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X - FACTOR EVALUATION UNDER RPI-X REGULATION FOR INDIAN ELECTRICITY DISTRIBUTION UTILITIES

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Abstract

With regulators' growing interest in improving operational efficiency and quality supply, the time is nearing when performance based regulation will become norm for regulating the distribution tariff in Indian electricity distribution sector. In this context, the State Electricity Regulatory Commissions proposed replacing rate-of-return regulation with most commonly used performance based regulatory regime, i.e., Price Cap regulation also known as RPI-X (Retail Price Index - Productivity Offset) regulatory framework. However, the potential problem associated with applying price cap regulation scheme in practice is the determination of productivity offset or X-factor used in price caps setting. This paper proposed an approach to calculate the X-factor for 58 government-owned and privately-owned electricity distribution utilities in India during a five year period from 2007/08 to 2011/12. A Stochastic Frontier model through an input distance function is first applied to compute the Malmquist Total Factor Productivity (TFP) and the estimated TFP is then used to calculate the utility-specific X-factor. With rely on calculated X-factor, the distribution utilities would be able to cap either on prices or revenues thus accounting the inflation in the tariff determination. This will be more realistic approach as compared to cost plus approach.

Keywords: Price cap regulation, RPI-X regulation, Performance based regulation, Malmquist total factor productivity, Indian energy distribution utilities.

1. Introduction

Traditionally, with vertically integrated mechanism, the Indian electricity distribution utilities have been price regulated by rate of return (ROR) or cost of

Nomenclatures

$I_{i,t,t-1}$	RPI associated with supplying service *i*, expressed in percentage between the periods *t* and *t-1*.
i	i^{th} utility in the sample of I utilities.
$\ln D_{it}^{I}$	Log of input distance
$P_{i,t}$	Maximum unit price of service *i* during the period *t*.
$P_{i,t-1}$	Maximum unit price of service *i* during the period *t-1*.
t	Time trend parameter (*t = 1, 2,….., T*)
u_{it}	Non negative inefficiency technical component
v_{it}	Two - sided noise error component
x_{nit}	*k x 1* vector of input quantities of *i-th* utility.
y_{it}	Output of *i - th* utility.

Greek Symbols

α's	Unknown production function parameters to be estimated
β's	Unknown production function parameters to be estimated
γ's	Unknown production function parameters to be estimated
θ's	Coefficients of time trend parameter to be estimated
τ	Set of time periods among the T periods

Abbreviations

COS	Cost of Service
DEA	Data Envelopment Analysis
PBR	Performance Based Regulation
ROR	Rate of Return
RPI	Retail Price Index
SF	Scale Factor
SFA	Stochastic Frontier Analysis
TFP	Total Factor Productivity

service (COS) regulation. ROR or COS regulatory framework establishes a fundamental relationship between the regulated utility's costs and prices. Under such a regulation regime, the regulatory authority offers the utility to recover all of the necessary costs, including a pre-determined rate of return over their physical assets [1]. Since it is basically a form of 'cost-plus' pricing, it ensures that the utility will remain solvent in times when unavoidable costs are increasing rapidly. However, the most significant criticism of the rate of return approach is that, because it is, in effect, a form of cost-plus arrangement, whereby allowable revenues are linked to costs, the utility has limited incentives to reduce operating costs and operate efficiently. In other words, because, under the pure form of rate of return regulation, any efficiency gains associated with cost reductions will automatically be translated into price reductions, the utility has no great incentive to seek out such efficiencies. Another drawback of rate of return regulation is that, because of its cost-plus characteristic, and the fact that the regulatory managers generally has limited information about a utility's costs, it may provide an opportunity for the utility to inflate or misrepresent its costs, leading the regulator to set prices that are too high [2].

Recognizing the shortcomings addressed above, the State Electricity Regulatory Commissions in Indian power sector intend to shift from conventional cost plus regulatory mechanism to performance based regulatory mechanism for setting the distribution tariff. The performance based regulation shall improve the business and operational efficiency which is a win-win solution for the distribution utility and consumers. The most common form of performance based regulation widely used in the monopoly context is price cap or RPI-X regulation [3, 4]. However, one of the critical issues with implementing price cap regulation in practice is how to set productivity offset, i.e., X-factor. To date there has been no published work on measures of X-factor (productivity offset) for Indian electricity distribution utilities, which is the main aim of the present work. With this motivation, the present paper is an attempt to calculate the utility-level X-factor for 58 Indian electricity distribution utilities using Stochastic Frontier Analysis (SFA) based Malmquist Total Factor Productivity (TFP) approach. Further, the findings of the present study would be useful for regulatory managers and policy makers to provide a basis for the effective implementation of price cap performance based regulation in Indian electricity distribution sector.

2. Price Cap (RPI-X) Regulation: An Overview

Regulation based on performance incentives introduces the component of productivity along with the reductions of costs as the main element of the regulatory method. This regulatory model encompasses different approaches that are based on

a. Capping price,
b. Capping revenue and
c. Yardstick approach.

The broader framework of Performance Based Regulation appealing to regulators and policymakers is the Price Cap or RPI-X (Retail Price Index-Productivity Offset) regulation because it gives the distribution utility a strong incentive to achieve productivity gains. Price Cap (i.e., RPI-X) regulation was first proposed by Stephen C Littlechild in 1983 as the regulatory scheme for the British Telecom and thereafter has been applied by various regulators throughout the world to regulate a number of industries including electricity sector, gas sector, water sector, telecommunication sector etc. RPI-X regulation consists of establishing an average maximum limit (cap) for the prices of the services being supplied during the regulatory period [5]. Thus, the regulatory managers retain the profits corresponding to the over-reduction of costs that occurs during this regulatory period, in addition to the expected gains in terms of productivity. In this way, the regulated managers are motivated to improve their (static) efficiency and increase innovation, with a view to reducing costs and consequently augmenting their profits. At the end of each price control period, the benefits of the cost reductions are transferred to consumers by means of reduction of prices during the following period.

RPI-X price cap regulatory framework comprises two parts: one corresponds to the Retail Price Index and the other to the expected change of productivity, which the utility is expected to obtain during the regulatory period (i.e., X-factor). The value of X is meant to reflect potential cost savings by the utility due to either increased efficiency or technological progress. The Price Cap formula in its general form is given by [6]:

$$P_t = P_0 \times (1 + RPI_t - X)^t \tag{1}$$

Here, P_0 is the initial price, P_t is price for year t of the regulatory period, RPI is the retail price index, and X is the annual price adjustment (i.e., Productivity Offset).

Figure 1 illustrates how a price cap with X-Factor shares efficiency gains with consumers. At the end of each period, the profits are reduced to a defined value and the benefits of the gains in productivity are passed on to consumers, but only for the following period. As the operator becomes increasingly efficient, the maximum value of the profits will be lower, i.e., the gains in efficiency that can be expected will be lower, as will transfers to consumers, since the utility will draw increasingly closer to the best practice efficiency frontier [7].

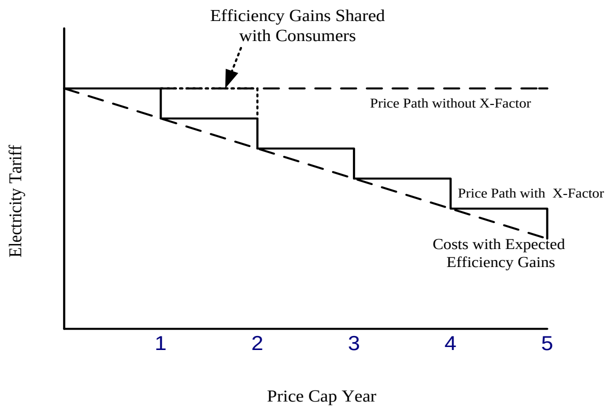

Fig. 1. Illustration of price cap with X-factor.

3. Methodology and Empirical Modelling

In the present study, we proposed SFA based Malmquist TFP approach to calculate the utility level X-factor in Indian electricity distribution industry. A stochastic frontier model through an input distance function is first applied to estimate the trends in TFP growth and the estimated TFP is then used to calculate the utility-level X-Factor for Indian electricity distribution utilities.

Input distance function and SFA

Malmquist Total Factor Productivity Index, pioneered by Caves et al. [8], and based on distance function [9], allows the separation of shifts in the frontier from catching up to the production frontier. Distance functions can be used to describe a production technology in the multi-input, multi-output framework without specifying any particular algebraic relationship between inputs and outputs as well as any behavioural objective such as profit minimization or cost-maximization [10]. Distance functions can be input-oriented as well as output-oriented. Input distance function suggests the degree to which a given input vector could maximum be proportionally contracted for a given output level and within the production possibilities. Similarly, an output oriented distance function focuses on how much output vector could maximum be proportionally expanded for a given level of input. In the present study, we adopted the input oriented distance function because the electricity demand is derived demand that is beyond the utility's control and has to be served [11].

The distance function can be estimated in many ways that mainly include Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA) etc. Compared with DEA, SFA has more solid theoretical foundation and can separate the potential impact caused by random errors and provide a variety of statistical tests to assess the feasibility of the model. The stochastic frontier model, originally put by Aigner *et al*. [12] and Meeusen and van den Broeck [13], involves the idea that all the deviations of an observation from the theoretical maximum is not attributed solely to the inefficiency of the utility [14]. The empirical estimation of parametric (i.e., SFA based) distance function requires the specification of functional form that must satisfy the following requirements [15]:

a. It must be flexible in nature,
b. Easy to compute and
c. Allows for imposing homogeneity and symmetry restrictions.

The translog functional model satisfies the above requirements, and thus chosen for the present paper. The parametric translog input distance function with $L\,(l=1,2,....,L)$ outputs and $N\,(n=1,2,....,N)$ inputs is specified as:

$$\ln D_{it}^{I} = \alpha_0 + \sum_{l=1}^{L}\alpha_l \ln y_{lit} + \frac{1}{2}\sum_{l=1}^{L}\sum_{k=1}^{L}\alpha_{lk}\ln y_{lit}\ln y_{kit} + \sum_{n=1}^{N}\beta_n \ln x_{nit} + \frac{1}{2}\sum_{n=1}^{N}\sum_{m=1}^{N}\beta_{nm}\ln x_{nit}\ln x_{mit} + \sum_{n=1}^{N}\sum_{l=1}^{L}\gamma_{nl}\ln x_{nit}\ln y_{lit} + \theta_1 t + \theta_{11}t^2 + \sum_{n=1}^{N}\lambda_{nt}\ln x_{nit}t + \sum_{l=1}^{L}\phi_{lt}\ln y_{lit}t \quad (2)$$

A necessary property of the translog input distance function is homogeneity (of degree + 1) in inputs, which signifies that [16]:

$$\sum_{n=1}^{N}\beta_n = 1, \qquad \sum_{m=1}^{N}\beta_{nm} = 0, \qquad \sum_{n=1}^{N}\gamma_{nl} = 0, \; and \quad \sum_{n=1}^{N}\lambda_{kn} = 0 \quad (3)$$

Symmetry is also imposed by following conditions:

$$\alpha_{lk} = \alpha_{kl}\,, \quad (l,k=1,2,.....) \quad and \quad \beta_{nm} = \beta_{mn}\,, \quad (n,m=1,2,......,N) \quad (4)$$

Imposing restrictions of homogeneity and symmetry upon Eq. (2) and normalizing all the inputs by selecting one of the inputs arbitrarily, the translog input distance function we estimate takes the following form:

$$-\ln x_{Nit} = \alpha_0 + \sum_{l=1}^{L}\alpha_l \ln y_{lit} + \frac{1}{2}\sum_{l=1}^{L}\sum_{k=1}^{L}\alpha_{lk}\ln y_{lit}\ln y_{kit} + \sum_{n=1}^{N}\beta_n \ln x^{*}_{nit} + \frac{1}{2}\sum_{n=1}^{N}\sum_{m=1}^{N}\beta_{nm}\ln x^{*}_{nit}\,\ln x^{*}_{mit} + \sum_{n=1}^{N}\sum_{l=1}^{L}\gamma_{nl}\ln x^{*}_{nit}\ln y_{lit} + \theta_1 t + \theta_{11}t^2 + \sum_{n=1}^{N}\lambda_{nt}\ln x^{*}_{nit}t + \sum_{l=1}^{L}\phi_{lt}\ln y_{lit}t \quad (5)$$

where $x^{*}_{nit} = \dfrac{x_{nit}}{x_{Nit}}$, $\ln D_{it}^{I} = v_{it} - u_{it}$; v_{it} is a two-sided noise error component, independently and identically distributed $(v_{it} \sim iid\; N(0,\sigma_v^2))$, intended to capture the factors that are beyond the control of the utilities, u_{it} is a non-negative error component that accounts the technical inefficiency of i^{th} distribution utility at time t, and assumed to have symmetric distribution $(u_{it} \sim iid\, N(0, \sigma_u^2))$.

Finally, we adopt the framework of Battese and Coelli [17] to investigate the temporal pattern technical inefficiency i.e.,

$$u_{it} = u_i \exp(-\eta(\tau - T\ )) \quad (6)$$

where, u_{it} is an independently and identically distributed non-negative technical inefficiency component following a truncated normal distribution, $N(\mu, \sigma_u^2)$, independent of the random noise and the regressors; η is a unknown scalar parameter to be estimated which introduces time-varying technical inefficiency and; τ ∈ [1, 2, ..., T] is the set of time periods among the T periods for which observations for the i^{th} producer are obtained.

Following the generalized input - oriented Malmquist Productivity Index suggested by Orea [18], the parameters estimated for the translog input distance function in equation (5) are then used to determine and decompose the Total Factor Productivity Change between the periods *t* and *t+1* in accordance with the following equation:

$$\begin{aligned} \ln(TFP_{i1}/TFP_{io}) = & \underbrace{\ln(TE_{i1}/TE_{i0})}_{I} + \underbrace{\frac{1}{2}[(\partial \ln D_{i1}/\partial t) + (\partial \ln D_{i0}/\partial t)]}_{II} \\ & + \underbrace{\frac{1}{2}\sum_{l=1}^{L}[(SF_{i1}\varepsilon_{li1} + SF_{li0}\varepsilon_{li0})(\ln y_{li1} - \ln y_{li0})]}_{III} \end{aligned} \quad (7)$$

with i = 1,2,…., I ; t = 1,2,….,T

The three terms on the right hand side- *I, II, and III* in equation (7) can be viewed as:

a. Technical efficiency change (TEC) (catching up the frontier),
b. Technical change (TC) (frontier shift), and
c. Scale efficiency change (SEC) (improvements in reaching the optimal scale of production) respectively.

A brief explanation of all the three terms: TEC, TC and SEC is covered in Section 6.

4. Data Variables

The data set considered in the current research work comprise of balanced panel of 58 public and private-owned electricity distribution utilities in India observed for a five year period from 2007/08 to 2011/12[1], i.e., a total of 290 observations.

Our data set was primarily extracted from the distribution utility annual reports and published report of Ministry of Power, Government of India [19]. The specific choice of input and output variables made in present study follows the general consensus found in the previous research studies. According to the comprehensive review in benchmarking studies [20] and expert opinions of relevant professionals; the input and output variables selected in the current study to compute the X-Factor of 58 Indian electricity supply utilities are defined as:

Input Variables:

a. Transmission and distribution (T&D) network line length in kilometers.
b. Number of employees.
c. Energy losses in Million Units (MU).

Output Variables:

a. Electricity sold to end consumers in Million Units (MU)
b. Number of consumers

The descriptive statistics of input and output variables used in the model is shown in Table 1.

Table 1. Descriptive statistics of input and output variables used in the model.

Variable	Minimum	Maximum	Mean	Standard Deviation
Desirable Inputs				
x_1**: Network line length (km)**	2077	818507	136555.1	152293
x_2**: Number of employees**	1130	116266	11891.86	15784.23
x_3**: Energy losses (MU)**	84.67	20665	2461.04	2138.81
Desirable Outputs				
y_1**: Electricity sold (MU)**	161.67	71280	8934.33	10585.17
y_2**:Number of end consumers (in thousands)**	134.13	22340	2905.06	3630.36

[1] The price control period 2007/08 to 2011/12 is considered in the present study since during the observed period all the State (Public) Electricity Boards have been corporatized or unbundled and the distribution business is privatized in some states like Delhi, Orissa etc.

5. Empirical Results and Discussions

For the purpose of present study, the maximum likelihood procedure is adopted to obtain the parameter estimates for translog input distance function. Table 2 shows the estimated parameters of input distance function.

In order to interpret the estimated first order coefficients associated with inputs and outputs in the translog distance function as distance function elasticities at sample means, each data variable is expressed in natural logarithm and is normalized from its sample mean. The estimated input elasticities give information about input contribution share. In the present study, the estimated first order input and output coefficients in the translog input distance function are statistically significant and have the expected signs, positive for input elasticities and negative for output elasticities; signifying that the fitted translog input distance function is strictly increasing in inputs and decreasing in outputs at the sample mean. Referring to the estimates of first order coefficients of energy sold (α_1) and the number of consumers supplied (α_2), it is found that they have negative sign as expected, and are statistically significant at 1% level of significance. In terms of absolute value, the sum of the estimated first order output coefficients (α_1 and α_2) is less than one (0.584), illustrating that increasing returns to scale are present at the sample mean of the data. This signifies that for increasing the levels of both the outputs by 1%, the input requirements are required to be increase only by .584%. The positive and significant pattern of the estimated coefficient of the time trend (θ_1 = .008) suggests almost insignificant technical change over time. The calculated results indicate that the ratio $\sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$ (i.e., γ parameter) is 0.969 and significantly different from zero; implying that the technical inefficiency effects are significant in explaining the differences among the distribution utilities and the change in the total factor productivity. The estimated parameter η is found positive (i.e., 0.0213) which implies that the technical efficiency level of sampled electricity distribution utilities are increasing over the time period considered.

Table 2. Maximum likelihood estimates of input distance function parameters.

Variable	Coefficient	Standard- error	t-ratio
α_0	1.143	0.0738	15.470
α_1	-0.325	0.051	-6.318***
α_2	-0.259	0.053	-4.891***
α_{12}	-0.036	0.112	0.322*
α_3	-0.054	0.055	-0.980*
α_4	-0.037	0.071	-0.523
β_1	0.282	0.037	7.494***
β_2	0.330	0.026	12.520***
β_{11}	0.099	0.023	4.207***
β_{22}	0.076	0.019	3.932***
β_{12}	-0.212	0.028	-7.416
γ_1	0.033	0.056	0.585*
γ_2	-0.118	0.055	-2.152**
γ_3	0.010	0.067	0.150*
γ_4	0.185	0.058	3.201***
θ_1	0.008	0.008	0.992*
θ_2	-0.002	0.003	-0.571
λ_1	-0.027	0.006	-4.121***
λ_2	0.024	0.008	3.023***
ϕ_1	-0.021	0.011	-1.176*
ϕ_2	0.024	0.012	1.924*
σ^2	0.202	0.028	7.135
γ	0.969	0.0037	259.9
μ	0.885	0.088	10.032
η	0.021	0.008	2.383
$\log likelihood\ function$			178.087

***, ** and * = Significant at 1%, 5% and 10% level of confidence

6. X-factor Determination via Malmquist TFP Approach

Since the X-factor is the key component of a price cap regulation and is a measure of productivity growth, the present paper adopted Malmquist TFP approach to calculate the utility specific and sector level X-factor in Indian electricity distribution sector. We first calculated and decompose the total factor productivity (TFP) and the estimated TFP is then used to derive the X-factor for 58 Indian electricity distribution utilities.

6.1. Malmquist calculation and decomposition

In accordance with Orea [18], Malmquist TFP change can be decomposed into three components: (a) technical efficiency change (b) technical change and (c) scale efficiency change.

6.1.1. Technical efficiency change

Technical efficiency change refers the ability of distribution utility to catch up with other more efficient distribution utilities defined by translog input distance function over time. In order to calculate the technical efficiency change for each utility between two specific periods, we first estimated the utility-level technical efficiency at each period.

The estimated technical efficiency score of 58 Indian electricity supply utilities derived from translog input distance function during the regulatory period 2007/08 to 2011/12 is shown in Fig. 2 and the year-wise mean efficiency score is presented in Fig. 3.

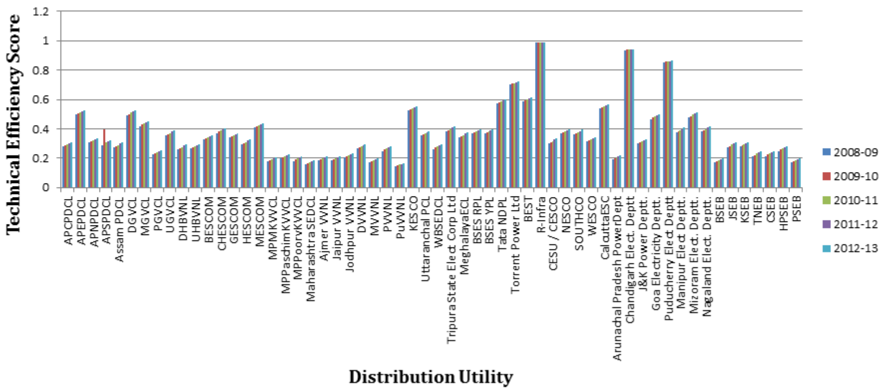

Fig. 2. Technical efficiency score of distribution utilities during 2007/08 to 2011/12.

Figure 2 illustrates that R-Infra with an estimated mean technical efficiency of 0.9872 is ranked the most efficient distribution utility followed by Chandigarh.

Electricity Department with an average technical efficiency of 0.9393 and Puducherry Electricity Department with 0.8588. The least efficient distribution utility is Purvanchal Vidyut Vitaran Nigam Limited (PuVVNL) with mean technical efficiency of 0.155 followed by Maharashtra State Electricity Distribution Utility Limited (MSEDCL) with 0.1736. Further, it is revealed from

Fig. 3 that the average technical efficiency score of sampled distribution utilities during the observed period 2007/08 to 2011/12 is calculated as 0.366, implying that the power distribution utilities can improve their output level by 63.38% utilizing the same bundle of given inputs and existing technology.

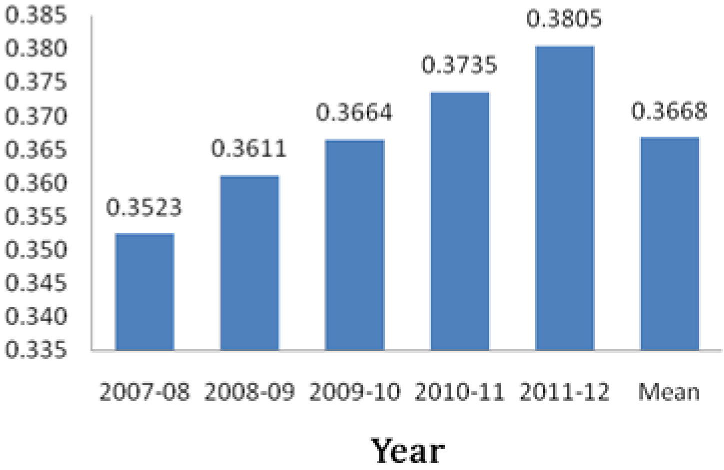

Fig. 3. Year wise mean efficiency score of distribution utilities.

Now, the technical efficiency change index between the periods *t* (the base period) and *t+1* is measured as :

Technical Efficiency Change $= \ln(TE_{i1} / TE_{i0})$ (8)

6.1.2. Technical change

Technical change refers to the extent to which the TFP growth is due to the shifts in production frontier over time and reflects the innovation capability of a utility. The technical change index at each data point (between the periods *t* (the base period) and *t+1*) is computed as :

Technical Change $= \frac{1}{2}[(\partial \ln D_{i1} / \partial t) + (\partial \ln D_{i0} / \partial t)]$ (9)

where lnD_i represents the log of input distance.

6.1.3. Scale efficiency change

Scale efficiency change measures the change in scale efficiency. Scale efficiency is a measure of the degree to which a utility is optimizing the size of its operations.

Scale Efficiency Change $= \frac{1}{2}\sum_{l=1}^{L}[(SF_{i1}\varepsilon_{li1} + SF_{li0}\varepsilon_{li0})(\ln y_{li1} - \ln y_{li0})]$ (10)

where $i = 1,2,....,I$; $t = 1,2,....,T$.

The determination of scale efficiency change requires the calculation of the production elasticities $\varepsilon = \left(\frac{\partial \ln D^I{}_{it}}{\partial y_{lit}}\right)$ for each output at each data point, and the calculation of scale factors $SF_{it} = \frac{(\varepsilon_{it} + 1)}{\varepsilon_{it}}$ at each data point, where $\varepsilon_{it} = \sum_{l=1}^{L} \varepsilon_{lit}$.

The decomposition of Malmquist TFP is obtained by adding all the three terms - technical efficiency change *(TEC)*, technical change *(TC)* and scale efficiency change (*SEC*), i.e.,

$$TFP = TEC + TC + SEC \tag{11}$$

The summary of industry's annual total factor productivity change (TFPCH) decomposition for the period 2007/08 to 2011/12 is shown in Table 3 and Fig. 4, which shows that the annual average TFP growth rate for Indian electricity distribution sector during the observed period is 4.538% and is mainly due to the contribution of technical efficiency change (2.341%) and the scale efficiency change (1.8037%). On the contrary, the contribution of technological progress to total factor productivity growth for all the distribution utilities is estimated as 0.3932%, and is found as statistically insignificant.

Table 3. Year wise Malmquist TFP change decomposition.

Year	Technical Eff. Change	Technological Change	Scale Efficiency Change	TFP Growth
2007/08 - 2008/09	2.25	1.4	-1.726	2.096
2008/09 - 2009/10	2.368	0.6968	1.385	4.449
2009/10 - 2010/11	2.325	-0.0625	2.446	4.708
2010/11 - 2011/12	2.422	-0.4612	5.11	6.898
Mean	**2.3412**	**0.3932**	**1.8037**	**4.538**

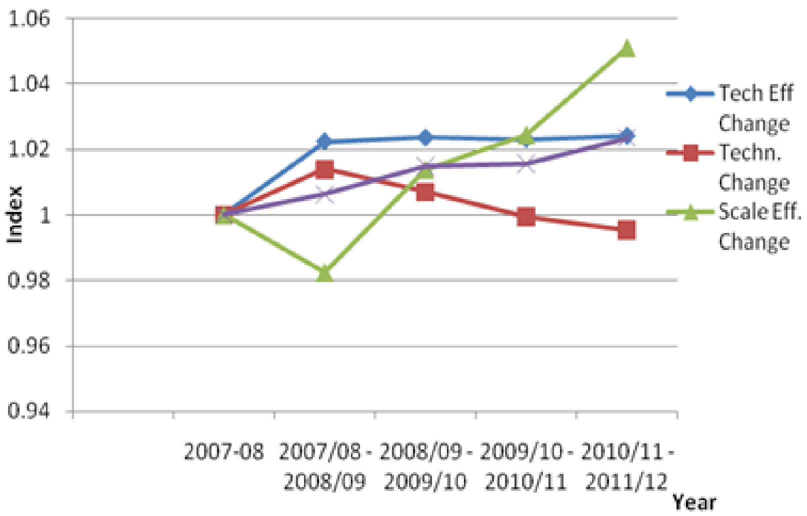

Fig. 4. Malmquist TFP Growth during period 2007/08 - 2011/12.

6.2. X-Factor (Productivity-offset) computation

The implementation of price cap regulation (i.e., RPI-X regime) for regulating the distribution prices requires the accurate determination of X-factor. X-factor is a mechanism, by which consumers receive benefits from the expected productivity growth of the companies. The proper choice of X-factor requires the considerable judgement of regulatory authorities. If too high X-factor is set, it will result in confiscation of the utility's property that will be both unfair and inefficient. If too low X-factor is set, it will dilute the incentive effect, and easy efficiency gains may not be achieved.

When setting X-factors, the regulatory authorities asks the frontier utilities to achieve an annual productivity improvement equal to the historical level of technical change (frontier shift), and wishes to ask the inefficient utilities (those below the frontier) to achieve frontier shift plus some technical efficiency improvement (catch up) [21, 22]. Frontier shift represents an estimate of the actual or potential productivity improvement achieved by a distribution utility that is already on the frontier and efficient in operations whereas catch-up or stretch factor refers to the efficiency gap that needs to be closed between the electricity distribution utility and the efficient frontier.

From Table 4, it is easily observed that the annual mean TFP growth for the Indian electricity distribution industry during the fiscal period 2007/08 - 2011/12 is obtained as 4.538% and is mainly the result of technical efficiency change of 2.341%. Thus the regulatory authorities and policy makers could include that asking all the electricity distribution utilities to achieve a minimum 4% percent TFP growth per year over the next review period (normally five years) would be acceptable. As discussed earlier that the utility-specific technical efficiency score over the observed period vary remarkably from .98682 for R-Infra (operating on the frontier) to 0.18282 for the most inefficient utility MSEDCL; the regulatory authorities or policy makers may direct to ask the inefficient utilities not to achieve a TFP growth rate equal to 4% per year, but also to attain a degree of catch-up to the frontier. The regulatory authorities could set the X-factor so as to ensure that each distribution utility has a technical efficiency score of 1 by the end of the five - year period. The estimated utility-specific and industry level X-factor (i.e., productivity offset) for 58 electricity distribution utilities in India over the regulatory period 2007/08 to 2011/12 is shown in Table 4. Overall, we obtained an average X-factor of 7% and positive X-factor implies that prices are expected to decrease over time. For instance if the rate of inflation (i.e., RPI) for Indian economy is 8% and if the regulator considered that the industry (or utility) could be expected to reduce its costs by 7% (X = 7%), then the price rises would be capped at 1%. On the other hand, a negative X-factor implies that the price cap results in a price increase.

Table 4. Utility-wise X-factor computation.

Utility	Mean Efficiency Score	Catch-Up	Frontier shift	X-Factor
Ajmer VVNL	0.1982	3.721	4	7.721
APCPDCL	0.2944	3.302	4	7.302
APEPDCL	0.5136	2.321	4	6.321
APNPDCL	0.3228	3.177	4	7.177
APSPDCL	0.30604	3.251	4	7.251
Arunachal Pradesh	0.207	3.683	4	7.683

Power Department				
Assam PDCL	0.2904	3.320	4	7.320
BESCOM	0.3418	3.093	4	7.093
BEST	0.6012	1.918	4	5.918
BSEB	0.18726	3.768	4	7.768
BSES RPL	0.38236	2.823	4	6.823
BSES YPL	0.38226	2.913	4	6.913
CalcuttaESC	0.5506	2.152	4	6.152
CESU / CESCO	0.3174	3.201	4	7.201
Chandigarh Elect. Deptt	0.93932	0.301	4	4.301
CHESCOM	0.388	2.888	4	6.888
CSEB	0.2302	3.582	4	7.582
DGVCL	0.5086	2.344	4	6.344
DHBVNL	0.27764	3.376	4	7.376
DVVNL	0.2788	3.370	4	7.370
GESCOM	0.3564	3.028	4	7.028
Goa Electricity Deptt.	0.4822	2.464	4	6.464
HESCOM	0.3114	3.227	4	7.227
HPSEB	0.26572	3.428	4	7.428
J&K Power Deptt.	0.3138	3.217	4	7.217
Jaipur VVNL	0.1984	3.720	4	7.720
Jodhpur VVNL	0.2192	3.630	4	7.630
JSEB	0.291	3.317	4	7.317
KESCO	0.541	2.196	4	6.196
KSEB	0.295	3.299	4	7.299
Maharashtra SEDCL	0.1736	3.827	4	7.827
Manipur Elect Deptt.	0.3916	2.872	4	6.872
MeghalayaECL	0.3582	3.020	4	7.020
MESCOM	0.4228	2.732	4	6.732
MGVCL	0.4344	2.680	4	6.680
Mizoram Elect. Deptt.	0.4958	2.402	4	6.402
MPMKVVCL	0.1914	3.750	4	7.750
MPPaschimKVVCL	0.214	3.653	4	7.653
MPPoorvKVVCL	0.196	3.731	4	7.731
MVVNL	0.1826	3.788	4	7.788
Nagaland Elect. Deptt.	0.3988	2.840	4	6.840
NESCO	0.3826	2.912	4	6.912
PGVCL	0.2414	3.534	4	7.534
PSEB	0.18282	3.787	4	7.787
Puducherry Elect Deptt	0.8588	0.696	4	4.696
PuVVNL	0.155	3.907	4	7.907
PVVNL	0.2648	3.432	4	7.432
R-Infra	0.98782	0.060	4	4.060
SOUTHCO	0.3778	2.933	4	6.933
Tata NDPL	0.587	1.984	4	5.984
TNEB	0.2296	3.585	4	7.585
Torrent Power Ltd	0.711	1.404	4	5.404
Tripura State Elect Corp Ltd	0.399	2.839	4	6.839
UGVCL	0.372	2.959	4	6.959
UHBVNL	0.279	3.370	4	7.370
Uttaranchal PCL	0.3708	2.964	4	6.964
WBSEDCL	0.2782	3.373	4	7.373
WESCO	0.3272	3.158	4	7.158
Mean	**0.3664**	**2.971**	**4**	**7.014**

(Source: Author's Own Calculations)

7. Conclusions

The regulatory authorities and policy makers in Indian electricity distribution industry intend to shift towards a tariff setting system for distribution services that rewards efficiency and results in lowering the distribution tariff. The most commonly adopted regulation for determining the distribution tariff is Price cap mechanism based on RPI-X Model. The proper choice of an X factor is critical for the long-term viability of RPI-X price cap regulation plan.

The present study has measured the X-factor under Price Cap Regulation mechanism (i.e., RPI-X) for 58 Indian electricity distribution utilities during the regulatory period 2007/08 to 2011/12. The average value of X-factor for the Indian electricity supply industry during the observed period is computed as 7.014% with a lower bound to R-Infra (4.06%) and upper bound to Purvanchal Vidyut Vitaran Nigam Limited (7.90%). The computed mean value of X-Factor specifies that the regulatory authorities mandate that price charged by the distribution utilities for providing distribution services should be reduced by about 7% per year during the next price control period. It is important to note that that the regulatory authorities and policy makers in Indian electricity supply industry could in principle use the calculated X-factor as a basis to begin discussions for proper development and implementation of price cap regulation framework for annual tariff determination for Indian electricity distribution utilities

Further, the empirical findings also confirmed that the yearly mean TFP growth for the entire Indian electricity distribution industry during the observed period is estimated as 4.538%, being this fact due to technical efficiency change that contributed an annual average growth rate of 2.341% and scale efficiency change with 1.803%. The privately - owned power distribution utilities (i.e., R-Infra, Torrent Power Limited, BEST, Tata NDPL) exhibit higher productivity than their public owned counterparts, results that are quite accurate and validated economically - private distribution utilities in comparison with government owned distribution utilities utilize minimum amount of inputs to obtain a specific output level.

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