International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 23s, 2025
https://theaspd.com/index.php

Technical Efficiency and Productivity Growth of DISCOMs in Northern India: Evaluating Reforms' Outcomes Using DEA-Malmquist Models

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Abstract:
The performance of power distribution utilities in India is crucial for ensuring affordable and reliable electricity access for all segments of society. This study assesses the technical efficiency and growth in the productivity of power distribution companies (DISCOMs) in Northern India from 2012-13 to 2022-23 using the DEA-based Malmquist Productivity Index (MPI). The analysis, conducted in R-Studio with the 'Productivity' package, employs an input-oriented CCR-based DEA-MPI framework. The findings indicate that DISCOMs with MPI greater than one have experienced positive growth. KESCO is leading. In contrast, UTPCL had the lowest productivity. Efficiency Change (EC) remains stable across most DISCOMs, while Technological Change (TC) is the prime mover of growth in productivity. KESCO and MVVN exhibited the highest technological improvements, whereas UTPCL and DVVN exhibited technological stagnation. Analysis highlights that DHBVN, UTPCL, and DVVN depend on input-driven advancements for Magnitude-Augmented Technological Change (matech) and Input-Biased Technological Change (ibtech). KESCO, MVVN, PSPCL, and AVVNL have maintained a balanced technological change. This study identifies the need for investment in technology strategically to fill efficiency gaps. Key policy insights for India's power distribution sector are required to enhance DISCOMs' operational performance.
Keywords: Electricity Reforms, DISCOMs, Efficiency Change, Technological Change, Malmquist Productivity Index, Productivity Growth, Performance Analysis.

1. INTRODUCTION

Electricity is a crucial catalyst for the expeditious growth of the primary, secondary, and tertiary sectors. The growth of these sectors collectively represents economic growth and helps alleviate poverty in developed and developing nations [1]. Electricity is an indicator of the development of technologies and socio-economic advancement. Therefore, a reliable and affordable supply of electricity is essential for the overall development and well-being of the state [2]. In India, the performance of Distribution Companies (DISCOMs) is of great importance because they play an important role in providing affordable and reliable electricity, which is essential for socio-economic development [3]. The task of assessing the productivity and efficiency of electricity distribution companies is vital because their operational performance depends on managerial effectiveness. In contrast, technological factors predominantly dictate performance outcomes in electricity generation. Therefore, evaluating the efficiency and productivity of electricity generation may be of limited value [4], [5].

Consumers are more closely related to electricity distribution companies than to electricity generation companies. Thus, a detailed evaluation of the effectiveness and performance of distribution utilities is required. In addition, the evolution of management processes is essential for effective resource utilisation. Such assessments are essential for enhancing operational efficiency. This enhanced operational efficiency ensures quality-of-service delivery to customers [6]. By assessing efficiency, strengths, and weaknesses across various operational aspects, which makes it possible to identify targeted strategies to enhance overall performance [7] and provide a better outlook for the utilisation of limited resources [8].

In this study, the improvement in the efficiency of DISCOMs owing to the effect of various schemes launched by the GOI is analysed. This study includes five states of north India: Haryana, Punjab, Rajasthan, Uttarakhand, and Uttar Pradesh. The GOI has launched schemes such as the Integrated Power Development Scheme, UDAY, SAUBHAGYA, PM-KUSUM, DDUGJY, and PMUY to make DISCOMs profitable and efficient. The impact of these schemes on technical efficiency and productivity is examined via the Malmquist DEA Index using R software [9]. The secondary data of the years 2012-13 and 2022-23 were used for analysis, and the variables were taken as power purchase cost, employee cost, total interest cost, and other costs as inputs, power sold, and total revenue as outputs.

1.1 ELECTRICITY REFORMS IN INDIA

The electricity distribution sector in India has undergone remarkable structural and policy-driven transformations aimed at enhancing efficiency, promoting competition, and ensuring financial viability. These reforms were implemented in multiple phases.

The Electricity Act of 2003 was a landmark reform that repealed previous electricity laws to introduce competition and efficiency in the power sector [10]. It enables open access, allowing consumers to choose electricity suppliers, thereby encouraging private sector participation, which increased its share in generation capacity from 13% in 2003 to 54.3% as of 31 May 2025 [11]. This act results in the unbundling of State Electricity Boards (SEBs) into separate entities, that is, transmission, generation, and distribution entities. National- and state-level regulatory commissions were established to oversee tariffs and sectoral governance. In addition, it aimed to reduce cross-subsidies. It supports microgrids and provides electricity to remote areas, all of which help improve the sector's operational and technical efficiency [12]. Today, it remains a remarkable act of electricity regulation in India.

DDUGJY emphasised improving electricity access in villages and strengthening rural electricity distribution networks to support rural economic growth. The Ujwal Discom Assurance Yojana (UDAY), 2015, was initiated to reduce the financial stress of DISCOMs by restructuring their debt. It is aimed at reducing aggregate AT&C losses and improving operational efficiency. The National Tariff Policy (2006, revised in 2016) aimed to regulate tariffs across the country. It also focuses on promoting renewable energy integration (CERC). The Integrated Power Development Scheme focused on the modernisation of distribution networks, ensuring a reliable electricity supply to urban areas and reducing AT & C losses [13]. SAUBHAGYA emphasised the electrification of rural households and improved socioeconomic development. The PM-KUSUM scheme aims to promote decentralised solar power generation. PMUY focuses on reducing the dependence on traditional biomass and promoting cleaner fuel adoption [14]. The Electricity (Amendment) Bill 2022 proposed licensing for the distribution sector. It promotes renewable energy, ensures greater competition, and enhances consumer choice (Ministry of Power, GOI). The Revamped Distribution Sector Scheme (RDSS) aims to reduce AT&C losses to 12-15% and the gap between Average Cost of Supply & Average Revenue Realised to zero by 2024-25 [15].

2. THE RATIONALE OF THE STUDY

Distribution plays a fundamental role in delivering electricity to end-users. DISCOMs operate as an interface between the generation and consumption of electricity, purchasing from public and private sources, and then distributing it to consumers in the industrial, residential, commercial, and agricultural sectors. Despite their vital role, DISCOMs face financial and operational challenges, including transmission and distribution losses, aggregate technical and commercial (AT&C) losses, and revenue deficits. To tackle these issues, successive reforms were initiated, particularly under the 2003 Electricity Act. These reforms aimed to enhance efficiency, productivity, financial sustainability, and the quality of service delivery. Despite these efforts, some bottlenecks remain, due to which North Indian DISCOMs continue to struggle with financial distress and inefficiency. These bottlenecks necessitate a rigorous empirical assessment of reform outcomes. This study uses the DEA-based Malmquist Productivity Index (MPI) to analyse the technical efficiency and growth in productivity of DISCOMs. MPI further decomposes productivity changes into technological change (TC) and efficiency change (EC). That is, it provides a vision of whether improvements arise from technological advancements or better resource utilisation. These slight variations in performance are not represented by traditional financial indicators. This research contributes to the existing literature by offering a comprehensive assessment of post-reform efficiency trends. It offers actionable policy recommendations for improving distribution efficiency, reducing losses, and ensuring the sector's long-term viability. This study's comprehensive econometric methodology will fill a critical research gap in assessing reforms in the electricity sector and offer a valuable resource for future studies in policy analysis and energy economics.

3. RESEARCH OBJECTIVE

To analyse the impact of electricity sector reforms on the productivity growth and technical performance of northern India's DISCOMs.

4. RESEARCH GAP

The productive growth and technical efficiency of DISCOMs in northern India remain insufficiently recognised, despite an abundance of research on power sector reforms. The majority of research concentrates on macro-level reforms, neglecting specialised quantitative techniques, such as the DEA-based Malmquist productivity index. Despite disparities in operational issues, financial structures, and regulatory frameworks, there are few comparative evaluations between states. Moreover, many studies fail to distinguish between efficiency improvements driven by technological progress and those resulting from policy changes or improved management. Another major gap is the absence of dynamic time-based analysis. MPI, which captures these time-based changes, is rarely used, leading to an incomplete understanding of the impact of reforms. This study aims to fill these gaps by using DEA-based Malmquist Models to track productivity growth, efficiency trends, and the real impact of reforms on DISCOMs across Northern India. In addition to evaluating technical and regulatory constraints and differentiating between management and technological efficiency drivers, this study provides a comparative state-level analysis. This study fills these gaps by offering evidence-based suggestions to boost the efficiency and sustainability of distribution utilities.

5. RESEARCH METHODOLOGY-

This study employs a quantitative research approach using the DEA-based Malmquist Productivity Index to analyse the productivity growth and technical efficiency of power distribution companies (DISCOMs) in Northern India. The methodology is structured to ensure a comprehensive empirical assessment of efficiency changes in response to electricity sector reforms. Thirteen DISCOMs under the jurisdiction of the state governments of Haryana (DHBVN & UHBVN), Rajasthan (JDVVNL, AVVNL, & JVVNL), Himachal Pradesh (HPSEBL), Uttar Pradesh (DVVN, POVVNL, MVVN, PAVVN & KESCO), Punjab (PSPCL), and Uttarakhand (UTPCL) are taken in this study. The analysis uses performance data from Power Finance Corporation Ltd.'s "Performance of Power Utilities' reports, which are used as a data source to analyse performance, covering the 2012–13 and 2022–23 periods.

Charnes et.al. developed Data Envelopment Analysis (DEA) [16]. It is used to determine the relative efficiency of homogeneous units with multiple inputs and outputs [17]. The BCC model was proposed by Banker et. al., which produces VRS [18],[19]. Indices are used to compare different datasets (usually economic or financial), especially over time. The Malmquist Index (MI) can assess productivity changes over time and between two economies. MPI was named after Professor S. Malmquist. MI addresses efficiency studies over time. Shepherd (1953) and Malmquist (1953) developed the idea of the distance function in economics. Inspired by Malmquist (1953) and Shepherd (1953), Caves et al. (1982) introduced MI as a theoretical index that was defined in terms of distance functions [20]. Later, Fare, Grosskopf, Lindgren, and Roos (FGLR, 1992) [21] and Fare, Grosskopf, Norries, and Zhang (FGNZ, 1994) [22] connected Farrell (1957), Charnes et al. (1978) [16], and Caves et al. (1982) propounded the CCR nonparametric DEA-based Malmquist Productivity Index. The MPI was decomposed into Pure Efficiency Change, Technological Change, and Scale Change under both the CRS and VRS by FGNZ in 1994. Two different versions of the basic DEA-based Malmquist index are available

a.)-Adjacent Index by FGNZ (1994).
b.)-Base period Index by Bery, Forsund & Jansen (1992).

DEA-based MPI measures total factor productivity change, and multiple inputs and outputs can be handled with a few assumptions and without any information on the prices of inputs or outputs [23]. Productivity change can be decomposed into Technological Change (Frontier Shift Effect) and Efficiency Change (catch-up effect). Using MPI, trends and patterns can be identified in the industry.

Efficiency Change (EC) measures whether a DISCOM has improved its operational efficiency relative to past performance. It can be calculated as

$$EC(a,b) = \frac{\theta_{bb}}{\theta_{aa}}$$

EC(a,b) is the change in efficiency in period b measured against period a. θ_{aa} and θ_{bb} are own period efficiency scores. These are managerial efficiencies over time.

Technological Change (TC) evaluates advancements in industry-wide best practices and innovations. It can be calculated as

$$TC(a,b) = \left(\frac{\theta_{aa}\,\theta_{ab}}{\theta_{ba}\,\theta_{bb}}\right)^{1/2}$$

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Where TC (a,b) is the technological efficiency change in period b measured against period a. θ_{ab}, and θ_{ba} are the cross-period or mixed-period efficiency scores. θ_{ab} is the efficiency score for observation in period 'b' measured against period 'a'. θ_{ba} is the efficiency score for observation in period 'a' measured against the frontier of period 'b'.

The expression for MPI can be obtained by multiplying EC and TC:

$$MPI = \left(\frac{\theta_{ab}}{\theta_{aa}} \times \frac{\theta_{bb}}{\theta_{ba}}\right)^{1/2}$$

MPI = EC × TC

$MPI > 1 \longrightarrow$ Productivity Improvement
$MPI < 1 \longrightarrow$ Productivity decline
$MPI = 1 \longrightarrow$ No Productivity Change

Subsequently, Ray and Desli (1997) proposed a three-component decomposition under the VRS [24]. MPI was decomposed into Pure Efficiency Change, Pure Technological Change, and Scale Change. Shestalova (2003), Pastov and Lovell (2005), Asmild and Tam (2007), Oh (2010), and Chen and Yang (2011) proposed different types of MPI.

5.1 VARIABLES (INPUTS AND OUTPUTS)-Numerous input and output factors can be used to evaluate India's state power utility performance. Toestimate efficiency, appropriate variables were selected based on their economic and operational relevancein the power distribution sector. The following variables are selected to measure MPI, Efficiency, andTechnological change.

5.1.1 INPUTS:

>Gross input energy
>Employee Cost
>Total Interest Cost
>Other Cost: This includes generation cost, operation and maintenance cost, depreciation, and other expenditures.

5.1.2 OUTPUTS:

>Power Sold

>Total Revenue

6. RESULTS AND ANALYSIS

The analysis was conducted using R-Studio software using the 'Productivity' package. MPI, EC, and TC were computed using input-oriented and CCR-based DEA-MPI. In this study, the Adjacent Index by FGLR (1992) with two-component decomposition was used.

TABLE 1. EFFICIENCY RESULTS FROM THE DEA-BASED MALMQUIST PRODUCTIVITY INDEX

SR. No.	DMU	MPI	EC	TC	IBTECH	MATECH
1	AVVNL	1.38	1.06	1.29	1.03	1.02
2	DHBVN	1.17	1.00	1.17	1.70	0.57
3	DVVN	0.96	1.00	0.96	1.40	0.54
4	HPSEBL	1.06	1.00	1.06	1.13	0.83
5	JDVVNL	1.29	1.07	1.21	1.04	0.94
6	JVVNL	1.35	1.10	1.23	0.97	1.03
7	KESCO	1.69	1.11	1.53	1.02	1.15
8	MVVN	1.48	1.04	1.43	1.03	1.07
9	PAVVN	1.20	1.00	1.20	1.33	0.72
10	POVVN	1.18	0.98	1.20	1.17	0.82
11	PSPCL	1.37	1.05	1.31	1.12	1.01
12	UHBVN	1.39	1.00	1.39	1.32	0.93
13	UTPCL	0.48	0.97	0.49	2.71	0.15

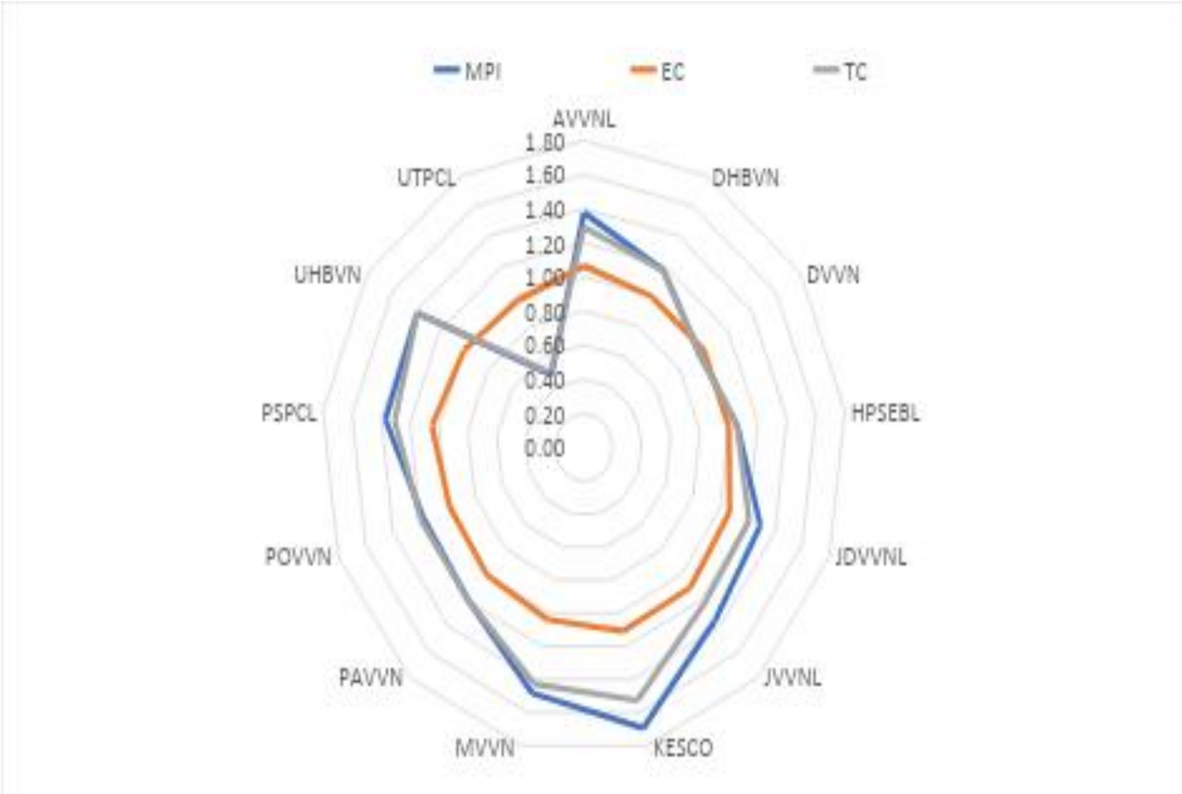
Source: Calculated by the author based on data from Power Finance Corporation reports.

In Table 1, the DMUs with MPI less than one are inefficient, and their growth has declined from 2012-13 to 2022-23 despite several reforms in the sector. The DISCOMs DVVN and UTPCL have negative growth, and UTPCL (MPI=0.48) performs worse than all DISCOMs. DISCOMs with more than one MPI are progressive and have positive growth. DISCOM, KESCO (MPI=1.69), exhibits the highest MPI and is the best of all DISCOMs. The DISCOMs AVVNL (MPI=1.38), DHBVN (MPI=1.17), JDVVNL (MPI=1.29), JVVNL (MPI=1.35), MVVN (MPI=1.48), PAVVN (MPI=1.20), POVVN (MPI=1.18), PSPCL (MPI=1.37), and UHBVN (MPI=1.39) also have positivegrowth. The DMU HPSEBL (MPI=1.06) has an MPI just above one, showing nearly steady growth.

Further, MPI can be divided into two parts:

Technological Change (TC) and Efficiency Change (EC).

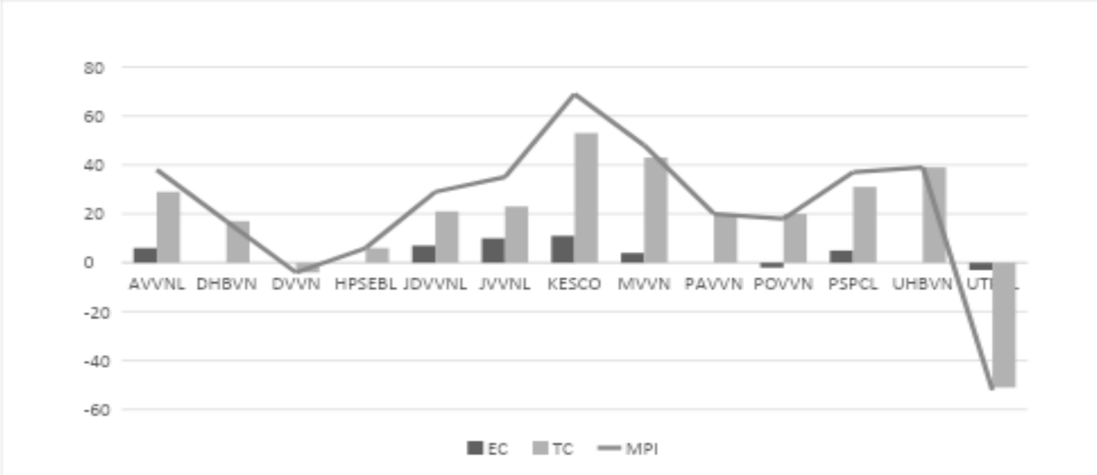
Figure 1:MPI, TC, and EC of DISCOMs



Source: Calculated by the author based on data from Power Finance Corporation reports.

In Figure 1, the radar chart visually represents MPI, technical changes, and efficiency changes for various power distribution companies (DMUs). The MPI curve exhibits significant variation across entities, indicating differences in overall productivity growth. The EC curve remains relatively stable across most DMUs, signifying that efficiency improvements are moderate and not the primary driver of productivity growth. KESCO had the highest Efficiency Change EC (1.11). AVVNL, JDVVNL, JVVNL, MVVN, and PSPCL have positive efficiency growth, while DHBVN, DVVN, HPSEBL, PAVVN, and UHBVN have not improved their efficiency from 2012-13 to 2022-23, i.e., EC = 1. POVVN and UTPCL show a decline in efficiency growth, that is, EC = 0.98 and 0.97, respectively. The TC curve closely follows MPI trends, reinforcing that technological advancements are the dominant factors that influence productivity variation. KESCO (TC = 1.53), MVVN (TC = 1.43), and UHBVN (TC = 1.39) exhibited the highest levels of technological improvement, emphasising the adoption of modern infrastructure and digital advancements. DVVN (TC = 0.96) and UTPCL (TC = 0.49) showed a decline in technological advancement. The remaining DMUs have moderate technological change from 2012-13 to 2022-23.

Figure 2: Percentage change in EC, TC, and MPI from 2012-13 to 2022-23

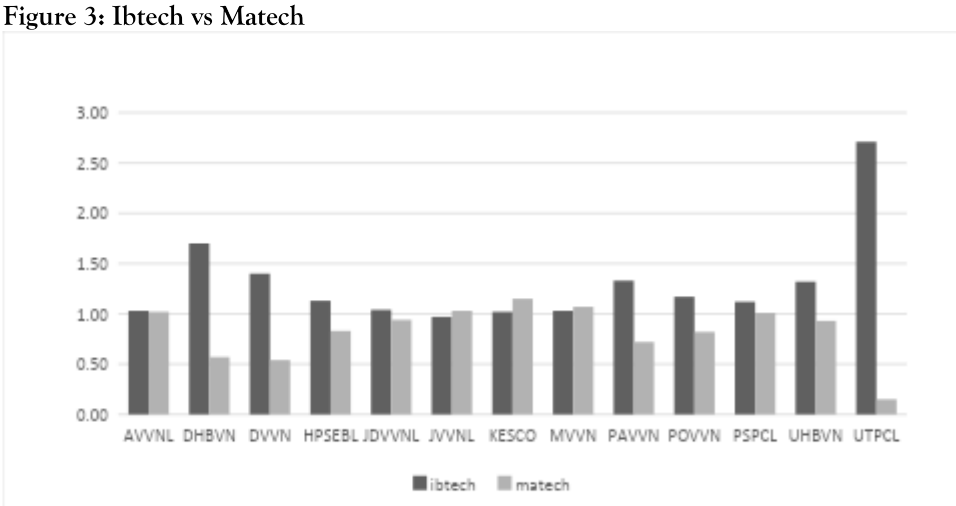


Source: Calculated by the author based on data from Power Finance Corporation reports.

In Figure 2, the DMUs are shown on the x-axis, and the efficiency change in percentage is shown on the y-axis. Percentage changes in EC and TC are represented as a bar diagram, and percentage changes in MPI are represented as a line graph for various power distribution companies (DMUs). This figure reveals the contributions of EC and TC to MPI. This figure shows whether managerial efficiency or technological advancement drives productivity improvements in the power distribution sector. Several DMUs, including MVVN, KESCO, and UHBVN, exhibit significant improvements in Technical Change, translating into a corresponding rise in overall productivity (MPI). KESCO, in particular, recorded the highest growth, indicating substantial technological advancements. UTPCL and DVVN show negative growth in MPI, with sharp declines in TC and EC, indicating severe inefficiency and technological stagnation. The steep drop in UTPCL productivity suggests systemic operational and investment challenges. Entities such as AVVNL, JDVVNL, JVVNL, and PSPCL demonstrate moderate but steady growth in TC and MPI, indicating a balanced approach to both efficiency and technological progress.

In Figure 3, the bar chart illustrates the Magnitude-Augmented Technological Change (matech) and Input-Biased Technological Change (ibtech) for power distribution companies (DISCOMs) in Northern India from 2012-13 to to 2022-23. The value of ibtech is represented on the y-axis and matech, while the x-axis lists the respective DMUs. These metrics provide insights into the nature and magnitude of technological advancements in power distribution. Several DISCOMs, such as DHBVN, DVVN, and UTPCL, exhibit high ib-tech value, indicating that technological advancements in these utilities have been more input-driven. The exceptionally high ib-tech value of the UTPCL suggests a significant shift in input utilisation, possibly due to investments in smart grids, automation, and workforce efficiency. Conversely, DISCOMs such as AVVNL, JDVVNL, KESCO, and MVVN demonstrate relatively lower ib-tech values, emphasising input-oriented technological change less.

Figure 3: Ibtech vs Matech



Source: Calculated by the author based on data from Power Finance Corporation reports.

The matech values are relatively lower than those of ibtech for most DISCOMs, indicating that although there have been technological improvements, the overall magnitude of their impact remains moderate. Utilities such as AVVNL, KESCO, MVVN, and PSPCL show comparatively balanced ib-tech and ma-tech values, reflecting a harmonised approach to technological integration rather than an over-reliance on input-driven efficiencies. DHBVN, DVVN, and UTPCL exhibit enormous disparity between ibtech and matech, suggesting that their technological advancements are predominantly input-driven rather than holistic in magnitude augmentation.

7. CONCLUSION & SUGGESTIONS-

The empirical analysis of MPI, technological change, efficiency change, magnitude-augmented technological change, and input-based technological change across power distribution companies (DISCOMs) in Northern India provides critical insights into the impact of electricity sector reforms. The findings highlight the significant heterogeneity in efficiency and technological progress among DISCOMs, reflecting the diverse implementation and adoption of reforms, investment patterns, and operational strategies.

The MPI indicates that most DISCOMs have a positive impact on reforms, except DVVN and UTPCL. KESCO shows the highest MPI values, suggesting strong productivity improvements primarily driven by technological advancements. The steep decline in UTPCL productivity suggests systemic operational and investment challenges. This study highlights the need for targeted policy interventions to enhance technological innovation and operational efficiency, particularly for underperforming DMUs.

Across most DMUs, TC surpasses efficiency change, suggesting that productivity growth is largely technology-driven rather than stemming from operational efficiency enhancement. KESCO, MVVN, and UHBVN exhibit the highest levels of technological improvement, emphasising the adoption of modern infrastructure and digital advancements. Entities such as AVVNL, JDVVNL, JVVNL, and PSPCL demonstrate relatively proportional improvements in both efficiency and technology, indicating a comprehensive approach to performance enhancement through both process optimisation and investment in new technologies. UTPCL has a significantly low TC, whereas its EC remains comparable to that of other DMUs. This finding suggests a lack of technological upgrade, leading to stagnation in productivity growth. Companies with low efficiency change should focus on capacity building, workforce training, and process optimisation to enhance their operational performance. Targeted investment in grid modernisation and automation could be crucial for underperforming utilities. The variation in EC and TC levels across different organisations highlights disparities in policy implementation, investment strategies, and technological adoption. While some companies have leveraged innovation and productivity, others remain constrained by inefficient management and outdated infrastructure.

A high ib-tech value indicates a strong dependency on technological improvements related to input factors such as labour, capital, or energy efficiency measures. A lower match value may suggest that the overall technological impact on productivity is limited, necessitating further strategic innovation efforts. DISCOMs should not rely solely on input-driven technological enhancements. However, they should focus on augmenting the magnitude of the technological impact by investing in smart automation, AI-driven load management, and digitalisation. Utilities with high in-tech but low ma-tech (UTPCL, DHBVN, PAVVN, and DVVN) should re-evaluate their technology deployment strategies, ensuring that the innovations translate into broader performance improvements rather than input efficiencies. Companies exhibiting a balanced approach (AVVNL, KESCO, MVVN, and PSPCL) could be benchmark organisations for other DISCOMs to adopt a more integrated technological advancement model.

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