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Chapter 1: Introduction and Summary

Ali Emrouznejad¹ [0000-0001-8094-4244], Centre for Business Analytics in Practice, Surrey Business School, University of Surrey, Guildford, Surrey, UK. A.emrouznejad@surrey.ac.uk

Subhash Ray [0000-0003-2274-5639], University of Connecticut, USA, subhash.ray@uconn.edu,

Gokulnanda Patel [0000-0002-4608-2924], Birla Institute of Management Technology, India, gn.patel@bimtech.ac.in

Abstract

This volume presents a comprehensive collection of cutting-edge research on Data Envelopment Analysis (DEA), featuring contributions from the DEA2024 Conference and leading scholars in the field. Organised into five thematic sections, it highlights both methodological advancements and diverse applications across sectors such as energy, finance, healthcare, education, and industry. The book underscores usefulness of DEA in addressing current challenges, including sustainability, digital transformation, and performance optimisation under uncertainty, reflecting its evolution into a dynamic tool for efficiency analysis and strategic decision-making.

1. Introduction

Data Envelopment Analysis (DEA), introduced by Charnes, Cooper, and Rhodes (1978), is a non-parametric method for evaluating the relative efficiency of entities transforming multiple inputs into multiple outputs. Using linear programming to construct an empirical efficiency frontier, DEA enables benchmarking of Decision-Making Units (DMUs) such as firms, hospitals, schools, and public services without requiring assumptions on input-output weights or functional forms.

To address the reality that not all DMUs operate at optimal scale, Banker, Charnes, and Cooper (1984) extended the CCR model to the BCC model, incorporating variable returns to scale. This advancement allowed differentiation between pure technical inefficiency and scale inefficiency, broadening DEA's analytical scope (Emrouznejad, Podinovski, et al., 2025).

Since its inception, DEA has grown into a central research methodology and practical tool across various disciplines. With over 27,000 publications since 1978 (Scopus – see Figure 1), DEA has been widely applied in healthcare, education, banking, energy, transportation, agriculture, and more. Research activity surged after 2000, with annual publications exceeding 1,800 since 2020, reflecting DEA's adaptability to emerging challenges like sustainability, performance management, and integration with advanced analytics.

¹ Corresponding author: Ali Emrouznejad* [0000-0001-8094-4244], Centre for Business Analytics in Practice, Surrey Business School, University of Surrey, Guildford, Surrey, UK. A.emrouznejad@surrey.ac.uk

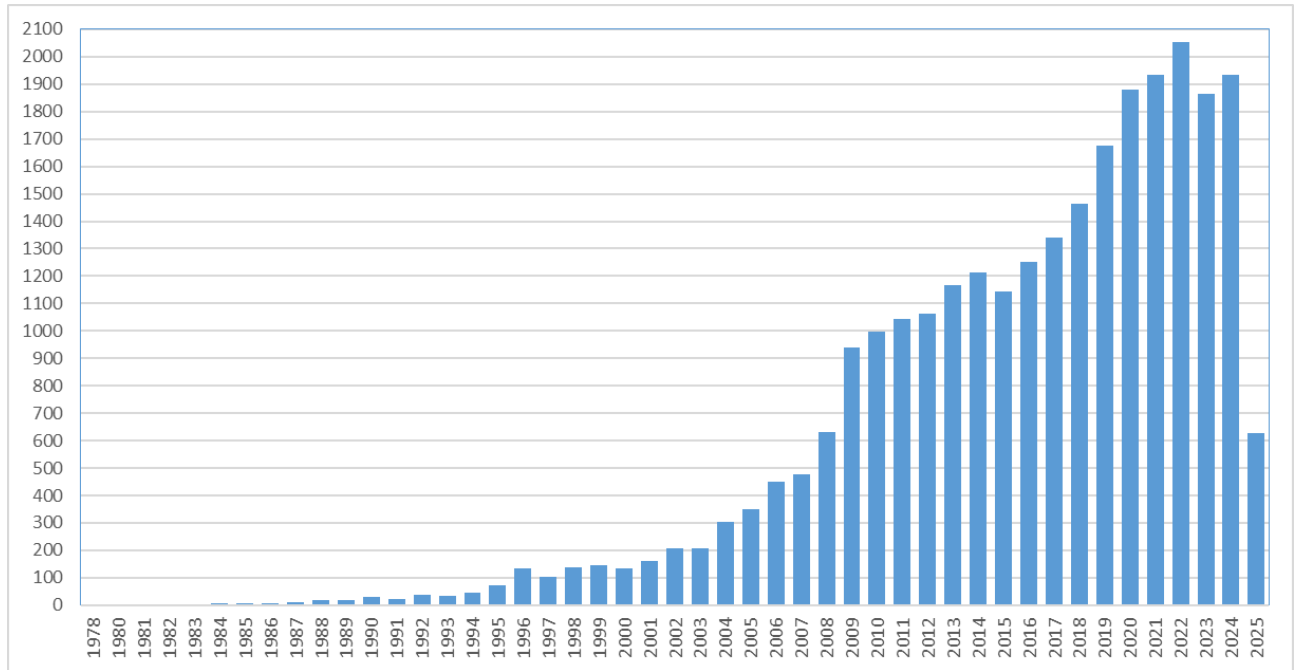


Figure 1. Number of documents (papers, books and chapter books) published since 1978

Over five decades (Mergoni, Emrouznejad, & De Witte, 2025), DEA has evolved beyond its original models to address complexities such as uncertainty, dynamic systems, and undesirable outputs (Ray, et al, 2018). Key advancements include the Nonparametric Productivity Index (Färe et al., 1994; Ray and Desli, 1978), Network DEA (Färe and Grosskopf 1996), and Slacks-Based Measure (Tone, 2001; Emrouznejad, Brzezicki, & Lu, 2025b). DEA’s flexibility has been further enhanced through integration with robust optimization, fuzzy logic (Hatami-Marbini, 2011), stochastic optimisation (Olesen et al., 2016), and machine learning techniques (Zhu et al., 2021), enabling applications in big data, predictive analytics, and decision support under uncertainty.

Today, DEA is not merely a tool for efficiency measurement but a dynamic framework for performance management, policy analysis, and strategic decision-making. This book reflects the latest developments in DEA, combining methodological innovations with practical applications across sectors. The contributions herein underscore DEA’s enduring relevance and its capacity to evolve in response to contemporary operational and societal challenges.

2. Contents of this book

This volume is collection of selected research contributions from the DEA2024 Conference, along with invited chapters from leading scholars in the field. The book showcases the latest methodological advancements and innovative applications of Data Envelopment Analysis (DEA) across a wide range of sectors. Organized into five thematic sections, it begins with theoretical developments and continues with applications in energy, finance, healthcare, education, and industry. Each chapter highlights DEA’s usefulness in addressing complex efficiency and productivity challenges in diverse contexts.

Section I: Methodological and Theoretical Developments in DEA

This section showcases innovative methodologies that push the boundaries of traditional DEA models. Building on the theme of robustness, *Peykani, Emrouznejad, Mahmoodirad, Nouri, and Arabjazi (2025)* propose a generalized leader-follower network DEA model that incorporates convex uncertainty sets. This model enhances DEA's capability to assess multi-stage decision-making units (DMUs) under

uncertain data conditions, particularly relevant for complex operational systems. The following chapter by *Peykani, Nouri, Shojaie, Ghiyasi and Esmaeeli (2025)* further expand the concept of robust DEA framework for evaluating intellectual capital efficiency under deep uncertainty. Their approach leverages conservative robust optimization to deliver stable efficiency scores in volatile environments, offering a significant contribution to DEA applications in intangible asset management.

In addressing dimensionality challenges, *Dalal, Agarwal, and Mathur (2025)* propose an important contribution by integrating DEA with Rough Set Theory. Their hybrid framework provides a structured method for optimal criteria selection, improving the discriminatory power of DEA in environments with large variable sets. This is followed by a chapter by *Prabhash and Valiyattoor (2025)* to introduce the novel concept of Imputation Propelled DEA (IPDEA), where machine learning techniques are employed to handle missing data and mitigate DEA's sensitivity to small samples. Their empirical analysis in the Indian food processing sector demonstrates how AI can effectively complement DEA for more robust performance evaluations. Following this *Yu (2025)* developed a Forest-Based resampling for confidence interval estimation of efficiencies in DEA.

A broader perspective is given by *Patel, Cvetkoska, and Kitanovikj (2025)*, who conduct a multi-technique bibliometric review of DEA applications in corporate sustainability. Their work not only maps the intellectual landscape of this field but also identifies key research clusters and outlines future directions, providing a valuable resource for scholars and practitioners. This is followed by a chapter from *Ramanathan and Li (2025)* to exploring the mediating role of innovation in the relationship between environmental regulations and firm performance. Using DEA, they provide critical insights into how firms can leverage innovation to balance regulatory compliance with competitive performance.

Finally, *Marques Júnior and Maciel Filho (2025)* present advancements in FRANCISCO 2.0, a specialized tool utilizing multiplicative DEA models and fractal analysis for forecasting efficiency in internet services. Their work enhances the usability and functionality of DEA in analysing modern, dynamic network infrastructures.

Section II: Energy, Environment, and Utilities

This section demonstrates DEA's utility in promoting sustainability, optimising resource use, and evaluating environmental performance. *Sufia, Singh, and Mishra (2025)* apply a two-stage DEA model combined with reliability indices to assess Indian electricity distribution utilities, offering practical recommendations for operational improvements in the energy sector. In a complementary study, *Veerlapati and Perumal (2025)* evaluate the efficiency of 19 Indian state-owned electricity generation utilities using a CCR DEA model. Their analysis identifies inefficiencies and benchmarks, providing strategic insights for policymakers and utility managers. This is followed by a chapter from *Kumar and Jain (2025)* who address the socio-economic impacts of decarbonization in India by employing DEA models based on by-production and weak disposability approaches. Their work quantifies the labour-related cost effects of environmental regulations, contributing to the discourse on sustainable transitions.

Turning to agriculture, *Pandey, Singh, and Tiwari (2025)* evaluate the environmental performance of European farms engaged in joint crop and animal husbandry production. Using DEA, they highlight best practices for sustainable farming operations, while *Pal, Chakraborty, and Ghose (2025)* investigate total factor productivity growth in Indian rice production through DEA combined with panel structural

break tests, offering insights into productivity trends and agricultural efficiency. In the same area *Murugesan (2025)* applied DEA to measure technical, pure technical and scale efficiency of primary agriculture cooperative credit societies in Tamil Nadu.

Addressing renewable energy, *Luhaniwal, Agarwal, and Mathur (2025)* propose a Fuzzy DEA model with exogenously fixed variables to rank renewable energy sources. Their approach addresses uncertainty in decision-making processes related to energy policy and resource allocation.

Section III: Banking, Finance, and Insurance

This section focuses on efficiency evaluations within financial institutions, highlighting DEA's role in enhancing financial performance and stability. *Muvungi (2025)* applies DEA to bank asset and liability management, introducing a semi-oriented radial measure model to handle negative interest rate gaps, thus offering a novel approach to optimizing balance sheet structures, while *Sinha (2025)* provides a comprehensive assessment of banking efficiency in India using non-parametric DEA, revealing operational strengths and weaknesses across the sector.

Expanding on predictive analytics, *Gupta, Puri, and Setia (2025)* integrate network DEA with support vector regression (SVR) to forecast cost efficiency in Indian banks, showcasing a powerful hybrid methodology for financial performance forecasting, while *Kushwaha and Kumar (2025)* propose an integrated DEA with an entropy-based Russell Measure to evaluate the performance of Central Banks of G20 countries.

In the insurance domain, *Sinha and Amirteimoori (2025)* employ a cluster-based DEA approach to evaluate the efficiency of Indian life insurance companies, identifying peer groups and operational benchmarks.

Section IV: Healthcare and Education

Efficiency in healthcare and education directly impacts societal outcomes, and this section highlights DEA's relevance in these critical sectors. *Devitt, Dineen, and Zieba (2025)* use a double-bootstrap DEA to evaluate cost and allocative efficiency across Irish public hospitals, identifying significant opportunities for cost reduction and efficiency improvement. In the same area, *Tigga, Sarkar, and Mor (2025)* utilize a slack-based DEA model to identify inefficiencies in India's health sector, focusing on excess resource utilization and output shortfalls.

Furthering this theme, *Sarkar and Tigga (2025)* evaluate the efficiency of public health expenditures in reducing child mortality across emerging market economies, offering valuable insights for health policy optimization. This is followed by a study on investigation and evaluation of efficiency in primary and secondary healthcare system of India by *Dar, Dar, and Gulbadin (2025)*.

Turning to education institutions, *Fallah and Rostamy-Malkhalifeh (2025)* apply a two-stage network DEA to assess mathematical proficiency in Portuguese high schools, providing actionable insights for educational resource optimization and targeted interventions, while *GÖLCÜKCÜ (2025)* developed a fuzzy DEA model for managerial ability assessment of Turkish state universities.

Stumbriene, Ruiz, and Sirvent (2025) address bi-objective benchmarking challenges in education using DEA, offering methodological solutions for balancing multiple educational performance goals, and finally, in an analysis of educational inequality, *Ghose and Choudhury (2025)* investigate the impact of

private tuition on the efficiency of government and aided schools in Kolkata, revealing how supplementary education influences institutional performance.

Section V: Industry-Specific Applications

The final section illustrates DEA's adaptability across various industries. In the pharmaceutical sector, *Mahajan (2025)* analyses the post-COVID efficiency of Indian MSMEs, shedding light on resilience factors critical to recovery and competitiveness. While *Kwatra and Patel (2025)* proposed a DEA model for performance mapping of startups in India. *Sithamparam and Thiagarajan (2025)* apply DEA window analysis to assess operational efficiency in the Malaysian telecommunications industry, capturing the dynamics of technological advancements and market restructuring, while *Singh, Pratap, and Laud (2025)* employ Malmquist DEA to evaluate efficiency and productivity changes in the top five global tourism destinations, highlighting the sector's recovery trajectory post-pandemic.

Turning to transportation systems, *Babazadeh, Al Raisi, and Kamran (2025)* assess container terminal efficiency in Southwest Asia, identifying operational inefficiencies and offering improvement strategies through DEA analysis. In the same vein, *Mansouri Kaleibar and Krmac (2025)* evaluate energy efficiency in Adriatic container ports, providing sustainability benchmarks for maritime logistics. Similarly, *Das, Sinha, and Mukherjee (2025)* combine stochastic frontier analysis (SFA) with the Malmquist index to examine technical efficiency and productivity trends in major Indian ports, offering a hybrid methodological perspective.

3. Acknowledgements

We extend our heartfelt gratitude to all the authors whose dedication, expertise, and scholarly contributions have made this volume possible. Their innovative research and commitment to advancing the field of Data Envelopment Analysis are the foundation of this collection. We also sincerely thank the reviewers for their invaluable feedback and constructive critiques, which have significantly enhanced the quality and rigor of each chapter.

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Furthermore, we gratefully acknowledge the efforts of the organizers of DEA2024, held at BIMTECH, India, in November 2024. Their outstanding work in hosting a successful conference provided the platform for many of the contributions featured in this volume.

Finally, it is important to clarify that the responsibility for the content, accuracy, and interpretations presented within each chapter lies solely with the respective authors. As editors, we have facilitated the compilation and organization of this volume but do not assume responsibility for any errors or omissions. We encourage readers to exercise their judgment when applying the insights provided.

We trust that this collection will serve as a valuable resource and a source of inspiration for ongoing research, practical applications, and future innovations in the dynamic and ever-evolving field of Data Envelopment Analysis.

4. Conclusions

This collection demonstrates DEA's continued growth as both a research discipline and a practical framework, showcasing its adaptability to complex, real-world problems across various domains. The innovative methodologies and applications featured in this volume not only advance the theoretical boundaries of DEA but also provide actionable insights for practitioners and policymakers. As DEA continues to evolve, this book serves as a catalyst for future research and a guide for leveraging DEA in addressing emerging operational and societal challenges.

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