'\lambda = 1$$

$$\lambda \geq 0, \qquad (6)$$

where $N1$ is an $N \times 1$ vector of ones. This approach forms a convex hull of interesting planes which envelope the data points more tightly than the CRS conical hull and thus provides technical efficiency scores which are greater than or equal to those obtained using the CRS model.

B. Stochastic frontier analysis

The SFA was originated by Aigner, Lovell and Schmidt and Meeusen and Van den Broeck in 1977 (Aigner et al. 1977, Meeusen and Broeck 1977). SFA is parametric method used to estimate the efficient frontier and efficiency scores. In this approach econometrics is used to construct a parametric frontier over the data (with adjustments for noise). The main advantage of this approach is that it takes into account influence of measurement errors and other noise. It also permits the estimation of standard errors and tests of hypotheses. SFA requires specification of a cost or production function involving assumptions about the firms' production technologies. Assessment of efficiency scores in SFA is similar to that of COLS. In addition, SFA recognizes the possibility of stochastic errors. This reduces reliance on measurements of a single efficient firm. However, accounting for stochastic errors requires specification of a probability function for distribution of the errors and distribution of inefficiencies (e.g. half normal).

The Stochastic Frontier Production Function

Aigner, Lovell and Schmidt and Meeusen and Van den Broeck independently proposed the stochastic frontier production function, defined as

$$\ln y_i = x_i\beta + v_i - u_i, \quad i = 1,2,..N \tag{7}$$

The random error, v_i, accounts for measurement error and other random factors, such as the effects of weather, strikes, luck, etc., on the output variable, together with the combined effects of unspecified input variables in the production function [89, 90].

A. Malmquist TFP Indices

Total Factor Productivity (TFP) is a productivity measure involving all factor of production. The Malmquist TFP indices calculated can be decomposed into two parts: one due to technical efficiency change (firms getting closer to the frontier) and another part due to technical change i.e. shift in the frontier itself (Coelli et al. 2010). Here we can define input distance functions and output distance functions. The TFP change index, efficiency change $(EFFCH)$ and the technical change $(TECHCH)$ between two period s and period t, for a single input and single output can be calculated as:

$$TFPCH = \frac{d_o^t(y_t, x_t)}{d_o^s(y_s, x_s)}\left[\frac{d_0^s(y_t, x_t)}{d_0^t(y_t, x_t)} \times \frac{d_0^s(y_s, x_s)}{d_0^t(y_s, x_s)}\right]^{1/2} \tag{10}$$

$$EFFCH = \left[\frac{d_0^t(y_t, x_t)}{d_0^s(y_s, x_s)}\right] \tag{11}$$

$$TECHCH = \left[\frac{d_0^s(y_t, x_t)}{d_0^t(y_t, x_t)} \times \frac{d_0^s(y_s, x_s)}{d_0^t(y_s, x_s)}\right]^{1/2} \tag{12}$$

III. PERFORMANCE ANALYSIS OF GENCOS

The study employs both DEA and SFA to estimate and compare technical efficiency scores due to the strength and weakness of each approach. It is possible that there are some inconsistencies in efficiency scores from different approaches. Hence the question of comparing and identifying the most and least efficient power plants arisesDEA and SFA has been applied as an analytical tool to assess the efficiencies and subsequently derive the performance benchmarks based on the comparison of the 30 Indian electricity generating companies (GENCOs) consisting of 7 SEBs, 8 Electricity/Power departments (EDs/PDs), 1 Power Corporation (PC) and 14 entities comprised the unbundled state owned electric utilities (SOEUs) as shown in table 1. Relative to SFA, DEA has several advantages. Important among them is the fact that it does not require specification of a functional form for the underlying technology and also does not require input prices, but instead physical inputs and outputs are used to evaluate input utilization (Kwoka and Pollitt 2007). On the other hand, the choice of input and output variables and also the numbers of variables in the model and observations overall can affect the efficiency scores [Zhang and Bartels 1998, Kwoka and Pollitt 2007].

Table 1
List of 30 Indian Electricity Generating Companies (GENCOs) Involved in the Performance Assessment

Region	State/UT	Utility	SEB/PD/PC /Unbundled Utility/ Privatized
Northern (NR)	Haryana	Haryana Power Generation Corporation Limited (HPGCL)	Unbundled utility
	Himachal Pradesh	Himachal Pradesh State Electricity Board (HPSEB)	SEB
	Jammu & Kashmir	Jammu and Kashmir Power Development Corporation Limited (J & K PDCL)	PD
	Punjab	Punjab State Electricity Board (PSEB)	SEB
	Rajasthan	Rajasthan Rajya Vidyut Utpadan Nigam Limited (RRVUNL)	Unbundled utility
	Uttar Pradesh	Uttar Pradesh Rajya Vidyut Utpadan Nigam Limited (UPRVUNL)	Unbundled utility
	Uttrakhand	Uttrakhand Jal Vidyut Nigam Limited (UJVNL)	Unbundled utility
	Delhi	Indra Prastha Generation Corporation Limited (IPGCL)	Privatized
Western (WR)	Gujarat	Gujarat State Electricity Corporation Limited (GSECL)	Unbundled utility
	Madhya Pradesh	Madhya Pradesh Power Generating Company Limited (MPGENCO/MPPGCL)	Unbundled utility
	Chhattisgarh	Chhattisgarh State Power Generation Company Limited (CSPGCL)	Unbundled utility
	Maharashtra	Maharashtra State Power Generation Company Limited (MAHAGENCO/MSPGCL)	Unbundled utility
	Goa	Goa Power Department (Goa PD)	Unbundled utility
Southern (SR)	Andhra Pradesh	Andhra Pradesh Power Generation Corporation Limited (APGENCO)	Unbundled utility
	Karnataka	Karnataka (KPC)	Unbundled utility
	Kerala	Kerala State Electricity Board (KSEB)	SEB
	Tamil Nadu	Tamil Nadu State Electricity Board (TNEB)	SEB
	Puducherry	Puducherry Power Corporation Limited (Puducherry PCL)	PD
Eastern (ER)	Bihar	Bihar State Electricity Board (BSEB)	SEB
	Jharkhand	Jharkhand State Electricity Board (JSEB)	SEB
	Orissa	Orissa Power Generation Corporation Limited (OPGCL) and Orissa Hydro Power Corporation Limited (OHPC)	Privatized
	West Bengal	West Bengal Power Development Corporation Limited (WBPDCL)	Unbundled utility
	Sikkim	Sikkim Power Department (Sikkim PD)	PD
North Eastern (NER)	Assam	Assam Power Generation Corporation Limited (APGCL)	Unbundled utility
	Manipur	Manipur Power Department (Manipur PD)	PD
	Meghalaya	Meghalaya State Electricity Board (MeSEB)	SEB
	Nagaland	Nagaland Power Department (Nagaland PD)	PD
	Tripura	Tripura State Electricity Corporation limited (TSECL)	PC
	Arunachal Pradesh	Arunachal Power Department (Arunachal PD)	PD
	Mizoram	Mizoram PD	PD

A. Input and Output Indicators

The choice of variables for input and output needs to take into account the international experience with electricity generation benchmarking, and is constrained by data availability. Performance evaluation is highly dependent on input and output selection. The study is based on standard input and output indicators recommended under international studies. The parameters of productivity measures considered in this study are installed capacity (capital), coal consumption (fuel), and labor which are estimated by the number of workers.

Table 2
Depiction of Input, Output and Environmental Factors for Analysis of GENCOs

Variable	Description	Mean	Std Dev.	Maximum	Minimum
Y	Total generation of electricity (GWh)	14477.57	18407.74	72770.46	21.08
X_K	Installed capacity/Capital (MW)	3256.29	3809.6	14580.46	30.67
X_F	Fuel consumption (MT)	6640.3	9444.78	39385	0
X_L	Labor (number of employees)	9395	19132	93152	62
Z_1	Plant load factor (%)	32.31	36.65	91.4	0
Z_2	Max demand (MW)	3426.51	3933.39	18411	30
Z_3	Per capita consumption (KWh)	739.26	535.71	2692.81	69.63
REG	Dummy variable to indicate unbundled utility	0.46	-	1	0
PRIV	Dummy variable to indicate privatized generation company	0.06	-	1	0
THER	Dummy variable to indicate thermal power generating company	0.6	-	1	0
HYD	Dummy variable to indicate hydro power generating company	0.7	-	1	0
THER+HYD	Dummy variable to indicate generating company producing both thermal and hydro power	0.56	-	1	0

Table 3
Correlation between Inputs and Output of output-Oriented DEA and SFA production Function Model of GENCOs

Variables	Installed Capacity	Coal Consumption	Labor	Units Generated
Installed Capacity	1			
Coal Consumption	0.939	1		
Labor	0.794	0.834	1	
Units Generated	0.988	0.956	0.843	1

B DEA Model Specification

The performance appraisal of Indian electricity generating companies has been analyzed by applying both constant returns to scale (CRS) as well as variable returns to scale (VRS) model. The output-oriented CCR and BCC models are used for examining the performance of GENCOs. The output-orientation measure is adopted both for DEA and SFA production functions because the aim behind estimating the production function of electricity generating company is to maximize the output (production-electricity generated).

C. SFA Production Function Model

The production function model for generating company can be expressed as:

$$Y = f(X_K, X_F, X_L, Z_1, Z_2, Z_3, REG, PRIV, THER, HYDR, THER + HYDR, T) \tag{13}$$

The output-oriented SFA model in cobb-douglas and translog forms for evaluating the technical efficiency and productivity of 30 Indian electricity generating companies are defined as in equations (14) and (15) respectively. The right alternative of model can be made by testing the hypotheses for the proper form for the adequate representation of the data.

$$\ln(Y_{it}) = \beta_0 + \beta_1 \ln(X_{Kit}) + \beta_2 \ln(X_{Fit}) + \beta_3 \ln(X_{Lit}) + \beta_t t + \delta_1 \ln(Z_{1it}) + \delta_2 \ln(Z_{2it}) + \delta_3 \ln(Z_{3it}) + \delta_4 (REG) + \delta_5 (PRIV) + \delta_6 (THER) + \delta_7 (HYDR) + \delta_8 (THER + HYDR) + v_{it} - u_{it},$$

$$i = 1,2,...30; \qquad (14)$$

where t = time trend, $t = 1,2,...6;$ and

$\beta_i s$ and $\delta_i s$ are unknown parameters to be estimated.

D. Data Source and Descriptive statistics

. The physical data for various states were obtained for the different years from "General Review" published by CEA (CEA, General Review 2004 to 2009).

E SFA Hypotheses Test Results

The results of the likelihood ratio tests are presented in table 4.

Table 4
Likelihood Ratio Tests for GENCOs

Null Hypotheses	χ^2-critical value	χ^2-calculated value	Decision
H_0: β_{jk} =0	18.3	52.28	H_0: Rejected
H_0: $\gamma = 0$	5.138	213.04	H_0: Rejected
H_0: $\mu = 0$	7.045	222.96	H_0: Rejected
H_0: $\gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = 0$	17.64	443.66	H_0: Rejected
H_0: $\eta = 0$	3.84	12.3	H_0: Rejected

F. Estimated Production Elasticities

The estimates of the stochastic frontier production function for cobb-douglas (CD) and translog (TR) form with the application of analysis software Frontier 4.1 are presented in table 7. In accordance with the estimation of SFA, the analysis of the results is shown as follows:

- The estimated gamma parameter (γ) of the preferred translog frontier model is 0.9987 and is significant at 1% level of significance. It means that, compared with the random interference term, the variability of errors almost comes from technical non-efficiency and the technical non-efficiency is significantly existent (almost 99.87 %).
- The estimated coefficients of the explanatory variables showed that installed capacity, coal consumption and had positive effect on the change in output. But only installed capacity and labor coefficients are significant at 1% level. The results of the estimated elasticities are presented in the table 8.
- The negative variables of the inefficient function mean positive impact on technical efficiency, and vice-versa. All environmental factors are significant except two (PLF and dummy THER in case of CD model and except three) PLF, dummy PRIV and dummy THER) for TR model of power generation companies.

Table 5: SFA Regression Results for GENCOs

Variables	Parameters	Cobb Douglas (CD)		Translog (TR)	
		Coefficient	T-ratio	Coefficient	T-ratio
	Production Factors				
Intercept	β_0	0.2727*	9.5160	0.2390*	4.0319
ln(Installed capacity)	β_1	0.7730*	48.6975	0.7189*	12.8482
ln(Coal consumption)	β_2	0.0453*	5.1611	0.0525	1.2516
ln(labor)	β_3	0.0764*	5.0932	0.1017*	3.0799
ln(Installed capacity)*ln(installedcapacity)	β_{11}			0.1099*	3.9518
ln(coal consumption)*ln(coal consumption)	β_{22}			0.0026	0.2659
ln(labor)*ln(labor)	β_{33}			-0.0376**	-2.2779
ln(Installed capacity)*ln(coal consumption)	β_{12}			-0.0295**	-2.5158
ln(Installed capacity)*ln(labor)	β_{13}			-0.0341**	2.5305
ln(coal consumption)*ln(labor)	β_{23}			-0.0097	-1.1608
ln(Installed capacity)*time	β_{1t}			0.0290*	4.5557
ln(coal consumption)*time	β_{2t}			-0.0057**	-1.9129
ln(labor)*time	β_{3t}			-0.0141**	-2.2088
time	β_t	-0.0015	-0.2034	0.0170	0.5084
time*time	β_{tt}			-0.0050	-0.5391
	Inefficiency Factors				
Intercept	δ_0	-3.8385*	-4.1006	-1.5516*	-5.0639
In(Plant load factor)	δ_1	-0.7060*	-3.2906	-0.2947	-1.1025
In(Max demand)	δ_2	1.1954*	5.1394	1.5758*	5.8297
In(Per capita consumption)	δ_3	-1.9050*	8.927	-2.0737*	-6.9560
Dummy REG	δ_4	-1.2306***	-1.7773	2.3505**	-2.5624
Dummy PRIV	δ_5	2.9857**	2.6406	1.7039	0.9651
Dummy THER	δ_6	0.8428	0.9734	1.2909	1.3043
Dummy HYDR	δ_7	0.9154***	-1.5115	-3.6117*	4.0053
Dummy THER+HYDR	δ_8	1.3514***	1.4137	4.0220**	2.7444
	Variance Factors				
Sigma squared	σ^2	1.3294*	8.5273	1.6478*	8.1852
Gamma	γ	0.9968*	1032.6707	0.9987*	942.1177
Loglikelihood function	LLF	-50.37		24.23	
LR test	LR	408.34		443.64	
No of Restrictions	R	10		10	

Note: *This value is obtained from table 1 of Kodde and Palm (1986) which gives critical values for the tests of null hypotheses.*
, **, * Estimate is significant at 1%, 5%, 10% level of significance respectively*

Table 6: Output Elasticities for Electricity Generating Companies

Estimated Output Elasticity With Respect To:	CD	TR
Installed capacity (E_1)	0.7730	0.7802
Fuel (E_2)	0.0453	0.0862
Labor (E_3)	0.0764	0.2211
Returns to scale ($RTS=E_1+E_2+E_3$)	0.8947	1.0875

G. Scale efficiencies and Returns-to-Scale

In BCC formulation, the results show that the average pure technical efficiency is 0.841 and the number of efficient utilities increased to 13. The average scale efficiency for the year 2008 is 0.925 and out of 3, only 11 utilities are scale efficient. The results indicate the possibility of restructuring of several utilities that display low scale efficiencies (table 9). The low value of scale efficiencies and the fact that these utilities exhibit decreasing returns to scale indicate that these have considerable scope for improvements in their efficiencies by resizing (downsizing) their scales of operations to the optimal scale defined by more productive utilities in the sample (Jain et al. 2010)

Table 7: Results of Output-Oriented CCR and BCC DEA Models of GENCOs

S.No	Utility	CRS TE	VRS TE	SE	RTS	Benchmarks
1	HPGCL	0.998	1	0.998	DRS	1
2	HPSEB	0.97	0.97	1	-	18 16
3	J & K PDCL	1	1	1	-	3
4	PSEB	0.755	0.978	0.772	DRS	8 9 16
5	RRVUNL	0.972	1	0.972	DRS	5
6	UPRVUNL	0.83	0.872	0.952	DRS	14 5 8
7	UJVNL	0.787	0.787	1	-	16 18
8	IPGCL	1	1	1	-	8
9	GSECL	0.815	1	0.815	DRS	9
10	MPGENCO/MPPGCL	0.852	0.879	0.969	DRS	8 14 5
11	CSPGCL	0.712	0.731	0.974	DRS	8 14 5
12	MAHAGENCO/MSPGCL	0.699	1	0.699	DRS	12
13	Goa PD	0.971	0.971	1	-	16 18
14	APGENCO	0.979	1	0.979	DRS	14
15	KPC	0.973	1	0.973	DRS	15
16	KSEB	1	1	1	-	16
17	TNEB	0.766	0.986	0.777	DRS	12 14 15
18	Puducherry PCL	1	1	1	-	18
19	BSEB	0.118	0.124	0.951	DRS	16 8 18
20	JSEB	0.7	0.702	0.997	IRS	23 16 8
21	OPGCL and OHPC	0.923	0.95	0.972	DRS	15 16 5 8
22	WBPDCL	0.991	1	0.991	DRS	22
23	Sikkim PD	0.628	1	0.628	IRS	23
24	APGCL	0.86	0.86	1	-	18 16
25	Manipur PD	0.063	0.063	1	-	18 16
26	MeSEB	0.741	0.741	1	-	16 18
27	Nagaland PD	0.455	1	0.455	IRS	27
28	TSECL	0.963	0.991	0.971	IRS	16 23 18
29	Arunachal PD	0.438	0.438	1	-	16 18
30	Mizoram PD	0.175	0.194	0.899	IRS	18 16 23
	Mean	0.771	0.841	0.925		

H. *Analysis of Average Efficiency Scores*

The yearly DEA efficiencies (CRS, VRS, SE) and SFA efficiencies for both CD and TR models are shown.It is quite clear that SE >DEA VRS (PTE)>DEA CRS >SFA TR > SFA CD.

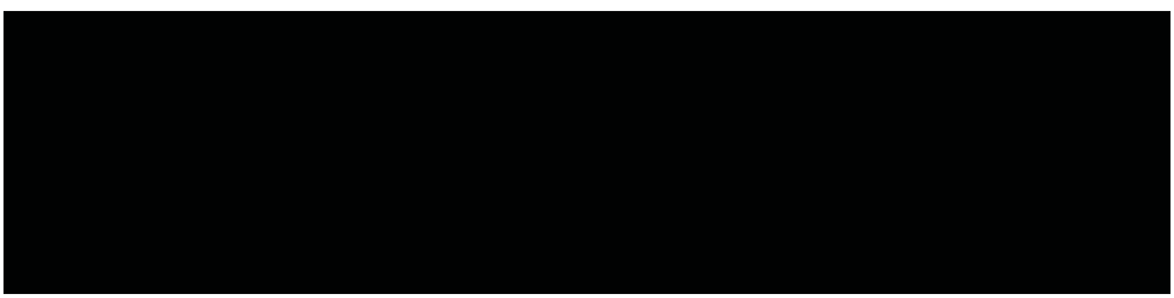

Fig 2 Estimated Average Efficiency Scores of Output-Oriented DEA and SFA Models of GENCOs

I. *Malmquist TFP Indices and Yearly Productivity Growth*

From the crisp overview of the 6 years panel data it is understandable that the overall capital productivity (net generation per installed capacity) of western region (WR) is greater than the other regions followed by southern, northern, eastern and north eastern regions.

Fig 6 Yearly Productivity Growths of GENCOs

The DEA Productivity results of GENCOs are shown in table 11 in terms of efficiency change (EFFCH), technical change (TECHCH), pure efficiency change (PECH), scale efficiency change (SECH) and total factor productivity change (TFPCH).The average EFFCH, TECHCH, PECH, SECH and TFHCH are 1.065, 1.039, 1.044, 1.021 and 1.107 respectively. Manipur PD is having the highest DEA based TFP change of 1.833 with EFFCH of 1.818 and TECHCH of 1.008.

Table 11: Malmquist Indices for Output Oriented DEA Model of GENCOs

S.No.	Utility	EFFCH	TECHCH	PECH	SECH	TFPCH
1	HPGCL	1	1.007	1	1	1.007
2	HPSEB	1.042	1.058	1.042	1	1.102
3	J & K PDCL	1	1.297	1	1	1.297
4	PSEB	1.037	1	0.996	1.04	1.037
5	RRVUNL	1.003	1.016	1	1.003	1.019
6	UPRVUNL	0.973	1.014	0.973	1	0.986
7	UJVNL	0.953	1.072	0.953	1	1.022
8	IPGCL	1.068	1.035	1.053	1.015	1.106
9	GSECL	1.03	1.004	1	1.03	1.034
10	MPGENCO/MPPGCL	0.975	1.01	0.977	0.998	0.984
11	CSPGCL	0.958	1.004	0.939	1.02	0.961
12	MAHAGENO/MSPGCL	1.009	1.004	1	1.009	1.013
13	Goa PD	1.023	1.013	1.023	1	1.037
14	APGENCO	1.015	1.017	1	1.015	1.032
15	KPC	1.018	1.047	1.003	1.015	1.065
16	KSEB	1	1.095	1	1	1.095
17	TNEB	0.994	1.069	1.005	0.989	1.062
18	Puducherry PCL	1	1	1	1	1
19	BSEB	0.854	1.098	0.859	0.994	0.938
20	JSEB	1.012	1.032	1.008	1.004	1.044
21	OPGCL and OHPC	1.123	1.043	1.126	0.997	1.172
22	WBPDCL	0.998	1.015	1	0.998	1.013
23	Sikkim PD	1.197	1.048	1	1.197	1.255
24	APGCL	1.134	1.061	1.134	1	1.203
25	Manipur PD	1.818	1.008	1.818	1	1.833
26	MeSEB	0.991	1.037	0.991	1	1.028
27	Nagaland PD	1.328	1.006	1	1.328	1.336
28	TSECL	1.064	1.059	1.059	1.005	1.127
29	Arunachal PD	1.379	1.009	1.379	1	1.392
30	Mizoram PD	1.321	1.032	1.291	1.024	1.364
	Mean	1.065	1.039	1.044	1.021	1.107

IV.CONCLUSION

This study gives the performance benchmarks for improving the operations of poorly performing power generation companies The performance of Indian electricity generation industry in terms of efficiency and productivity evaluated by incorporating parametric (SFA) and non-parametric (DEA) performance benchmarking techniques will afford an indication of the rate of previous productivity gains and help to establish the expected rate over the regulatory period. The application of the non parametric and parametric production and cost frontier models to Indian power generation industry can be used as a tool for policy makers. Regulators can use benchmarking to define the degree of inefficiency of regulated/deregulated generation companies, by reference to some target or frontier and will have to adopt incentive regulation schemes that rely on performance benchmarking to improve the efficiency of Indian electricity generation facilities.

The foremost policy allegation of this analysis is that increased regulation is playing a major role in technical efficiency advancement and productivity improvement of electricity generation companies of India. The regulator should be conscious that cost and quality efficiency are contradictory. Utilities are advised to reduce their share of labor price and the electricity companies still regulated should be deregulated in order reduce cost inefficiency. This study contributes to the conclusion that the privatization of GENCOs is not found to be more cost efficient than state owned utilities.

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