Artificial Intelligence, Data Envelopment Analysis and Sustainable Economic Performance: A Bibliometric Analysis

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Abstract

Purpose

The increasing integration of artificial intelligence (AI) and machine learning (ML) with Data Envelopment Analysis (DEA) methodology is transforming conventional efficiency assessment into a more predictive, optimization-oriented, and sustainability-focused research domain. While DEA has traditionally been applied to assess technical and economic efficiency, recent studies have combined it with AI-based methods to address energy efficiency, environmental performance, sustainable development, and resource optimization. This study maps the development, conceptual structure, geographical distribution, and thematic evolution of research at the intersection of DEA, AI, and sustainable economic performance. Particular attention is given to the transition from conventional efficiency measurement toward AI-supported approaches and to emerging research directions connecting digital and green dimensions of economic transformation.

Design/methodology/approach

A bibliometric analysis was conducted using publications retrieved from the Web of Science Core Collection and Scopus. The search strategy was designed around three mandatory conceptual dimensions: (1) DEA and its methodological extensions, (2) AI and machine-learning techniques, and (3) sustainability and economic/environmental performance.

Web of Science (Topic field):

TS=(
("data envelopment analysis" OR "SBM-DEA" OR "network DEA"
OR "dynamic DEA" OR "super-efficiency DEA" OR "two-stage DEA")
AND
("artificial intelligence" OR "machine learning" OR "deep learning"

OR "neural network*")
AND
(sustainab* OR "sustainable development" OR "green economy"
OR "green growth" OR "environmental efficiency" OR "energy efficiency"
OR "environmental performance" OR "carbon emission*" OR decarboni*
OR "economic performance" OR "economic efficiency")
)

The equivalent query was applied to the TITLE-ABS-KEY fields in Scopus. The searches initially identified 218 records in Web of Science and 224 in Scopus. After database merging and duplicate removal, the final bibliographic dataset comprised 299 unique documents published between 2009 and 2026. The records were analysed using Bibliometrix/Biblioshiny. The analysis included descriptive bibliometric indicators, annual scientific production, keyword frequency and co-occurrence, thematic mapping, thematic evolution, trend-topic analysis, country scientific production, international collaboration, and citation impact. Author keywords were standardized through a thesaurus to consolidate synonymous variants of DEA, machine learning, artificial intelligence, and neural-network terminology.

Findings

The results reveal a rapidly expanding research domain. The 299 documents were published across 212 sources and involved 776 authors, with an annual publication growth rate of 21.91%. Scientific production remained relatively limited during the early years of the study period, increased gradually after 2017, and accelerated markedly after 2021, which is in line with the development and increased application of AI technologies. International co-authorship accounted for 24.08% of the dataset, indicating a moderate but developing level of cross-country collaboration.

Keyword and co-occurrence analyses identify DEA as the methodological core of the field, closely connected with machine learning, artificial intelligence, neural networks, deep learning, random forest, optimization, energy efficiency, environmental performance, and sustainable development. The thematic map further reveals a broad basic research cluster linking machine learning and neural-network approaches with sustainability, energy efficiency, and energy consumption. More specialized themes encompass circular economy, energy optimization, environmental performance, life-cycle assessment, supplier selection, and decision-support applications.

The longitudinal analysis reveals a particularly clear transformation of the field. During 2009-2019, research was predominantly centred on DEA, technical efficiency, eco-efficiency, networks, and early neural-network applications. In 2020-2023, the knowledge base diversified toward machine learning, energy efficiency, energy consumption, life-cycle assessment, sustainable development, and uncertainty. In the most recent period, 2024-2026, artificial intelligence emerged as a distinct theme alongside circular economy and performance, while DEA remained a persistent methodological backbone. The evolution therefore indicates a transition from conventional efficiency measurement toward a more integrated research agenda combining DEA with AI-driven analytical and predictive approaches for

sustainability-oriented performance assessment.
The trend-topic analysis reinforces this development. Machine learning, deep learning, artificial intelligence, sustainability, energy efficiency, and multi-objective optimization are among the most prominent recent research directions. The results reveal that the frontier of the field is moving beyond retrospective efficiency benchmarking toward predictive modelling, advanced optimization, and AI-supported decision-making for sustainable performance.
The geographical analysis demonstrates a pronounced concentration of research activity in Asia. China is by far the leading contributor, followed by Iran and India, while Spain, the United States, and Italy constitute important contributors outside the leading Asian group. China also records the highest citation impact (2,287 citations), followed by Iran (1,036) and the United States (642). The distribution of Single Country Publications and Multiple Country Publications indicates that research remains largely driven by national research systems, although international collaboration is clearly present. At the document level, the most globally cited contribution received 477 citations, followed by publications with 258 and 211 citations, indicating a relatively concentrated intellectual influence.
Discussion and implications
The findings suggest that DEA is progressively evolving from a predominantly retrospective benchmarking methodology into a component of hybrid analytical frameworks capable of combining efficiency measurement with prediction, classification, optimization, and decision support. The simultaneous emergence of AI, circular economy, sustainability, energy efficiency, and performance themes indicates increasing convergence between digital and green research trajectories. However, the explicit concept of the twin transition remains less developed than its constituent digital and sustainability dimensions. The results should therefore be interpreted as evidence of convergence toward the digital and green dimensions associated with the twin transition rather than evidence that the twin transition itself is already an established research cluster.
Originality/value
This study contributes to the literature by jointly examining DEA, AI, and sustainable economic performance rather than treating efficiency analysis, artificial intelligence, and sustainability as separate research streams. By integrating performance indicators with co-word analysis, thematic mapping, thematic evolution, trend-topic analysis, geographical patterns, collaboration, and citation impact, the study provides a longitudinal view of how the field has evolved from traditional efficiency assessment toward AI-enabled and sustainability-oriented performance analysis. It also identifies emerging opportunities for integrating DEA with explainable AI, advanced machine-learning models, multi-objective optimization, circular-economy assessment, and predictive decision-support systems.

Keywords: Artificial Intelligence; Data Envelopment Analysis; Machine Learning; Sustainability; Economic Performance; Energy Efficiency; Circular Economy; Bibliometric Analysis