Measurement of Change in Technical Efficiency, Scale Efficiency and Productivity Growth of DISCOMs in Karnataka Using DEA and Malmquist Productivity Index: Evaluating Reforms' Outcomes

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Abstract: ***The performance of electricity distribution companies (DISCOMs) is vital for ensuring reliable, affordable, and sustainable power supply, which underpins socio-economic development. This study evaluates the efficiency and productivity of five Karnataka DISCOMs- BESCOM, CESCOM, GESCOM, HESCOM, and MESCOM- over the period 2009-10 to 2024-25 in the context of power sector reforms. Data Envelopment Analysis (DEA), using both CCR and BCC models, is applied to estimate technical and scale efficiency, while the Malmquist Productivity Index (MPI) is employed to examine productivity changes over time. The analysis considers power purchase cost, employee cost, and interest cost as input variables, electricity sales and revenue as desirable output, and AT&C losses as an undesirable variable reflecting operational inefficiencies. The results reveal notable variation in efficiency across DISCOMs and years. BESCOM and MESCOM consistently perform closer to the efficiency frontier, whereas CESCOM, GESCOM, and HESCOM show relatively lower and more volatile efficiency levels. Scale inefficiency emerges as a key source of overall inefficiency, indicating suboptimal operational size. MPI findings suggest that productivity changes are inconsistent and largely driven by technological factors rather than managerial improvements. The study underscores the importance of reducing AT&C losses, optimizing costs, and enhancing operational scale to improve overall performance and financial sustainability.***

Keywords: Electricity Distribution Efficiency, Power Sector Reforms, Technical Productivity Analysis, AT&C Loss Reduction, Financial Sustainability

1. Introduction

The Power Distribution segment is the most critical component of the power sector, as it directly serves the final consumers and is responsible for generating revenue for the entire system. Electricity is not only a basic necessity but also a vital service that should be universally accessible to all, ensuring quality, reliability, sustainability, and affordability (*National Electricity Policy*). The per capita electricity consumption is widely regarded as an important indicator of economic progress and technological advancement (Zhu et al., 2021). The supply of electrical energy is now regarded as economic development and social progress (Priyadarshi et al., 2019). The provision of electricity enables economic growth of the nation and helps in poverty eradication in developed and developing nations (Ramaiah & Jayasankar, 2022). Therefore, ensuring a reliable and affordable supply of electricity is indeed essential for the holistic development and well-being of a state.

Since consumers interact more closely with distribution companies than with generation entities, a comprehensive evaluation of the performance of DISCOMs indeed essential. Such evaluation facilitates the identification of operational strengths and weaknesses, enabling targeted strategies for performance improvement (Panahi et al., n.d.). Furthermore, continuous evolution in management practices is necessary for optimal utilization of limited resources, which in turn enhances service quality and operational efficiency(Santos et al., 2011).

In the Indian context, particularly in the state of Karnataka the performance of electricity distribution companies (DISCOMs) assumes significant importance, as they are directly responsible for delivering electricity to end consumers (Rajkumari & Gayithri, 2018) (Pargal & Banerjee, 2014). Their role in providing affordable and reliable power is critical for sustaining socio-economic development. Unlike electricity generation, where performance outcomes are largely influenced by technological factors, the operational performance of DISCOMs is predominantly shaped by managerial efficiency and resource utilization (Dhillon & Vachharajani, 2017) (Khetrapal, 2020). Hence, assessing the efficiency and productivity of distribution utilities becomes particularly important.

The Karnataka's Economic Survey, 2025-26 indicates that Karnataka has made significant progress in strengthening its power sector through capacity expansion, renewable energy adoption, and modernization of transmission and distribution systems. The State has achieved near self-sufficiency, with over 53% of installed capacity from renewable sources, alongside reductions in T&D and AT&C losses, reflecting improved efficiency and financial performance. Policy initiatives such as feeder solarisation, smart metering, and the Gruha Jyothi Yojana have enhanced energy access, reliability, and social equity. However, the consumption-revenue structure highlights cross-subsidization, while rising demand necessitates continued investments in infrastructure and sustainable energy solutions.

Therefore the present study measures the efficiency of five DISCOMs in Karnataka, namely BESCOM, CESCOM, GESCOM, HESCOM, and MESCOM, in light of various reform initiatives undertaken in the state. The Data Envelopment Analysis (DEA), specifically the CCR and BCC models are used to measure the technical and scale efficiency of these utilities over time. Further, the Malmquist Productivity Index is also used to analyze changes in productivity over time. The analysis was performed using R statistical software and R Studio IDE for implementing DEA and productivity analysis R Core Team, 2025 and is based on secondary quantitative data covering the period from 2009-10 to 2024-25 collected from performance reports of power finance corporation. The input variables include power purchase cost, employee cost, and interest cost, while electricity sales and total revenue are considered as desirable outputs. AT&C losses are incorporated as an undesirable output, reflecting inefficiencies in the distribution system.

1.1 Electricity Sector Reforms in India with Special Reference to Karnataka

The history of the power sector in India, as well as in the state of Karnataka, highlights the challenges that have been faced in delivering reliable and affordable electricity to consumers. Prior to independence, the electricity sector in India was fragmented, with private companies and local authorities responsible for supplying electricity. The Electricity Supply Act of 1948 established the Central Electricity Authority (CEA) and State Electricity Boards (SEBs) as the main agencies responsible for supplying power throughout India, including the formation of the Karnataka Electricity Board in 1957. Although the creation of SEBs led to significant growth in the availability and accessibility of electricity, there were issues such as monopoly in operations, financial losses, high AT&C losses, lack of financial resources, and technological complexities. To address these problems, the government of India initiated reforms in the power sector in the 1990s, which included the introduction of private Independent Power Producers (IPPs). However, private investment did not materialize, and the IPP policy was viewed as a flawed and half-hearted approach to reforms. To improve the performance of the power sector, the government of Karnataka passed the Karnataka Electricity Reforms Act in 1999, which led to the bifurcation of the Karnataka Electricity Board into two companies, KPTCL and VVNL, and also establishment of the Karnataka Electricity Regulatory Commission (KERC). In subsequent stages, the transmission and distribution activities carried out by KPTCL were unbundled, and four power distribution companies were formed in 2002 namely Bengaluru Electricity Supply Company (BESCOM), Mangaluru Electricity Supply Company (MESCOM), Gulbarga Electricity Supply Company (GESCOM), and Hubli Electricity Supply Company (HESCOM) and in 2004 Chamundeshwari Electricity Supply Company (CESC) to manage the distribution of power in the state.

Table 1: Power Sector Reforms in India and Karnataka

Reform / Policy	Year	Key Features / Details
National Electricity Policy	2005	Targeted universal electrification, demand fulfillment, and sector viability.
RGGVY	2005	Rural household electrification with capital subsidies.
R-APDRP	2008	Focus on AT&C loss reduction, IT-enabled energy accounting.
Niranthara Jyothi Yojana	2008-09	Feeder segregation and 24-hour rural supply improvement.
IPDS	2014-15	Strengthening urban distribution networks and IT systems.
DDUGJY	2015	Strengthening rural networks and feeder separation.
UDAY (Ujwal DISCOM Assurance Yojana)	2015	State takeover of 75% DISCOM debt, cost reduction, efficiency improvement.
Saubhagya Scheme	2017	Electricity access to all households (rural & urban).
KUSUM Scheme	2018	Solarization of agricultural pumps and decentralized solar power.
Smart Metering Initiatives	2019-2022	Prepaid smart meters, improved billing efficiency, loss reduction.
Electricity (Amendment) Bill (Draft)	2020-2023	DBT for subsidies, competition in distribution, regulatory strengthening.
Revamped Distribution Sector Scheme (RDSS)	2021	Smart metering, infrastructure upgrades, reduction of AT&C losses (target 12-15%).
Late Payment Surcharge (LPS) Rules	2022	Ensures timely payments by DISCOMs, reduces debt stress.
Green Energy & Renewable Policies (incl. Green Hydrogen Mission)	2022-2023	Focus on renewable integration, RPO targets, green hydrogen.
Smart Meter National Programme Expansion (SMNP)	2022-2024	Nationwide rollout of smart prepaid meters and real-time monitoring.

Source: Compiled by the researcher

2. Review of Literature

The power sector and its role in infrastructure development have attracted attention in both academia and policy-making arenas. This is primarily due to the extensive structural and policy reforms that the sector has witnessed over the past two decades across the world. Consequently, there has been lot of scholarly research and formal debate on various dimensions of power sector reforms and their performance. Although numerous studies have examined power sector reforms in different countries, it is essential to focus on those studies that are particularly relevant to the present research. Accordingly, a comprehensive review of the pertinent literature has been undertaken.

Charnes et al., 1978 a nonlinear (non-convex) programming model provided a new definition of efficiency for use in evaluating activities of not-for-profit entities participating in public programs. A scalar measure of the efficiency of each participating unit is thereby provided, along with methods for objectively determining weights by reference to the observational data for the multiple outputs and multiple inputs that characterize such programs. Equivalences are established to *ordinary* linear programming models for effecting computations. The duals to these linear programming models provide a new way for estimating extremal relations from observational data. Connections between engineering and economic approaches to efficiency are delineated along with new interpretations and ways of using them in evaluating and controlling managerial behavior in public programs. Caves et al., 1982 developed index number procedures for making comparisons under very general circumstances. Malmquist input, output, and productivity comparisons are defined for structures of production with arbitrary returns to scale, substitution possibilities and biases in productivity change. For translog production structures, Törnqvist output and input indexes are shown to equal the mean of two Malmquist indexes. The Törnqvist productivity index, corrected by a scale factor, is shown to equal the mean of two Malmquist productivity indexes. Similar results are given for making cost of living comparisons under general structures of consumer preferences. The Banker et al., 1984 further extended a CCR model to separate into technical and scale efficiencies is accomplished by the methods developed in this paper without altering the latter conditions for use of DEA directly on observational data. Technical inefficiencies are identified with failures to achieve best possible output levels and/or usage of excessive amounts of inputs. Methods for identifying and correcting the magnitudes of these inefficiencies, as supplied in prior work, are illustrated. In the present paper, a new separate variable is introduced which makes it possible to determine whether operations were conducted in regions of increasing, constant or decreasing returns to scale (in multiple input and multiple output situations). The results are discussed and related not only to classical (single output) economics but also to more modern versions of economics which are identified with “contestable market theories.” The Bjure k, 1996 defined the Malmquist output and input quantity indexes specified by Caves et al. (1982) are applied in this study. Based on these indexes, a "Malmquist total factor productivity index" is derived for general production structures. The definition maintains the fundamental characteristic of a productivity index as a ratio between an output quantity change index and an input quantity change index. This index provides a remedy for the shortcoming of the traditional definition of the Malmquist productivity index in that the latter does not correctly measure changes in productivity in the presence of changes in returns to scale. Färe et al., 1997 analyzed the rates of productivity growth over the period 1979- 1988 in 17 OECD countries. They used DEA to measure Malmquist productivity indices for the individual countries by the ratio of the values of the output distance functions for a reference technology exhibiting constant returns to scale (CRS) at the input-output bundles of the same country observed in adjacent years. The Malmquist index is first decomposed into two factors: one showing technical change and the other, changes in technical efficiency, which can be interpreted as "catching up." The "catching up" term is further factored into two terms: one representing pure technical efficiency change and the other, changes in scale efficiency. This extended decomposition conceptualizes a technology characterized by variable returns to scale (VRS). Their use of CRS and VRS within the same decomposition of the Malmquist index raises a problem of internal consistency. Their technical change (TECHCH) measure corresponds to shifts over time in the CRS frontier. The other factors-pure efficiency change (PEFFCH) and scale efficiency change (SCH) are derived from VRS frontiers from two different periods, however. If CRS is assumed to hold, the TECHCH term correctly shows the shift in the frontier. But, under CRS no scale effect exists at all. Hence, the extended decomposition is misleading. On the other hand, if the VRS assumption is correct, TECHCH does not show how the maximum producible output changes due to technical change holding the input bundle constant. Kumbhakar & Hjalmarsson, 1998 focused on productive efficiency in Swedish retail electricity distribution during 1970-1990 using hedonic output(s) constructed from physical outputs and their qualities and network characteristics. The main focus is on efficiency of privately owned, municipal utilities, municipal companies, and companies with mixed ownerships. Three different approaches are used to examine whether ownership of the distribution companies has any systematic impact on the above issues. We also examine returns to scale and technical change. Empirical results from the three alternative approaches show that privately owned companies are relatively more efficient. We find evidence of scale economies and technical progress. McMullen & Okuyama, 2000 used Malmquist productivity indices to examine motor carrier productivity in the U.S. both before and after the Motor Carrier Act of 1980. Although overall productivity did not appear to change following regulatory reform, decomposition of the Malmquist Index shows significant gains in technical efficiency (firms moving closer to their production frontiers) following 1980. However, these efficiency gains were offset by what appears to be simultaneous technological regression, resulting in no net change in productivity. It is suggested here that the observed technological regress may be due to the changes in the way trucking firms do business in the less regulated environment, especially the increasing emphasis on quality of service. It is also possible that exogenous factors, such as deterioration on the highway system and increasing congestion, may contribute to this result. Tone, 2004 used Malmquist index (MI) evaluates the efficiency change over time. In the non-parametric framework, it is measured as the product of catch-up (or recovery) and frontier-shift (or innovation) terms, both coming from the DEA technologies. We introduce three different approaches for measuring the Malmquist index along with scale efficiency related subjects. Jha et al., 2007 analyzed performance of the hydropower plants owned by Nepal Electricity Authority (NEA), through investigation of operational relative efficiency of the respective plants. NEA is sole owner and operator of the Integrated Nepal Power Systems (INPS) which, covers over 95% of the total electrified area of the country. Modified DEA model, based on expert's opinion as well as available economic parameters, has been formulated to analyze operational performance of the hydropower plants. The model incorporates a wide range of inputs and outputs capturing essence of electricity production process by the hydropower plants. The results obtained are compared against those from conventional DEA model. Sensitivity analysis is carried out in order to investigate the robustness of the results and to identify the improvement directions for each hydropower plant. Based on the results of the sensitivity analysis, strengths and weaknesses of individual plants are identified. Jain & Thakur, 2010 presented a framework for accessing efficiency analysis of State Owned Electric Utilities (SOEUs), which have been mainly responsible for the generation, distribution and transmission of electricity in India. Efficiency Performance of Thirty state owned generation companies was evaluated using the Data Envelopment Analysis (DEA) for the time periods 2006-07. This efficiency performance of regulated electric utilities of India is very important for future requirement. The results give a mixed technical and scale efficiency scores showing that State owned electric utilities (SOEU) generation companies are inefficient in operation and need improvement. Chen & Yang, 2011 extended the metafrontier Malmquist productivity index, which takes into account the effect of scale efficiency change in its decomposition for both the non-parametric and parametric frameworks. Meanwhile, the 'catch-up' in the index is also disintegrated as two components: pure technological catch-up and frontier catch-up. An empirical application that uses unbalanced panel data of the Taiwanese and Chinese commercial banking industry is also conducted under a parametric framework. The results reveal that the adverse scale efficiency change is the key factor to inducing the inferior productivity growth seen in Chinese banks compared with Taiwanese banks, which spotlights the importance of the scale efficiency change term on productivity measures. It also provides one possible explanation for the recent hot issue about the motives for the two shores of the Taiwan Straits advancing financial openness to each other and mutually signing a banking Memorandum of Understanding. Yadav, 2016 measured Productivity change of Power sector in India during the period of 2000-01 to 2013-14. To fulfill the objectives of the study secondary data has been collected from GOI, Indiastat.com and Ministry of Power. In this study the nature of efficiency and productivity change is investigated through the Malmquist Productivity Index (MPI).The Malmquist productivity index has the components which are used in performance measurement; such as changes in technical efficiency, change in technological change, change in pure technical efficiency, change in scale efficiency as well as change in Total factor productivity. This study has taken two highest power generating sources -thermal and hydro. Symbols here listed as DMU1 and DMU2 respectively. The results of the study show that DMU1 (thermal) is efficient than DMU2 (Hydro). Rajesh Kumar, 2024 since the initiation of electricity sector reforms in 1991, the focus has been on improving efficiency, expanding generation capacity, promoting renewable energy, strengthening distribution systems, and encouraging private sector participation. The literature highlights that these reforms have led to significant improvements over the period from 1997-98 to 2021-22, particularly in terms of increased installed capacity, reduction in the demand-supply gap, enhanced operational efficiency, lower transmission and distribution losses, and improved financial viability of power utilities. However, despite these achievements, studies also point out the persistence of several structural and operational challenges within the sector. They have suggested the need for continued policy interventions and strategic measures to enhance the sustainability and overall performance of the Indian electricity sector.

3. Methodology

3.1 Data Collection

The study is based on secondary quantitative data obtained from performance reports of DISCOMs published by the Power Finance Corporation, Ministry of Power (Government of India), along with India Climate and Energy reports, the Economic Survey of Karnataka, and the annual reports of DISCOMs in Karnataka.

3.2 Time Frame of the Study

The study spans a period of sixteen years, covering 2009-10 to 2024-25.

3.3 Sampling and Sample Size

The study covers five DISCOMs in Karnataka, namely BESCOM, CESCOM, HESCOM, GESCOM, and MESCOM. To ensure adequacy for Data Envelopment Analysis (DEA), panel data for 16 years were utilized, resulting in a total of 80 decision-making units (DMUs). This sample size satisfies the commonly accepted DEA requirement, which recommends that the number of DMUs should be at least three times the total number of input and output variables.

3.4 Data Analysis Tools

The data analysis was conducted using the Posit RStudio IDE (version 2026.01.1), along with the *deaR* and *DiagrammeR* packages.

3.5 Data Envelopment Analysis

Farrel introduced the assessment of efficiency in 1957, whereas the method of Data Envelopment Analysis was developed by Charnes et al. in 1978 for the evaluation of efficiency based on input and output factors. According to the method of DEA, the efficiency is the weighted output over the weighted input, which gives the advantage of its applicability to varied input units, qualitative as well as quantitative information, and its role in decision-making for management.

DEA is a two-step procedure, in the first step of which the problem is formulated in fractional form, which is further simplified in the second step to linear form. This is where the idea of DEA comes to the rescue, which states that the efficiency level can be computed as the weighted sum of output to the weighted sum of input, mathematically expressed as

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

Data Envelopment Analysis (DEA) is widely recognized in the literature for its ability to provide comprehensive evaluations of performance, based on a limited number of assumptions while incorporating multiple inputs and outputs dimensions **Mergoni et al., 2025**. DEA is a non-parametric mathematical programming approach for frontier estimation. It involves the use of linear programming methods to examine the relative efficiency of decision making units (DMUs).

3.5.1 CCR Model

The study employs the input-oriented CCR model of Data Envelopment Analysis (DEA) to estimate the relative technical efficiency of Karnataka DISCOMs. The CCR model, developed by Charnes, Cooper, and Rhodes (1978), is based on the assumption of constant returns to scale, implying that outputs change in the same proportion as inputs. The input orientation is used because the study aims to examine the extent to which DISCOMs can reduce their input consumption while maintaining the existing level of outputs. The efficiency score obtained from the model varies between 0 and 1, where a value of 1 represents full technical efficiency and values below 1 indicate inefficiency. The CCR model measures Overall Efficiency (OE) by aggregating both technical and scale efficiencies.

For a set of *n* DMUs, where each DMU uses *m* inputs to produce *s* outputs, the linear programming problem for the *i-th* DMU is given as:

Objective Function:

$$\text{Minimize } \theta$$

Subject to

$$\sum_{j=1}^{n} \lambda j x i j \leq \theta x i 0, \quad i = 1,2,\ldots,m$$

$$\sum_{j=1}^{n} \lambda j x y r j \geq y r 0, \quad r = 1,2,\ldots,s$$

$$\lambda j \geq 0, j = 1,2,\ldots,n$$

Where:

- θ = Efficiency score (0 < θ\thetaθ ≤ 1)
- λj = Intensity variables (weights assigned to peer DMUs)
- xij = Amount of input *i* used by DMU *j*
- yrj = Amount of output *r* produced by DMU *j*
- xi0, yr0x = Inputs and outputs of the DMU under evaluation

The value of *θ* obtained will be the efficiency score for the i-th DMU.

Interpretation of Results:

- If θ=1: The DMU is technically efficient
- If θ<1: The DMU is inefficient

3.5.2 BCC Model

The input-oriented BCC model, developed by Banker, Charnes, and Cooper (1984), is an extension of the CCR model and is based on the assumption of variable returns to scale. The model evaluates the relative efficiency of decision-making units by identifying the extent to which inputs can be proportionally reduced while maintaining the same level of outputs. Unlike the CCR model, the BCC model includes the convexity constraint, Σ λj = 1, which permits variable returns to scale and enables the measurement of pure technical efficiency. An efficiency score equal to 1 indicates that the DMU is purely technically efficient, whereas a score less than 1 indicate inefficiency. The mathematical formulation of the input-oriented BCC model is as follows:

Objective Function:

Minimize θ

Subject to:

Σ λj xij ≤ θ xi0 (for i = 1, 2, …, m)
Σ λj yrj ≥ yr0 (for r = 1, 2, …, s)
Σ λj = 1
λj ≥ 0 (for j = 1, 2, …, n)

Where:

θ = Efficiency score
λj = Intensity variables
xij = Input i for DMU j
yrj = Output r for DMU j
xi0, yr0 = Inputs and outputs of the DMU under evaluation

3.5.3 Scale Efficiency in DEA

Scale Efficiency (SE) is computed as the ratio of technical efficiency under constant returns to scale (CCR model) to pure technical efficiency under variable returns to scale (BCC model). It indicates whether a DMU is operating at an optimal scale. A value of unity signifies scale efficiency, whereas a value less than unity indicate scale inefficiency. The decomposition of overall technical efficiency into pure technical efficiency and scale efficiency enables the identification of whether inefficiency arises from managerial factors or suboptimal scale of operation.

$$\textit{Scale Efficiency} = \frac{\textbf{CCR Efficiency}}{\textbf{BCC Efficiency}}$$

Interpretation

- SE = 1 → DMU is scale efficient (operating at optimal size)

- SE < 1 → DMU is scale inefficient
- If BCC = 1 but CCR < 1 → inefficiency is due to scale, not management

Returns to Scale Interpretation
Scale efficiency also helps to identify the type of returns to scale:
- Increasing Returns to Scale (IRS)
  → DMU is operating below optimal size
  → It should expand operations
- Decreasing Returns to Scale (DRS)
  → DMU is operating above optimal size
  → It should reduce scale
- Constant Returns to Scale (CRS)
  → DMU is operating at optimal scale

3.5.4 Malmquist Productivity Index (MPI)
The Malmquist Productivity Index (MPI) is employed to assess productivity changes of DISCOMs over time. It decomposes total factor productivity into efficiency change (catch-up effect) and technological change (frontier shift). Efficiency change reflects the ability of a DMU to move closer to the efficient frontier, while technological change captures shifts in the frontier itself. An MPI value greater than unity indicates productivity improvement, whereas a value less than unity signifies productivity deterioration. The mathematical expression of the MPI is as follows:

MPI= $\boldsymbol{Efficiency\ Change \times Technological\ Change}$
Decomposition

1) Efficiency Change (EFFCH)
$EFFCH = TE_{t+1} / TE_t$
This measures improvement in efficiency relative to the frontier (catch-up).

2) Technological Change (TECHCH)
$TECHCH = [\, D^t(x_{t+1}, y_{t+1}) / D^{t+1}(x_{t+1}, y_{t+1}) \times D^t(x_t, y_t) / D^{t+1}(x_t, y_t)]^{1/2}$
This measures shift in the production frontier (innovation/technology effect).

Interpretation
- MPI > 1 → Productivity improvement
- MPI = 1 → No change
- MPI < 1 → Productivity decline

Similarly:
- EFFCH > 1 → Efficiency improved
- TECHCH > 1 → Technological progress

4. Results and Discussion

This section presents descriptive statistics, correlation analysis, DEA CCR and BCC efficiency estimation, and MPI-based productivity analysis of Karnataka DISCOMs. Descriptive statistics highlight variability in inputs and outputs, while correlation analysis examines relationships among variables. DEA models estimate efficiency, and MPI evaluates productivity changes over time.

Table 2: Descriptive Statistics

Variable	Mean	Median	SD	Min	Max	CV
PowerCost	6133.273	3867.5	5963.41	877	28963	0.972305
EmployeeCost	674.6768	527	533.3007	128	3351.67	0.790454
InterestCost	394.6949	273.545	378.3138	51	1779.75	0.958497
ATCLoss	18.02738	17.795	6.011095	8.76	38.05	0.333443
Sales	11371.14	7205	8739.34	3512	36185	0.768554
Revenue	7218.241	4725.5	6961.146	946	33731.28	0.964383
Source Author’s calculations						

The descriptive statistics reveal significant heterogeneity in cost structures and operational performance across Karnataka DISCOMs. While power and interest costs show substantial variability, indicating differences in scale and financial management, AT&C losses remain consistently high, pointing to structural inefficiencies in the distribution system. The results suggest that improving financial management and reducing AT&C losses are crucial for enhancing the operational efficiency of DISCOMs.

Table 3: Correlation Matrix

Variable	PowerCost	EmployeeCost	InterestCost	ATCLoss	Sales	Revenue
PowerCost	1	0.893705	0.854254	-0.3399	0.909582	0.99343
EmployeeCost	0.893705	1	0.872292	-0.45627	0.717519	0.916046
InterestCost	0.854254	0.872292	1	-0.32922	0.666776	0.866377
ATCLoss	-0.3399	-0.45627	-0.32922	1	-0.17986	-0.38894
Sales	0.909582	0.717519	0.666776	-0.17986	1	0.88917
Revenue	0.99343	0.916046	0.866377	-0.38894	0.88917	1
Source Author’s calculations						

The correlation matrix indicates strong interrelationships among financial and operational variables of DISCOMs. Power cost shows a very high positive correlation with revenue (0.993) and sales (0.910), suggesting that higher power procurement is directly associated with greater energy sales and revenue generation. Similarly, employee cost and interest cost are strongly correlated with power cost (0.894 and 0.854 respectively), reflecting that larger utilities with higher operational scale tend to incur greater labor and financing expenses. Revenue is also highly correlated with employee cost (0.916) and interest cost (0.866), reinforcing the scale effect in financial performance. In contrast, AT&C losses exhibit a negative correlation with all major variables, particularly with employee cost (-0.456) and revenue (-0.389), indicating that higher losses are associated with weaker financial and operational outcomes. The relatively weak negative correlation between AT&C losses and sales (-0.180) suggests that loss reduction does not always proportionately translate into higher sales but still impacts revenue efficiency. Overall, the results highlight strong scale-driven relationships among cost and revenue variables, while emphasizing the adverse impact of AT&C losses on DISCOM performance.

Table 4: DEA- CCR and BCC Results

DMU	Year	CCR Efficiency Score	BCC Efficiency Score	Scale Efficiency Score	Efficiency
BESCOM	2009-10	1.00	1.00	1.00	Efficient
	2010-11	0.97	0.98	1.00	Efficient
	2011-12	1.00	1.00	1.00	Efficient
	2012-13	0.98	1.00	0.98	Efficient
	2013-14	0.96	1.00	0.96	Inefficient
	2014-15	1.00	1.00	1.00	Efficient
	2015-16	0.96	0.96	1.00	Efficient
	2016-17	1.00	1.00	1.00	Efficient
	2017-18	0.98	0.98	1.00	Efficient
	2018-19	0.87	0.94	0.92	Inefficient
	2019-20	0.88	0.95	0.93	Inefficient
	2020-21	0.88	0.89	0.99	Inefficient
	2021-22	1.00	1.00	1.00	Efficient
	2022-23	0.91	1.00	0.91	Inefficient
	2023-24	0.93	1.00	0.93	Inefficient
	2024-25	0.85	1.00	0.85	Inefficient
CESCOM	2009-10	0.94	0.94	1.00	Efficient
	2010-11	0.81	0.81	0.99	Inefficient
	2011-12	0.80	0.80	0.99	Inefficient
	2012-13	0.74	0.75	0.99	Inefficient
	2013-14	0.72	0.73	0.99	Inefficient
	2014-15	0.77	0.78	0.98	Inefficient
	2015-16	0.90	0.91	0.98	Inefficient
	2016-17	0.80	0.82	0.98	Inefficient
	2017-18	0.75	0.75	1.00	Efficient
	2018-19	0.81	0.81	0.99	Inefficient
	2019-20	0.83	0.84	0.99	Inefficient
	2020-21	0.73	0.73	1.00	Efficient
	2021-22	0.97	0.98	0.99	Inefficient
	2022-23	0.84	0.93	0.91	Inefficient
	2023-24	0.79	0.79	1.00	Efficient
	2024-25	0.72	0.84	0.86	Inefficient
GESCOM	2009-10	1.00	1.00	1.00	Efficient
	2010-11	0.88	0.89	0.99	Inefficient
	2011-12	1.00	1.00	1.00	Efficient
	2012-13	0.99	1.00	0.99	Inefficient
	2013-14	0.95	0.95	1.00	Efficient
	2014-15	0.96	0.96	1.00	Efficient
	2015-16	0.96	0.96	1.00	Efficient
	2016-17	0.85	0.87	0.98	Inefficient
	2017-18	0.84	0.84	0.99	Inefficient
	2018-19	0.81	0.81	1.00	Efficient
	2019-20	0.82	0.82	1.00	Efficient
	2020-21	0.75	0.75	1.00	Efficient
	2021-22	0.97	0.99	0.98	Inefficient
	2022-23	0.80	0.82	0.98	Inefficient
	2023-24	0.70	0.75	0.93	Inefficient
	2024-25	0.71	0.84	0.85	Inefficient
HESCOM	2009-10	0.93	0.97	0.96	Inefficient
	2010-11	0.87	0.89	0.99	Inefficient
	2011-12	0.84	0.86	0.97	Inefficient
	2012-13	0.79	0.79	1.00	Efficient
	2013-14	0.78	0.78	0.99	Inefficient
	2014-15	0.91	0.91	0.99	Inefficient
	2015-16	0.78	0.78	1.00	Efficient
	2016-17	0.80	0.80	1.00	Efficient
	2017-18	0.73	0.74	1.00	Efficient
	2018-19	0.70	0.70	0.99	Inefficient
	2019-20	0.89	0.99	0.91	Inefficient
	2020-21	0.77	0.80	0.96	Inefficient
	2021-22	0.96	0.99	0.98	Inefficient
	2022-23	0.82	0.87	0.94	Inefficient
	2023-24	0.78	0.85	0.92	Inefficient
	2024-25	0.72	0.90	0.80	Inefficient
MESCOM	2009-10	1.00	1.00	1.00	Efficient
	2010-11	0.99	0.99	1.00	Efficient
	2011-12	0.98	0.98	1.00	Efficient
	2012-13	0.90	0.93	0.97	Inefficient
	2013-14	0.92	0.95	0.96	Inefficient
	2014-15	0.94	0.96	0.97	Inefficient
	2015-16	0.83	0.86	0.97	Inefficient
	2016-17	0.79	0.82	0.97	Inefficient
	2017-18	0.82	0.85	0.97	Inefficient
	2018-19	0.87	0.91	0.95	Inefficient
	2019-20	0.83	0.84	0.99	Inefficient
	2020-21	0.76	0.76	1.00	Efficient
	2021-22	1.00	1.00	1.00	Efficient
	2022-23	0.94	0.94	1.00	Efficient
	2023-24	0.83	0.83	1.00	Efficient
	2024-25	0.72	0.75	0.96	Inefficient

Source: Author's calculations

The DEA results for Karnataka DISCOMs reveal notable variations in efficiency across time and utilities. **BESCOM** demonstrates relatively strong performance, achieving full efficiency (CCR = BCC = 1) in multiple years, although recent declines (CCR = 0.85 in 2024-25) indicate emerging scale inefficiencies. **CESCOM** consistently records lower efficiency scores, particularly in earlier years (CCR as low as 0.72), reflecting persistent operational and scale inefficiencies despite slight improvements in select years. **GESCOM** shows moderate performance with occasional efficiency peaks, but a declining trend in recent years suggests weakening operational performance. **HESCOM** exhibits fluctuating efficiency with generally lower CCR scores, indicating both technical and scale inefficiencies across most periods. **MESCOM** performs comparatively better among the smaller utilities, maintaining high efficiency in initial years and achieving full efficiency again in 2021-22, though recent years show some deterioration. Overall, the gap between CCR and BCC scores across utilities suggests that inefficiencies are largely driven by **scale inefficiencies**

rather than pure technical inefficiency, highlighting the need for optimal resource utilization and restructuring of operational scale to improve performance.

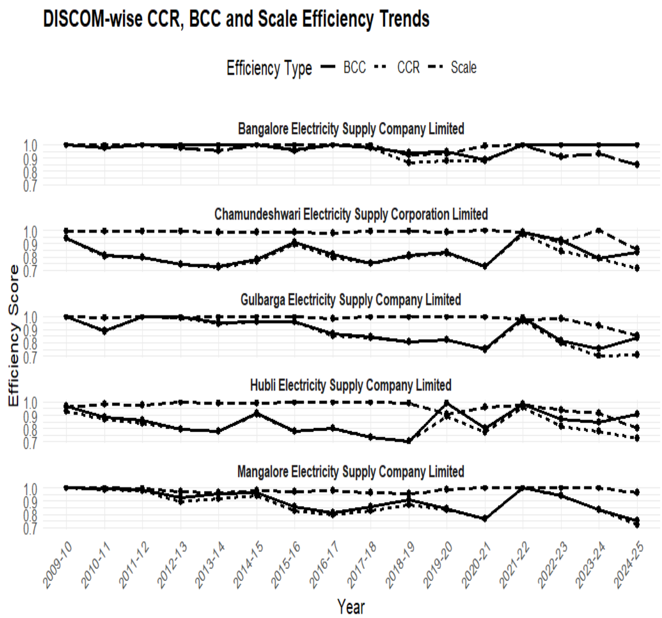

Figure 1: Shows DISCOM- wise CCR, BCC and Scale Efficiency Trends
Source: Primary Data

The figure 1 presents the time-series trends of CCR (overall technical efficiency), BCC (pure technical efficiency), and Scale efficiency for five Karnataka DISCOMs from 2009-10 to 2024-25, highlighting both temporal changes and inter-utility differences. Overall, BCC scores remain consistently higher and closer to 1 across all DISCOMs, indicating that most utilities are relatively efficient in their pure technical operations (i.e., managerial efficiency). In contrast, CCR scores are comparatively lower and more volatile, suggesting that overall efficiency is constrained when scale effects are considered. The gap between BCC and CCR across most years implies that scale inefficiency is a major source of performance gaps. At the utility level, BESCOM shows strong and stable performance, with efficiency scores frequently reaching or approaching unity, although a slight dip is observed in recent years. CESCOM exhibits consistently lower CCR scores with noticeable fluctuations, indicating persistent inefficiencies and weaker scale performance. GESCOM shows moderate efficiency with a declining trend in later years, particularly in CCR and scale efficiency. HESCOM demonstrates significant variability, with efficiency dipping in several periods, reflecting both technical and scale-related challenges. MESCOM performs relatively well, maintaining high efficiency in earlier years and achieving full efficiency around 2021-22, but shows some decline toward the end of the period.

Table 5: Malmquist Productivity Index (MPI) Results

DMU	Year	MI (TFP Change)	EC (EC)	TC (T C)
BESCOM	2010-11	0.97	1.00	0.97
	2011-12	1.28	1.00	1.28
	2012-13	0.83	1.00	0.83
	2013-14	0.90	1.00	0.90
	2014-15	0.98	1.00	0.98
	2015-16	0.83	1.00	0.83
	2016-17	0.92	1.00	0.92
	2017-18	0.93	1.00	0.93
	2018-19	0.94	1.00	0.94
	2019-20	0.96	1.00	0.96
	2020-21	0.93	1.00	0.93
	2021-22	1.07	1.00	1.07
	2022-23	0.90	1.00	0.90
	2023-24	1.07	1.00	1.07
	2024-25	0.79	1.00	0.79
CESCOM	2010-11	0.86	0.98	0.88
	2011-12	0.99	0.98	1.01
	2012-13	0.94	1.11	0.85
	2013-14	0.97	0.97	1.01
	2014-15	0.97	0.97	1.00
	2015-16	0.86	1.06	0.81
	2016-17	0.91	1.00	0.91
	2017-18	1.00	1.00	1.00
	2018-19	1.05	0.94	1.11
	2019-20	1.01	1.06	0.95
	2020-21	0.84	1.00	0.84
	2021-22	1.16	0.97	1.20
	2022-23	0.87	1.03	0.85
	2023-24	0.88	1.00	0.88
	2024-25	0.99	1.00	0.99
GESCOM	2010-11	0.87	0.98	0.89
	2011-12	1.16	1.02	1.14
	2012-13	0.91	1.00	0.91
	2013-14	0.92	1.00	0.92
	2014-15	0.96	1.00	0.96
	2015-16	0.84	1.00	0.84
	2016-17	0.79	0.97	0.81
	2017-18	1.03	1.03	1.00
	2018-19	1.00	0.99	1.01
	2019-20	0.93	0.93	1.00
	2020-21	0.92	1.09	0.85
	2021-22	1.15	0.97	1.19
	2022-23	0.83	0.96	0.87
	2023-24	0.91	1.01	0.90
	2024-25	1.08	1.07	1.01
HESCOM	2010-11	0.95	1.02	0.93
	2011-12	0.97	0.89	1.09
	2012-13	0.93	1.09	0.86
	2013-14	0.96	0.92	1.04
	2014-15	1.17	1.14	1.03
	2015-16	0.81	1.03	0.78
	2016-17	0.87	0.94	0.93
	2017-18	0.92	0.98	0.94
	2018-19	1.02	1.06	0.96
	2019-20	1.02	1.02	1.00
	2020-21	0.85	0.99	0.86
	2021-22	1.11	0.98	1.14
	2022-23	0.86	0.98	0.88
	2023-24	1.00	1.06	0.94
	2024-25	0.98	0.99	0.99
MESCOM	2010-11	0.98	1.00	0.98
	2011-12	1.02	1.00	1.02
	2012-13	0.91	1.00	0.91
	2013-14	1.03	1.00	1.03

	2014-15	1.02	1.00	1.02
	2015-16	0.78	0.95	0.82
	2016-17	0.97	1.05	0.92
	2017-18	1.04	1.00	1.04
	2018-19	1.01	1.00	1.01
	2019-20	0.95	1.00	0.95
	2020-21	0.88	1.00	0.88
	2021-22	1.21	1.00	1.21
	2022-23	0.97	1.00	0.97
	2023-24	0.94	1.00	0.94
	2024-25	0.71	1.00	0.71
Source: Author's calculations				

The Malmquist Productivity Index (MPI) results reveal dynamic changes in productivity across Karnataka DISCOMs, decomposed into Efficiency Change (EC) and Technological Change (TC). For **BESCOM**, EC remains consistently equal to 1 throughout the period, indicating no change in managerial efficiency, while variations in MI are entirely driven by TC; productivity improvements (MI > 1) in years such as 2011-12, 2021-22, and 2023-24 reflect technological progress, whereas declines (e.g., 2024-25: MI = 0.79) indicate technological regression. **CESCOM** shows fluctuating productivity with both EC and TC contributing to changes; notable improvements (e.g., 2021-22: MI = 1.16) are driven largely by technological gains, while declines are due to technological setbacks despite occasional efficiency improvements. **GESCOM** demonstrates moderate variability, with productivity growth in select years (e.g., 2011-12 and 2024-25) supported by both efficiency and technology, but overall instability persists due to alternating regressions. **HESCOM** exhibits significant fluctuations, where both EC and TC alternately drive productivity changes; strong gains (e.g., 2014-15 and 2021-22) contrast with notable declines (e.g., 2015-16), indicating inconsistent performance. **MESCOM** generally maintains stable efficiency (EC ≈ 1), with productivity changes largely driven by TC; a peak in 2021-22 (MI = 1.21) suggests strong technological advancement, while the sharp decline in 2024-25 (MI = 0.71) indicates substantial technological regression. Overall, the findings suggest that technological change is the primary driver of productivity variations across DISCOMs, while efficiency change remains relatively stable, highlighting the importance of technological upgrades and innovation in improving power distribution performance.

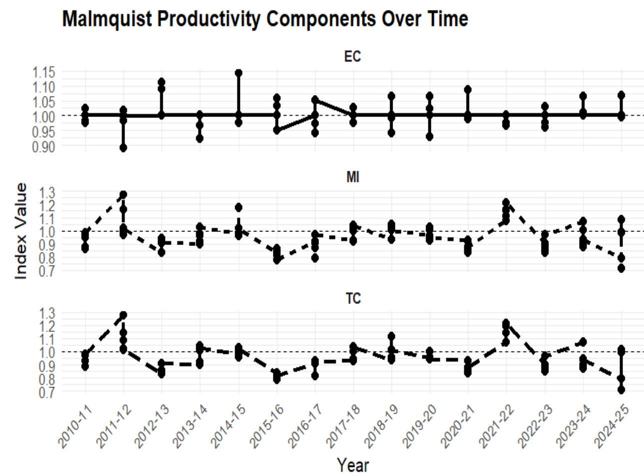

Figure 2: Shows Malmquist Productivity Components Overt Time
Source: Primary Data

The figure 2 illustrates the time-wise trends of Malmquist Productivity Index (MI), Efficiency Change (EC), and Technological Change (TC) for the DISCOMs, with the dotted line at 1 indicating the benchmark (values >1 = improvement, <1 = decline). The EC (Efficiency Change) panel shows that most values are clustered around 1, indicating relative stability in managerial or operational efficiency over time, with only minor fluctuations. This suggests that DISCOMs are generally maintaining their efficiency levels rather than significantly improving or deteriorating in terms of internal operations.

In contrast, the MI (Malmquist Index) panel exhibits greater variability, with several years showing values below 1 (notably around 2012-13, 2015-16, and 2024-25), indicating periods of productivity decline, while some years (such as 2011-12 and 2021-22) show improvement. This inconsistency implies that overall productivity growth has not been sustained across the study period. The TC (Technological Change) panel closely mirrors the pattern of MI, confirming that technological change is the primary driver of productivity variations. Periods of technological progress (TC > 1) correspond with productivity gains, while technological regress (TC < 1) aligns with productivity decline.

Overall, the figure highlights that productivity changes in DISCOMs are largely driven by technological shifts rather than efficiency improvements, with efficiency remaining relatively constant but insufficient to ensure consistent productivity growth.

5. Conclusion

The study concludes that **BESCOM and MESCOM** consistently demonstrate relatively higher efficiency, often operating on or near the efficiency frontier, whereas **CESCOM, GESCOM, and HESCOM** exhibit lower and more volatile efficiency levels, indicating persistent structural and operational challenges. The Malmquist Productivity Index analysis reveals that productivity growth has been inconsistent over the study period, with fluctuations driven primarily by technological change rather than improvements in managerial efficiency, suggesting limited progress in internal operational practices. Further, the observed negative relationship between AT&C losses and financial performance confirms that loss reduction is critical for enhancing revenue realization and overall financial health.

From a policy perspective, the findings underscore the need for targeted reforms in both operational efficiency and technological advancement. First, aggressive reduction of AT&C losses through smart metering, energy auditing and strengthened billing and collection mechanisms should be prioritized. Second, cost rationalization strategies, particularly in power procurement, employee expenses, and interest burden, are essential to improve financial sustainability. Third, there is a need to promote technology-driven interventions, including grid modernization, digitalization, and automation, to address the dominant role of technological change in productivity. Fourth, optimal scale restructuring and benchmarking practices should be encouraged to address scale inefficiencies identified in DEA results. Finally, regulatory support and performance-linked incentives can play a crucial role in driving accountability and efficiency improvements across DISCOMs. Collectively, these policy measures can enhance operational efficiency, ensure long-term financial viability, and support the sustainable transformation of the power distribution sector.

6. Future Scope

Future research can extend this study by including more DISCOMs across different states for broader comparison. Incorporating additional variables such as renewable energy integration, service quality, and digitalization (e.g., smart metering) would provide a more comprehensive evaluation. Advanced methods like network DEA, dynamic DEA, or Stochastic Frontier Analysis (SFA) can be used for deeper insights. Further, panel regression analysis may help identify key determinants of efficiency, including policy reforms and tariff structures. Integrating environmental and consumer-centric aspects can also enhance the overall assessment of DISCOM performance.

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