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Application of Artificial Intelligence in Carbon Accounting and Firm Performance: A Review Using Qualitative Analysis

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Abstract: The increasing role of the corporate sector in global carbon emissions has raised significant concern among stakeholders, leading to a thorough reassessment of corporate responsibility. Corporations, directly influencing society due to their carbon emissions, acknowledged as externalities, are facing growing pressure to tackle this environmental challenge actively. As a reaction, companies are increasingly implementing carbon accounting and other environmentally conscious practices in line with a broader dedication to comprehensive environmental ethics. The accounting department, tasked with incorporating carbon accounting into non-financial reports alongside regular financial statements, encounters adoption obstacles such as limited awareness, insufficient expertise, unclear guidelines, and a lack of standardized terminology. This paper conducts a comprehensive study to evaluate the feasibility of using artificial intelligence (AI) solutions in carbon accounting and its subsequent effect on firm performance based on the well-established effectiveness of AI in financial reporting and accounting tasks. As of 2021, Saudi Aramco, the foremost emitter of carbon dioxide worldwide, accounts for more than 4 percent of global Greenhouse Gas Emissions. This highlights the pressing necessity for intervention in this industry. Moreover, the study highlights electricity and heat production as the primary global sources of carbon emissions. The research demonstrates a clear link between effective carbon accounting practices and improved firm performance, especially when stakeholders are highly aware of sustainability issues. Nevertheless, the paper highlights the considerable obstacles and the urgent requirement for extensive advancement in AI applications to fully exploit its potential as a significant resolution to the complexities of carbon accounting. The study is limited by the wide range of accounting standards companies use to disclose their environmental impact and a need for more information on using artificial intelligence in carbon accounting. The research highlights the crucial significance of collaborative endeavours in promoting AI solutions to strengthen carbon accounting practices, thereby enhancing corporate sustainability and overall performance.

Introduction

Carbon impact reporting presents a measurement challenge as it is still a new accounting area involving collaboration between climate science and professional accountancy (Ong et al., 2021). There still needs to be a consistent carbon accounting definition. Environmental impact reporting, a critical research area in non-financial reporting, includes narrative and numerical information regarding an entity's environmental impact, usually accompanying the end-year financial reports. Accountants play a significant role in non-financial reporting, continuously attracting stakeholders' concerns. The reporting targets corporate environmental accountability.

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Financial reporting provides valuable information that influences stakeholders' decision-making. In contrast, Environment, Social, and Governance (ESG) reporting refers to disclosure thresholds alongside regular financial reporting that organizations fulfil to communicate their sustainability initiatives.

Governments worldwide are increasingly participating in initiatives that examine environmental and social sustainability, as demonstrated by the acronym ESG (Saini et al., 2022). Moreover, investors have substantial power in advocating ESG practices and ethical behavior. Incorporating ESG considerations into decision-making processes showcases their effectiveness in identifying, managing, and reducing risks (Duuren et al., 2015; Cappucci, 2018). Multiple academic investigations, conducted through literature reviews have explored the relationship between ESG and various other factors. These include the areas of organizational learning (Xia, 2022), social innovation, energy transitions, circularity (Popescu et al., 2022), business models (Aldowaish et al., 2022), corporate value (Wang et al., 2023), and the exceptional COVID-19 outbreak (Savio et al., 2023).

For instance, carbon accounting is an ESG component that involves reporting the amount of greenhouse gases an entity emits (Tsang et al., 2022). Stakeholders such as investors rely on ESG reports to evaluate their target venture choices. The contemporary consumer, another stakeholder, prefers engaging with firms that uphold corporate ethics. Society also benefits from corporate externality control in several ways, including reduced carbon emissions.

Firms highly contribute to carbon emissions. Electricity and heat production are the leading global sectors in carbon dioxide emissions (Ritchie et al., 2020). Today, Saudi Aramco, a state-owned corporation, was the world's leading greenhouse gas emitter as of 2021 (Tiseo, 2021). The scenario has raised stakeholder concerns about corporate ethics in sustainability reporting.

Technology has enhanced accounting reporting efficiency (Wang, 2023). Only some studies address the significant challenges in carbon accounting due to the non-streamlined nature of the practice and its slow adoption in firms. Although studies like Habib and Mourad (2023) and Lin and Qamruzzaman (2023) cover carbon accounting and firm performance, few studies address a technological solution regarding the development of the practice towards potentially improving firm performance. Yixuan Chen and Shanyue Jin (2023) emphasize the importance of artificial intelligence (AI) in reducing manufacturing carbon emissions during climate change. The study used a fixed-effect model (Figure 2) to examine corporate AI's carbon emissions intensity abatement effect on manufacturing companies listed on China's A-share Shanghai and Shenzhen stock exchanges between 2012 and 2021.

The results show two main conclusions. First, business AI levels negatively correlate with the intensity of carbon emissions, suggesting AI could reduce environmental effects. The second finding is that green technology, management, and product improvement strengthen AI's carbon emission inhibitory benefits.

The study has theoretical and practical implications. The micro-level study of AI and carbon emissions reduction in individual firms helps explain the need for digitization and intelligence for low-carbon development. It also expands micro-enterprise research by adding three green innovation moderating variables.

The ramifications affect government, industry, and businesses. Governments should create or adapt green market policies to stimulate new-generation technology development and transformation. Manufacturing should prioritize intelligent transformation to improve operational efficiency and environmental performance. The results show that industrial companies must integrate AI to achieve a green economy and sustainable growth. For economic and environmental benefits, businesses should allocate resources wisely, improve energy efficiency, manage the environment, and boost green innovation.

However, the research acknowledges few shortcomings. It may have overlooked industry heterogeneity or the application of findings to non-listed manufacturing companies and SMEs by focusing on listed companies. Focusing on three green innovation characteristics allowed for further investigation into additional inventive dimensions. The study only considered AI technology, ignoring other digital technologies that boost intellect. Future studies should address these constraints to better understand how technology, innovation, and carbon emissions reduction in manufacturing interact.

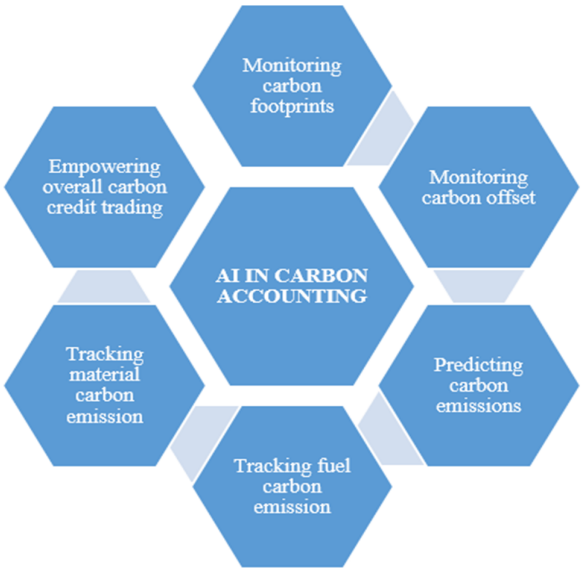

Figure 1. Applications of Artificial Intelligence in Carbon Credits Auditing

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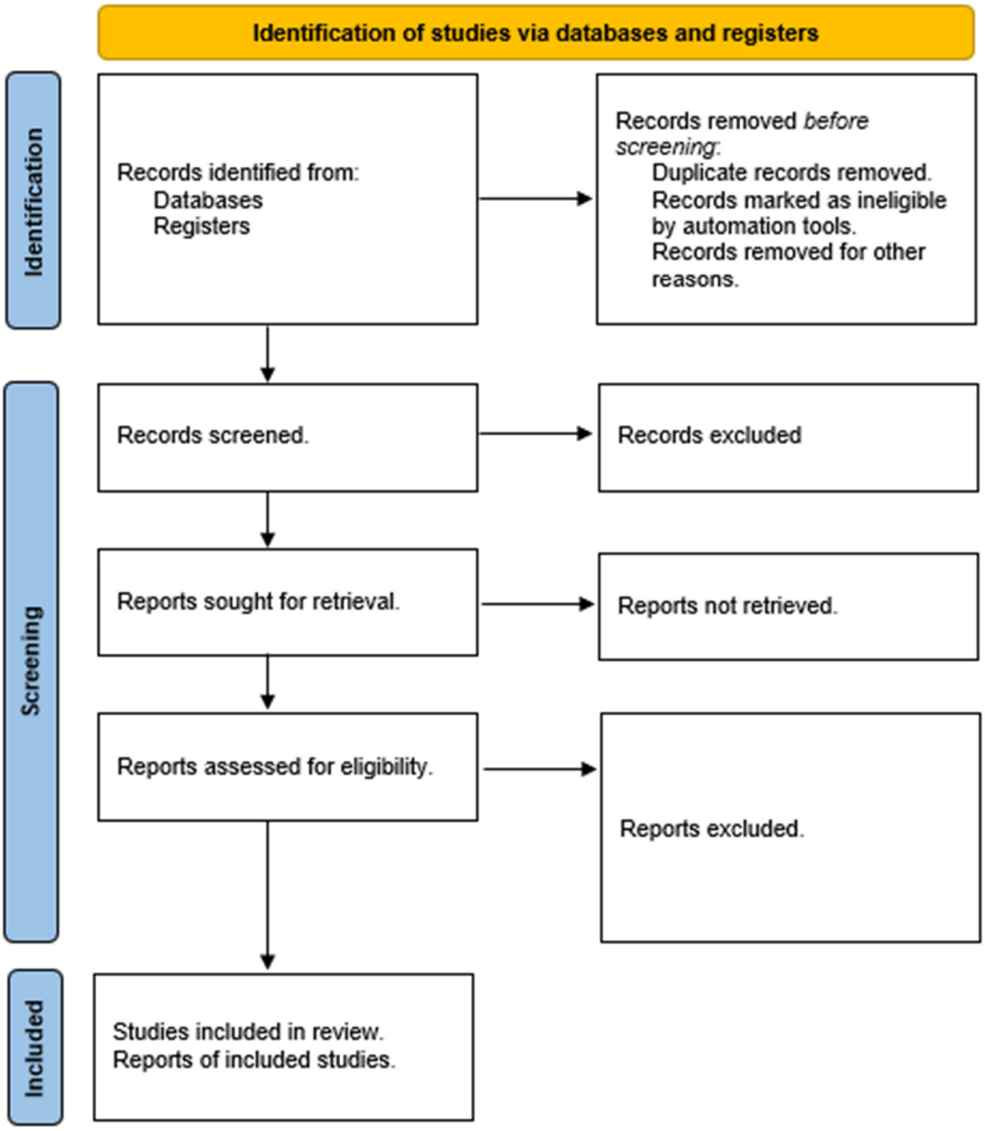

Figure 2. Flow diagram for new systematic reviews (Adapted from Page et al., 2021)

With its scenario-based artificial intelligence, viAct (A leading Asian AI based company with a sustainability focus that specializes in providing creative solutions using "Scenario-based Vision Intelligence) plays a crucial part in tracking, measuring, forecasting, and lowering carbon emissions. Solutions, including fleet management, AI modules for air quality detection, C&D waste classification, and unlawful dumping detection to optimise machinery usage and address environmental concerns are implemented. With the help of viAct's AI monitoring platform, viHUB, stakeholders can now manage and trade carbon credits more effectively by facilitating auto-documentation and analytics. To put it simply, viAct is at the forefront of sustainable practices, using AI to promote change and a greener future for global enterprises.

In this investigation, using artificial intelligence (AI), we look at the ways carbon accounting strategies affect CSR, stakeholder views, and financial results. This review aims to offer a thorough overview of the present state of affairs, pinpoint information gaps, and propose future research directions in the dynamic intersection of AI, carbon accounting, and company performance by synthesizing previous studies.

Materials and Methods

In recent years, environmental impact reporting has gained increasing concern as information that should accompany regular financial reporting. Firms play a significant role in carbon emissions. Preventing such global-wide business externalities heavily relies on corporate accountability practices such as carbon accounting. However, despite corporations' massive contribution to global carbon emissions, only some studies address a technological solution regarding the development of carbon accounting towards potentially improving firm performance.

This qualitative research has applied an integrated literature review to depict a comprehensive view of the application of AI in carbon accounting and firm

performance. The researcher explored previous empirical and theoretical literature to meet the above objectives, relying on secondary methodologies to collect pertinent research information. The criteria for selecting suitable literature review papers were based on their research topic relevance. The author also prioritized publication quality as one of the paper's criteria, selecting the most credible sources based on the most recent research information and relationship with the research goals.

The researcher collected data from secondary sources, including peer-reviewed journals and other scholarly sources such as but not limited to scholar.google.com and sciencedirect.com. The paper also used keywords from credible academic websites to achieve the best results, enhancing the research reliability by citing sources under five years old before analyzing the researcher's discussions and findings regarding the application of AI in carbon accounting and firm performance. The researcher explored previous related secondary research, evaluating their strengths, gaps and limitations before arriving at a conclusion and recommendation for further studies.

Findings

Do Firms Significantly Contribute to Carbon Emissions?

As of 2017, less than 20 fossil fuel companies contribute approximately 35 percent of global carbon emissions (Taylor and Watts, 2019). As of 2023, Saudi Aramco, the leading carbon dioxide emitter globally as of 2021, contributes to more than 4 percent of global Greenhouse Gas Emissions. Electricity and heat production topped the global carbon-generating sector as of 2020 (Ritchie et al., 2020). Corporations are the most significant contributors to the degradation of sustainability.

Relationship between Carbon Disclosure and the Accounting Profession

Carbon disclosure is one of the concepts of non-financial environmental impact reporting. More research is needed to associate environmental reporting with the accounting profession directly. However, different organizations apply divergent carbon accounting to measure their carbon footprint, including spend-based, activity-based, average-data, supplier-specific, and hybrid methods. Such measures require a combination of accountants and environmental expert knowledge. As such, although carbon accounting is a component of accounting, it is indirectly related to the profession. Carbon accounting generally refers to calculating the quantitative extent of an organization's greenhouse gas emission (He et al., 2022). Unlike financial accounting, it tracks the carbon impact of the firm's business activities, which measures an entity's financial implications. However, like financial accounting, organizational stakeholders, including the government, investors, employees, customers, and regulatory bodies, are keen on firms' carbon footprints. Jurisdictions require corporations to issue environmental impact reports alongside their periodic financial statements. Like other professional thresholds, continuous consciousness about firms' environmental impact could attract standard regulatory measures for carbon impact reporting.

Accountants play a significant but partial role in environmental impact accounting (He et al., 2022). Environmental impact reporting requires environmental experts' professional scrutiny to attain ISO 14064 standards and other jurisdiction-specific thresholds. International regulatory agencies should strive to streamline corporate environmental impact reporting standards.

Carbon disclosure reports will constitute a significant part of the accounting profession once organizations fully adopt the practice, acquire an awareness of carbon accounting, and invest in carbon accounting skills. Regional and international streamlining of carbon accounting measures will also spur the corporate intensity of such disclosures.

Carbon Accounting and Firm Performance

In a McKinsey survey of 2020, at least 60 percent of respondents preferred sustainable packaging, even if it meant paying higher than average prices (Frey et al., 2023). Seventy-eight percent of consumers in the USA regard the importance of sustainable living. Frey et al. (2023) note that although many organizations claim their products and services are sustainable, they fail to meet environmental sustainability standards, hence the need for carbon accounting as a transparency accountability measure. In the UK, consumers are continuously adopting more sustainable lifestyles in 2022. In the same year, 38 percent of consumers paid extra for more durable products, while another 40 percent opted for brands that uphold environmentally sustainable values, like carbon impact reporting (Archer et al., 2023). Environmental sustainability has become a prioritized factor in many parts of the world, especially regarding consumers' perspectives of corporations. Carbon accounting enhances a firm's social standing, improving its publicity.

Apart from consumers, other stakeholders also prefer environmentally ethical firms. Governments are progressively making it mandatory for corporations to produce environmental impact reports. China requires its cities to regularly submit air quality reports (Lu et al., 2023). The European Union successfully incorporated regulations requiring large entities with more than 500 employees to adhere to the EU Non-Financial Reporting Directive that mandates the targeted firms to disclose their environmental and social impact during their annual reporting (Helfaya, Morris and Aboud, 2023). In the USA, the Securities and Exchange Commission is working to ensure all corporations produce an environmental impact report in the future. In the future, non-compliance to carbon accounting and other

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Here is a summary of some of the previously discussed and other related studies on the applications of Artificial Intelligence in Carbon Accounting and Firm Performance:

Title	Authors	Year	Outcome of the Study
Is There a Conflict between Automation and Environment? Implications of Artificial Intelligence for Carbon Emissions in China	Xianpu Xu, Yuchen Song	2023	Artificial intelligence has significantly lowered carbon emissions.
Carbon Productivity Improvement for Manufacturing Based on AI	Zhuo Wang, Xuhai Wang	2023	AI technology can drive the manufacturing industry's carbon productivity improvement.
Optimization of the environmental protection tax system design based on artificial intelligence	Jing Zhang	2023	Artificial intelligence promotes the efficiency of a bonded governance environment and boosts national management modernization.
Do Artificial Intelligence Applications Affect Carbon Emission Performance?—Evidence from Panel Data Analysis of Chinese Cities	Ping Chen, Jiawei Gao, Zheng Ji, Han Liang, Yuxia Peng	2022	Artificial intelligence reduces carbon emissions by optimizing industrial structure, enhancing information infrastructure, and improving green technology innovation.
Modeling and Estimation of CO2 Emissions in China Based on Artificial Intelligence	Pan Wang, Yangyang Zhong, Z. Yao	2022	The hybrid intelligent algorithm model designed in this paper has stronger robustness and accuracy in the advanced prediction of CO2 emissions.
Carbon emission intensity and firm performance: An empirical investigation in Indian context	Najul Laskar, Nikhil Kulshrestha, P. C. Bahuguna, N. K. Adichwal	2022	The effect of carbon emission on firm performance is negative and statistically significant.
Carbon Accounting: A Systematic Literature Review and Directions for Future Research	Jillene Marlowe, Amelia Clarke	2022	Carbon accounting is an evolving approach to support decision-making for climate action and reporting of progress.
Research on Influencing Factors of Carbon Accounting Information Disclosure	Huijuan Wu, Jingbo Wang, Hongfei Sun, Wen Qin	2021	The five influencing factors (size, development ability, equity characteristics, market approval, and whether) correlate with the carbon accounting information disclosure level from 2015 to 2017.
Carbon Emissions and Firm Performance: Evidence from Financial and Non-Financial Firms from Selected Emerging Economies	Mohammad Dulal Miah, R. Hasan, Mohammed A. M. Usman	2021	financial firms emit less carbon than non-financial firms, carbon emissions reduce firms' return on equity, Tobin's Q, Z score, and credit rating
Framework of the Smart Finance and Accounting Management Model under the Artificial Intelligence Perspective	Yaping Chen	2021	Artificial intelligence technology has promoted the development of the smart accounting management model architecture.
An Innovative Artificial Intelligence Framework for Reducing Carbon Footprint in Reservoir Management	Klemens Katterbauer, Abdulkarim Al Sofi, A. Marsala, A. Yousif	2021	The artificial intelligence approach has a twofold benefit.

noted that mandatory carbon reporting increases corporate

The Effect of Carbon Emission Disclosure on Firm Value: Environmental Performance and Industrial Type	Mohammad Hardiyansah, A. Agustini, I. Purnamawati	2021	Carbon emission disclosure had a positive and significant effect on firm value, environmental performance, and industrial type can strengthen the influence relationship of carbon emission disclosure on firm value
Artificial Intelligence in Accounting and Finance: Meta-Analysis	Oguljan Berdiyeva, Muhammad Umar Islam, M. Saeedi	2021	Implementing AI systems in accounting and finance processes can increase efficiency.
Environmental cost control system of manufacturing enterprises using artificial intelligence based on the value chain of circular economy	Min Chen, Qian Liu, Shuai Huang, Chenlu Dang	2020	Artificial intelligence was applied in designing manufacturing enterprises' environmental cost control systems to realize the internalization of environmental costs.
An Efficiency Perspective on Carbon Emissions and Financial Performance	Arjan Trinks, Machiel Mulder, Bert Scholtens	2020	Carbon-efficient production can be valuable from both operational and risk management perspectives.
Case Study of Carbon Accounting Information Disclosure Under the Background of Green Credit — Based on the Analytic Hierarchy Process	Yunhui Qu, Jingyuan Ma, Xu Yan	2019	The disclosure of carbon accounting information on the heavy pollution industry is imperative.
The Application of Artificial Intelligence to Reduce Greenhouse Gas Emissions in the Mining Industry	A. Soofastaei	2018	Artificial intelligence methods to reduce gas emissions in surface mines are a new revolution in the mining industry.
Corporate Carbon and Financial Performance: A Meta-analysis	T. Busch, Stefan Lewandowski	2018	Relative emissions are more likely to produce statistically significant results than absolute emissions.
The Role of Carbon Accountant in Corporate Carbon Management Systems: A Holistic Approach	F. Egbunike, O. Emudainohwo	2017	Carbon accounting improves the identification and assignment of carbon-related expenses and overheads to products, services, customers, and organizational processes.
Corporate Carbon and Financial Performance: The Role of Emission Reductions	Stefan Lewandowski	2017	Carbon emission mitigation is linearly and significantly positively related to return on sales.
Exploring the determinants and long-term performance outcomes of corporate carbon strategies	Matthias Damert, Arijit Paul, Rupert J. Baumgartner	2017	Institutional and stakeholder pressure on emission reduction activities can be established.

ecological reporting standards could attract litigation across many industries, deteriorating firm performance through profit minimization and negative publicity.

Few studies directly address carbon disclosure impacts on firm performance conclusively. Grewal, Richardson, and Wang (2022) note that mandatory carbon reporting increases corporate responsibility toward the environment and reduces falsified carbon impact accounting, improving their publicity, hence firm value. Houqe et al. (2022), Habib and Mourad (2023), and Lin and Qamruzzaman (2023) responsibility toward the environment and reduces falsified carbon impact accounting, improving their publicity, hence firm value. Chen et al. (2023) link environmental impact reporting to positive stock exchange liquidity. Hessani and Bahini (2022) found that proper holistic ESG reporting can improve firm performance in the long run. Sharma and Gupta (2022) observe that environmental reporting enhances a firm's ESG ratings, leading to better competitive advantage and financial performance. Miah, Hasan, and Usman (2021) found that carbon emissions externalities

minimize a firm's return on equity and return on assets. Other scholars like Hazaea et al. (2023) conclude that carbon accounting enhances companies' financial performance by increasing social sustainability competition and improving brand value.

The paper found no relevant studies linking firm performance with environmental reporting in areas such as Saudi Arabia where such awareness is low. This indicates that stakeholder awareness levels enhance the relationship between carbon accounting, environmental impact disclosure reports, and firm performance. Ghose, Makan, and Kabra (2023) found that carbon productivity positively impacts firms' financial performance in India in a high carbon-emission environment. Maama and Gani (2022) observe that carbon accounting alone does not affect the financial performance of companies. Other factors like management quality contribute to financial performance, especially in non-carbon-intensive entities like banks.

The Significance of Artificial Intelligence in Carbon Accounting

Carbon accounting poses several challenges. Assessing the carbon impact of firms is difficult due to the use of different calculation methodologies. Furthermore, there is a scarcity of carbon accounting data, particularly in comparative information. The presence of divergent jurisdictional requirements poses a challenge to establishing a standardized carbon accounting formula (Tóth, Szigeti, & Suta, 2021). A proficient workforce is deficient in effectively managing carbon accounting in companies. Additional obstacles encompass the exorbitant expense of carbon accounting, ongoing innovations, and regulation alterations. Despite the numerous challenges, the study establishes that AI can only partially solve carbon accounting concerns. The significant role of AI in carbon accounting is to enhance the accuracy, speed, and efficiency of carbon predictions. AI tools like adaptive network-based fuzzy inference systems (ANFIS), long short-term memory (LSTM), and feed-forward neural networks (FFNN) significantly predict annual carbon emissions. However, AI experts are still developing technology to aid firms in achieving the carbon neutrality mission. Like other accounting areas, for instance, financial accounting, AI developers should improve the digitization's specific application to carbon accounting.

AI applications are attributable to general accounting rather than exclusive to carbon accounting. Machine learning algorithms like convolutional neural networks and artificial neural networks that predict physical properties and evaluate mechanical stability, monitoring carbon migration and leakage during storage apply to general carbon footprint measures rather than exclusive carbon accounting. Accountants can use carbon impact predictive analysis to gauge forecasted and actual results variances. In auditing, significant variances can aid in raising audit queries and initiating further fraud or error investigations. The research establishes a gap for future scholars to examine other direct AI applications in carbon accounting apart from predictive analysis and their influence on firm performance.

Challenges

Data Quality and Availability

a. Insufficient or erroneous data: The utilization of AI in carbon accounting necessitates using data of superior quality and encompassing all relevant aspects. There needs to be more accurate or correct datasets to ensure the efficiency of AI models, resulting in flawed carbon reporting.

b. Data Accessibility: Certain companies may encounter difficulties in obtaining pertinent carbon-related data, impeding the AI's capacity to generate precise predictions and evaluations.

Carbon emissions measurement complexity: a. Diverse emission sources: The varied nature of emission sources poses a challenge for AI models to precisely measure and include all sources, particularly when dealing with intricate supply chains and indirect emissions.

Complexity of Carbon Emissions Measurement

a. Diverse Emission Sources: The wide range of emission sources poses a challenge for AI models to precisely measure and consider all sources, particularly when dealing with intricate supply chains and indirect emissions.

b. Emissions Scope: Determining the extent of emissions (Scope 1, 2, and 3) is problematic because it involves integrating and analyzing extensive data, which may exceed the capabilities of traditional AI models.

Interdisciplinary Collaboration

The efficient use of artificial intelligence for carbon accounting requires cooperation between climate scientists and professional accountants. The alignment of these disciplines presents a challenge due to divergent methodologies and terminologies.

Algorithmic Bias

AI models are vulnerable to biases in the training data, potentially amplifying or perpetuating pre-existing environmental inequalities. This bias can result in inaccurate carbon assessments and potentially perpetuate unjust practices.

Regulatory Compliance

The absence of uniform regulations for AI in carbon accounting presents a difficulty for companies striving to adhere to varied and ever-changing reporting standards. Consistency can lead to clarity and impede international endeavours to tackle climate change.

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Ethical Considerations

Elucidation of AI Models

Ensuring the transparency of AI models' decision-making process is of utmost importance. The need for more transparency in intricate algorithms may give rise to accountability concerns and necessitate explicit communication with stakeholders regarding the decision-making process.

Privacy Concerns

The extensive quantity of data necessary for precise carbon accounting gives rise to apprehensions regarding the privacy of individuals and corporations. Ensuring a harmonious equilibrium between gathering data for sustainability objectives and upholding privacy rights emerges as a pivotal ethical deliberation.

Equity and Environmental Justice

The advantages and disadvantages of AI-powered carbon accounting should be allocated fairly. Ethical considerations encompass avoiding disproportionate effects on marginalized communities and assuring that the integration of AI in carbon reporting supports environmental equity.

Job Displacement

The incorporation of AI in carbon accounting could result in workforce modifications, potentially resulting in the displacement of jobs in conventional accounting positions. Ethical considerations encompass the provision of assistance and opportunities for retraining to individuals who are impacted.

Responsible Innovation

Ethical considerations encompass the conscientious advancement and implementation of AI technologies. Achieving a harmonious equilibrium between innovation and ethical considerations necessitates meticulously evaluating risks and implementing strategies to minimize them.

Long-Term Environmental Impact

Ethical concerns arise from the environmental impact of the AI infrastructure, which encompasses data centers and computing hardware. Pursuing sustainability in both the development of artificial intelligence and the accounting of carbon emissions is crucial.

It is crucial to address the challenges and ethical considerations to ensure that AI's application in carbon accounting contributes positively to both firm performance and environmental sustainability. Exercising responsible and well-informed decision-making will be essential in successfully navigating these intricacies.

Conclusion

Recent focus on AI technology in manufacturing has made AI a key component of the digital economy. AI can help create environmentally friendly supply chains, fostering a low-carbon industry. AI in manufacturing promises efficiency and convenience despite environmental risks.

However, integrating AI into manufacturing requires balancing resources, manpower, knowledge, technology, and networks. The study shows that AI improves energy efficiency and lowers costs, but cost reductions may increase energy use and environmental waste.

Recent studies examine the micro-level relationship between corporate AI technology and carbon emissions reduction in the ongoing academic debate on AI's environmental impacts. The moderating effect of green innovation on technology and production is also examined. It confirms that AI offers significant environmental protection opportunities. AI can improve research and development, lower operational costs, and promote green production when used properly. AI's transformative capabilities—information integration, risk assessment, and machine learning—are essential to green manufacturing companies' sustainability goals.

Carbon accounting is increasingly being included in periodic firm financial reports due to stakeholder awareness of sustainability issues, according to the study. This domain faces challenges like diverse regulatory standards, measurement practices, and a knowledge and skill gap. Significantly, the study highlights the limited research on AI in carbon accounting and firm performance. It suggests further research on AI carbon accounting digitization, particularly in variance analysis and auditing. Future research could incorporate AI into spend-based, activity-based, average-data, supplier-specific, and hybrid carbon accounting methods. AI developers must recognize the importance of environmental impact reporting and the potential of AI to improve financial reporting efficiency. The study encourages further research on AI, environmental sustainability, and financial reporting.

Conflicts of interest

There are no conflicts of interest for the author.

References

Ababneh, A. (2019). The impact of carbon accounting on corporate financial performance: evidence from the energy sector in Jordan. In *Proceedings of the International Conference on Industrial Engineering and Operations Management,* pp.1157-1163.

Aldowaish, A., Kokuryo, J., Almazyad, O., & Goi, H.C. (2022). Environmental, Social, and Governance Integration into the Business Model: Literature Review and Research Agenda, *Sustainability, 14,* 2959. https://doi.org/10.3390/su14052959

Archer, T., Cromwell, E., & Fenech, C. (2022). *How Consumers are Embracing Sustainability.* [Online] Available at: https://www2.deloitte.com/uk/en/pages/consumer-business/articles/sustainable-consumer.html [Accessed 05 July 2023].

Baratta, A., Cimino, A., Longo, F., Solina, V., & Verteramo, S., (2023). The impact of ESG practices in industry focusing on carbon emissions: Insights and future perspectives. *Sustainability*, *15*(8), 6685. http://dx.doi.org/10.3390/su15086685

Bui, B., Houqe, M. N., & Zahir-ul-Hassan, M. K. (2022). The moderating effect of carbon accounting systems on strategy and carbon performance: a CDP analysis. *Journal of Management Control*, *33*(4), 483-524. https://doi.org/10.1007/s00187-022-00346-7

Cappucci, M. (2018). The ESG Integration Paradox. *J. Appl. Corp. Financ., 30,* 22–28. https://doi.org/10.1111/jacf.12296

Chen, Y., & Jin, S. (2023). Artificial Intelligence and Carbon Emissions in Manufacturing Firms: The Moderating Role of Green Innovation. *Processes 2023, 11*, 2705. https://doi.org/10.3390/pr11092705

Deloitte (2023). Persefoni CEO: How carbon accounting advances climate strategy, disclosure. *The Wall Street Journal*. Available at: https://deloitte.wsj.com/articles/persefoni-ceo-how-carbon-accounting-advances-climate-strategy-disclosure-493900c0?tesla=y (Accessed: 22 August 2023).

Duuren, V. E., Plantinga, A., & Scholtens, B. (2015). ESG Integration and the Investment Management Process: Fundamental Investing Reinvented. *J. Bus. Ethics, 138,* 525–533. https://doi.org/10.1007/s10551-015-2610-8

Frey. S., Jordan B.A., Doshi, V., Malik, A., & Noble, S. (2023). Consumers care about sustainability—and back it up with their Wallets. [Online] Available at: https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/consumers-care-about-sustainability-and-back-it-up-with-their-wallets [Accessed 04 October 2023].

Frost, G., Jones, S., & Yu, M., (2023). Voluntary Carbon Reporting Prediction: A Machine Learning Approach. *Abacus*, 1-51. https://doi.org/10.1111/abac.12298

Ghose, B., Makan, L. T., & Kabra, K. C. (2023). Impact of carbon productivity on firm performance: the moderating role of industry type and firm size. *Managerial Finance*, *49*(5), 866-883. https://doi.org/10.1108/MF-07-2022-0319

Gipper, B., Ross, S., & Shi, S. (2022). ESG Assurance in the United States. Stanford University Graduate School of Business Research, Paper No. 4263085. https://doi.org/10.2139/ssrn.4263085

Hamrouni, D., Zohra, K., & Ayidth, A. (2019). Foreign Direct Investment and Employment in Saudi Arabia: Reality and Challenge of the Saudi Vision 2030. *International Journal of Economics, Commerce and Management, VII*(2), 236-251.

Hazaea, S.A., Al-Matari, E.M., Alosaimi, M. H., Farhan, N. H., Abubakar, A., & Zhu, J. (2023). Past, present, and future of carbon accounting: Insights from scholarly research. *Frontiers in Energy Research*, *10*, 958362. https://doi.org/10.3389/fenrg.2022.958362

He, R., Luo, L., Shamsuddin, A., & Tang, Q. (2022). Corporate carbon accounting: A literature review of carbon accounting research from the Kyoto Protocol to the Paris Agreement. *Accounting & Finance*, *62*(1), 261-298. https://doi.org/10.1111/acfi.12789

Helfaya, A., Morris, R., & Aboud, A. (2023). Investigating the Factors That Determine the ESG Disclosure Practices in Europe. *Sustainability*, *15*(6), 5508. https://doi.org/10.3390/su15065508

Hossain, M. M. (2019). Environmental accounting challenges of selected manufacturing enterprises in Bangladesh. *Open Journal of Business and Management*, *7*(02), 709. https://doi.org/10.4236/ojbm.2019.72048

Isayan, N. (2019). UN Environment and Saudi Arabia sign deal to strengthen environmental protection. [Online] Available at: https://www.unep.org/news-and-stories/press-release/un-environment-and-saudi-arabia-sign-deal-strengthen-environmental [Accessed 24 June 2023].

Kovalenko, S. N., Kalutskaya, N. A., Bolvachev, A. I., & Prodanova, N. A. (2021). Artificial Intelligence in the Accounting Profession. *LAplage Em Revista, 7*, 378. https://doi.org/10.24115/S2446-622020217Extra-B938p.378-383

Lu, P., Hamori, S., & Tian, S. (2023). Can ESG investments and new environmental laws improve

social happiness in China? *Frontiers in Environmental Science*, *11*, 1089486. https://doi.org/10.3389/fenvs.2023.1089486

Maama, H., & Gani, S. (2022). Carbon Accounting, Management Quality, and Bank Performance in East Africa. Environmental Economics, 1, 114-125. https://doi.org/10.21511/ee.13(1).2022.10

Mati, A., & Rehman, S. (2022). *Saudi Arabia to Grow at Fastest Pace in a Decade.* [Online] Available at: https://www.imf.org/en/News/Articles/2022/08/09/CF-Saudi-Arabia-to-grow-at-fastest-pace [Accessed 23 June 2023].

Miah, M. D., Hasan, R., & Usman, M. (2021). Carbon emissions and firm performance: evidence from financial and non-financial firms from selected emerging economies. *Sustainability*, *13*(23), 13281. https://doi.org/10.3390/su132313281

Nassef, A. M., Olabi, A. G., Rezk, H., & Abdelkareem, M. A. (2023). Application of Artificial Intelligence to Predict CO2 Emissions: Critical Step towards Sustainable Environment. *Sustainability*, *15*(9), 7648. https://doi.org/10.3390/su15097648

Ong, T. S., Kasbun, N. F. B., Teh, B. H., Muhammad, H., & Javeed, S. A. (2021). Carbon accounting system: the bridge between carbon governance and carbon performance in Malaysian Companies. *Ecosystem Health and Sustainability*, *7*(1), 1927851. https://doi.org/10.1080/20964129.2021.1927851

Page, M. J, McKenzie J. E, Bossuyt, P. M, Boutron, I., Hoffmann, T.C., & Mulrow, C. D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ, 372,* n71. https://doi.org/10.1136/bmj.n71

Popescu, C., Hysa, E., Kruja, A., & Mansi, E. (2022). Social Innovation, Circularity and Energy Transition for Environmental, Social and Governance (ESG) Practices—A Comprehensive Review. *Energies, 15,* 9028. https://doi.org/10.3390/en15239028

Ritchie, H., Rosado, P., & Roser, M. (2020). *Emissions by Sector.* [Online] Available at: https://ourworldindata.org/emissions-by-sector [Accessed 14 Nov 2023].

Saini, N., Singhania, M., Hasan, M., Yadav, M. P., & Abedin, M. Z. (2022). Non-financial disclosures and sustainable development: A scientometric analysis. *J. Clean. Prod., 381,* 135173. https://doi.org/10.1016/j.jclepro.2022.135173

Sharma, U., Gupta, A., & Gupta, S. K. (2022). The pertinence of incorporating ESG ratings to make investment decisions: a quantitative analysis using machine learning. *Journal of Sustainable Finance & Investment*, 1-15. https://doi.org/10.1080/20430795.2021.2013151

Shrestha, P., Choi, B., & Luo, L. (2023). Carbon Management System Quality and Corporate Financial Performance. *The International Journal of Accounting*, *58*(01), 2350001. https://doi.org/10.1142/S1094406023500014

Savio, R., D'Andrassi, E., & Ventimiglia, F. A. (2023). Systematic Literature Review on ESG during the COVID-19 Pandemic. *Sustainability, 15, 2020.*

Taylor, M., & Watts, J. (2019). *Revealed: the 20 Firms behind a Third of All Carbon Emissions.* [Online] Available at: https://www.theguardian.com/environment/2019/oct/09/revealed-20-firms-third-carbon-emissions [Accessed 23 June 2023].

Tiseo, I. (2021). *Saudi Aramco's Greenhouse Gas Emissions 2019-2021.* [Online] Available at: https://www.statista.com/statistics/1385616/saudi-aramco-gas-emissions/ [Accessed 14 Nov 2023].

Tóth, Á., Szigeti, C., & Suta, A. (2021). Carbon accounting measurement with digital non-financial corporate reporting and a comparison to European automotive companies statements. *Energies*, 14(18), 5607. https://doi.org/10.3390/en14185607

Tsang, A., Frost, T., & Cao, H. (2022). Environmental, Social, and Governance (ESG) Disclosure: A Literature Review. *The British Accounting Review*, 101149. https://doi.org/10.2139/ssrn.4270942

Üçoğlu, D. (2022). Challenges and threats to environmental accounting and reporting. In T. Eugénio, G. Azevedo, & A. Fialho (Eds.), IGI Global, *Modern Regulations and Practices for Social and Environmental Accounting,* 1-25. https://doi.org/10.4018/978-1-7998-9410-0.ch001

Wang, Q. (2023). Financial effects of carbon risk and carbon disclosure: A review. *Accounting & Finance*, 00, 1-45. https://do i.org/10.1111/acfi.13090

Xia, J. A. (2022). Systematic Review: How Does Organisational Learning Enable ESG Performance (from 2001 to 2021), *Sustainability, 14,* 16962.

Wang, N., Pan, H., Feng, Y., & Du, S. (2023). How do ESG practices create value for businesses? Research review and prospects. *Sustain. Account. Manag. Policy J.* Vol. ahead-of-print No. ahead-

of-print. https://do i.org/10.1108/sampj-12-2021-0515

Yao, P., Yu, Z., Zhang, Y., & Xu, T. (2023). Application of machine learning in carbon capture and storage: An in-depth insight from the perspective of geoscience. *Fuel*, *333*, 126296. https://doi.org/10.1016/j.fuel.2022.126296

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