frontiers | Frontiers in Environmental Science

TYPE Editorial
PUBLISHED 19 November 2024
DOI 10.3389/fenvs.2024.1514467

OPEN ACCESS

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RECEIVED 21 October 2024
ACCEPTED 08 November 2024
PUBLISHED 19 November 2024

CITATION
Cheong TS, Li T, Shi X and Yu J (2024) Editorial: New directions of digital economy, energy transition, and climate change in the post-COVID-19 era: application of machine learning and other advanced analytical techniques. *Front. Environ. Sci.* 12:1514467. doi: 10.3389/fenvs.2024.1514467

Editorial: New directions of digital economy, energy transition, and climate change in the post-COVID-19 era: application of machine learning and other advanced analytical techniques

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KEYWORDS

editorial, digital economy, green innovation, green transformation, ESG, digital value chain, artificial intelligence

Editorial on the Research Topic
New directions of digital economy, energy transition, and climate change in the post-COVID-19 era: application of machine learning and other advanced analytical techniques

1 Introduction

Since the outbreak of COVID-19, international energy prices have fluctuated dramatically, leading to historic shifts in energy supply and demand and causing significant disruption to the global energy system (Yu et al., 2021). In response, countries worldwide have embraced green, low-carbon, efficient, and renewable energy as key components of energy transition (Yu et al., 2023). As the world moves into the post-COVID-19 era, accelerating the clean use of fossil fuels and upgrading energy structures has become a critical challenge for all nations (Shen et al., 2024). The pandemic has catalyzed transformative changes in lifestyles, production methods, economic systems, and governance models, pushing humanity toward the digital economy (Wang et al., 2023). The digital economy, empowered by data and technology, has spurred industrial refinement, automation, and intelligent development, reducing energy and resource consumption while providing favorable conditions for global industrial upgrades, energy transition, and climate action. The digital economy's wide application across industries, from energy to manufacturing and transportation, has proven to reduce CO_2 emissions, offering technical support for energy transition and climate improvement (Lu et al., 2023). This editorial synthesizes findings from 16 papers that explore the intersections of the digital economy, energy transition, and climate change, focusing on the application of machine learning and advanced analytical techniques in the post-pandemic era. These

studies illuminate new pathways for reducing carbon emissions, enhancing green innovation, and navigating the global energy transition.

2 Digital economy and carbon emission reduction

The development of the digital economy has emerged as a critical factor in reducing carbon emissions, particularly in the context of industrial and regional transformations (Lu et al., 2023). Several studies provide empirical evidence that digital technologies can reduce carbon emissions by optimizing industrial structures, improving resource allocation, and fostering green innovation. Lyu et al. examined how digital economy development in China has reduced carbon emission intensity, with regional disparities showing more significant effects in the eastern provinces. Similarly, Liu et al. demonstrated how the integration of digital technologies in Chinese cities improves carbon efficiency, particularly in large-scale and resource-based cities.

The relationship between digitalization and carbon emissions extends beyond individual industries. Lyu et al. explored how digital value chain embeddedness impacts trade-related carbon emissions across 41 countries, revealing an inverted U-shaped relationship. The environmental benefits of digitalization only become apparent once a country reaches a certain threshold of digital integration, with developing countries lagging behind in realizing these benefits. Jiang et al. used the panel data of 275 cities in China to analysis the non-linear effect of digital economy on industrial structure upgrading and urban carbon emissions. In addition, Li et al. used the CFPS data in China and investigated the influence of digital economy on private donation behavior.

3 Industrial transformation and green innovation

Industrial sectors are at the forefront of the global push for carbon neutrality, and digital technologies are playing an increasingly important role in driving green innovation. Liu et al. focused on China's industrial green transformation, which is being driven by digitalization and technological advances. The study identified regional disparities, with more developed areas making faster progress in green industrial practices. This echoes the findings of Zhong et al., which examined the coupling between the digital economy and green development in Guangdong Province. The research showed that cities with stronger digital economies tend to have better green development outcomes, but significant regional imbalances persist.

The construction industry, traditionally a high-emission sector, is also undergoing a digital transformation. Yang et al. explored how digital construction technologies are reducing carbon emission intensity in Chinese enterprises by enhancing innovation capacity and improving productivity. This paper highlights the potential for digital technologies to accelerate green transitions in traditionally resource-intensive industries, particularly through the adoption of new tools and processes. The role of digital technologies in supporting green innovation is further explored in Gao et al., which used machine learning to assess the impact of industrial land-use policies on firms' green technology innovation. The study found that reforms in land-use policies significantly promote green innovation, especially in regions with advanced digital infrastructure.

4 Energy transition and the role of digital infrastructure

The global energy transition is a key component of efforts to combat climate change, and digital technologies are playing a crucial role in facilitating this shift. Yan et al. examined the impact of the Broadband China Policy on rural households' adoption of clean renewable energy. The study found that digital infrastructure significantly influences clean energy adoption, though the effects vary by region. The role of financial systems in supporting energy transitions is also highlighted in Jia et al., which investigated how financial openness influences energy structure transformation. The study found that financial reforms are critical to enabling investments in clean energy, particularly in regions with underdeveloped financial markets.

Machine learning and artificial intelligence (AI) are also being applied to optimize energy use and reduce emissions. Xie and Wang explored the nonlinear carbon reduction effects of AI across Chinese provinces, finding that AI technologies can significantly reduce carbon emissions, particularly in regions with high levels of digital infrastructure and economic development. In addition, Li and He used the text analysis method to directly construct the national, provincial, and prefecture-level environmental policy uncertainty index (EPUI) in China and investigated the impact of EPUI on China's energy transition.

5 Corporate sustainability, ESG, and the post-pandemic green shift

In the post-pandemic era, corporate sustainability efforts are becoming increasingly focused on environmental, social, and governance (ESG) performance. Several papers explore how digital technologies and machine learning are enhancing corporate efforts to reduce carbon emissions and align with ESG goals. Ye and Xu provided empirical evidence that strong ESG performance is associated with significant reductions in corporate carbon emissions. The study highlights that digital transformation amplifies the effectiveness of ESG strategies, suggesting that companies with advanced digital tools are better positioned to meet their sustainability goals. The impact of resource dependence on corporate ESG performance is further examined in Fei et al., which found that companies in regions with high resource dependence tend to have lower ESG scores, particularly in environmental and social dimensions. This study argued that digital tools can help mitigate the negative effects of resource dependence by enabling more efficient resource use and improving corporate governance practices.

The COVID-19 pandemic has also reshaped corporate investment strategies, with implications for green development. He et al. documented the negative impact of the pandemic on

green investment in China, as firms faced financial constraints that limited their ability to invest in sustainable projects. However, the study also found that while overall investment levels were maintained, the structure of investments shifted away from green initiatives. This finding underscores the importance of targeted financial policies to support green investment in the post-pandemic recovery.

6 Conclusion

All the 16 papers reviewed in this editorial collectively highlight the transformative potential of the digital economy, machine learning, and advanced analytical techniques in driving energy transitions and addressing climate change. This unique edition encompasses four distinct yet interconnected thematic areas that hold significant relevance in the context of the digital economy, energy transition, and climate change in the post-COVID-19 era. These areas include Digital Economy and Carbon Emission Reduction, Industrial Transformation and Green Innovation, Energy Transition and the Role of Digital Infrastructure, and Corporate Sustainability, ESG, and the Post-Pandemic Green Shift. Collectively, these areas offer numerous practical pathways and enrich the existing body of literature by seamlessly integrating the digital economy into energy transition strategies aimed at mitigating the impact of climate change.

Digital technologies are already contributing to carbon emission reductions, enhancing industrial green innovation, and supporting the global shift toward renewable energy. However, significant challenges remain, particularly in ensuring equitable access to digital infrastructure and financial resources, which are critical to realizing the full potential of these technologies. As we move into the post-COVID-19 era, it is essential for policymakers, businesses, and researchers to collaborate on leveraging digital tools to accelerate the transition to a sustainable, low-carbon economy. By integrating digitalization with green policies and supporting innovation across industries, the global community can make meaningful progress toward achieving climate goals and ensuring a resilient, sustainable future.

In order to realize these objectives, it is essential to expand future research endeavours into diverse domains. Noteworthy areas for prospective investigation, as highlighted by the authors, include extending the research scope across various industries and geographies to afford a comprehensive insight into the impact of ESG performance on carbon reduction within distinct business environments (Ye and Xu). Furthermore, it is necessary to delve into the dynamics of the interplay between the digital economy and sustainable development pre- and post-epidemic, elucidating the coupling and coordination mechanisms, as well as to holistically assess the repercussions of the COVID-19 outbreak on the interrelationship between digital economy and sustainable practices (Zhong et al.). Lastly, a pertinent suggestion posits the necessity of investigating the influence of AI on carbon emissions through an analysis of spatial spillover effects (Xie and Wang). These delineated avenues for future research not only promise valuable insights for forthcoming studies but also present opportunities for the inception of specialized editions to delve deeper into these pertinent themes.

Author contributions

TC: Writing–original draft, Writing–review and editing. TL: Writing–original draft, Writing–review and editing. XS: Writing–original draft, Writing–review and editing. JY: Writing–original draft, Writing–review and editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This work was supported by National Natural Science Foundation of China (72174056, 72373172).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

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