



Climate change management and companies' financial performance: Exploring the moderating role of carbon credits

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ABSTRACT

The purpose of this paper is to examine how carbon emissions affect companies' financial performance, exploring the moderating role of carbon credits. Drawing on institutional theory, this study analyses 118 companies that used carbon offsets in 2018–2022. The results reveal that carbon emissions have a detrimental effect on financial performance; however, this negative impact can be mitigated by adopting climate finance tools, such as carbon credits, which can moderate this relationship. This research offers valuable contributions to both theoretical and practical domains, supporting regulators in monitoring carbon emissions.

1. Introduction

The issue of climate change is of utmost importance and has a significant impact on every aspect of society and business worldwide. This was emphasised in the Global Risks Report 2024, compiled by the World Economic Forum. According to 1500 experts, five of the ten most serious risks in the next 10 years will be environmental, with climate change leading the way. The frequent occurrence of extreme natural events is a clear indication of the need to address this matter urgently and with the utmost attention and care. In July 2023, the UN Secretary-General, António Guterres, drew attention to the measures being implemented to mitigate the effects of global warming, declaring an "era of global boiling", to emphasise the importance of finding effective solutions to address climate change (Niranjan, 2023). Among these measures are carbon offsets/credits, which were introduced under the Kyoto Protocol as the final document of the 1997 Conference of the Parties (COP 3). They were subsequently implemented through the 2015 Paris Agreement, which also established the Sustainable Development Goals (SDGs). These goals include a 45 % cut in global greenhouse gas emissions and the use of climate finance instruments.

The rising urgency to address climate change has increased the importance placed on carbon offsets/credits over the past couple of years (Gurgel, 2022). Many companies are investing in these climate finance tools to mitigate their greenhouse gas emissions (Harvey, 2021). It is worth noting that every offset/credit is a representation of a ton of emissions that have either been avoided or removed from the atmosphere. Investments in carbon offsetting have recently come under scrutiny due to concerns of over-crediting and the selling of offsets that promise more emissions reductions than they can deliver, as highlighted by Fan et al. (2021). Despite these

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challenges, the carbon offset market has demonstrated resilience and has even made progress during the ongoing coronavirus pandemic; this was, in part, due to a boost in corporate demand and high-profile initiatives (Gross, 2020). Although the terms ‘carbon credits’ and ‘carbon offsets’ are often used interchangeably, it is important to note that they refer to two distinct things, each with its own specific purpose. A carbon offset involves removing greenhouse gases from the atmosphere in sectors and/or geographic areas different from those in which the company operates, while a carbon credit represents a reduction in the amount of greenhouse gases released into the atmosphere (Calel et al., 2021). In conclusion, both terms are often used to balance emissions that are difficult to remove and have gained traction as an essential element of corporate sustainability initiatives. However, their impact on financial outcomes remains an area of ongoing debate (Wang, 2023; Wang et al., 2022; Busch et al., 2022). Because the tool has only recently been deployed, no differentiation is made between credits and offsets in accounting terminology. Therefore, for the purposes of this study, we will refer to a single variable known as carbon credits/offsets.

Recent literature in the field of emissions has examined the effect of carbon emissions and emission reduction on financial performance (Sitompul et al., 2023; Busch et al., 2022; Ganda, 2022; Siddique et al., 2021). Nevertheless, a definitive conclusion has not yet been reached. Divergence in the findings can be attributed to specific sectors and analytical approaches, as well as to country-specific focuses influenced by regulatory and normative factors related to emissions. Additionally, there has been no comprehensive study on this relationship, focusing on the automotive sector during the peak of the COVID-19 pandemic, a time when many companies stopped their operations due to lockdowns. The aim of this paper is to explore the relationship between carbon emissions and a company’s financial performance, and to analyse the impact of climate finance instruments and carbon offsets/credits on this relationship (Peterson, 2022), with a specific focus on the years of pandemic and post-pandemic. The purpose of this study is to examine the relationship between carbon emissions and financial performance, with a particular emphasis on the role of carbon credits. Moreover, empirical evidence is provided to enhance our understanding of the effects of climate change practices on financial performance, highlighting the role of climate finance tools. Considering the fact that firms may not be able to reduce their greenhouse gas emissions through the incorporation of new technologies, would carbon credits serve as a practical measure in curbing emissions?

Recent research has examined the correlation between carbon emissions, financial performance, and carbon credits from various theoretical perspectives concerning sustainability (Sitompul et al., 2023). First, carbon offsets/credits can be seen as important resources or capabilities that a company can use to improve its competitive advantage, according to the Resource-Based View (Kaplan et al., 2023; Shrestha et al., 2023). Furthermore, carbon offsets/credits can help companies gain or maintain legitimacy in the eyes of stakeholders and meet their responsibilities, as stated by Legitimacy Theory (Suchman, 1995; Dowling and Pfeffer, 1975) and Stakeholder Theory (Cornell and Shapiro, 2021; Jones et al., 2017). The current research is framed from the perspective of institutional theory, a concept widely debated in sustainability studies, especially in the context of climate change, a phenomenon described as institutional isomorphism (DiMaggio and Powell, 1991). Institutional isomorphism occurs through coercive pressures (e.g., regulations and compliance requirements), mimetic pressures (e.g., imitation of successful organisations), and normative pressures (e.g., professional norms and standards). These mechanisms collectively drive organisations to adopt similar sustainability practices and behaviours, shaping their responses to climate change challenges. It underscores the influence of institutional pressures in shaping the adoption of voluntary sustainable practices (Daddi et al., 2018). Therefore, from a theoretical perspective, we have focused on institutional theory as a theoretical framework, to understand whether carbon offset/credit programs are able to develop a reduction in carbon emissions by complying with government policies, market forces, and social norms, which are becoming more and more mandatory due to the pressing nature of the matter (Moufity et al., 2024; Matten and Moon, 2020; Campbell, 2007; DiMaggio and Powell, 1991).

In the current scenario, where environmental concerns are on the rise, many organisations are adopting carbon offset/credit as a strategic measure to mitigate their carbon footprint (Cadez et al., 2019). It is important to understand the role of carbon offsets, which are becoming increasingly necessary due to stakeholder pressure and emerging regulatory obligations. The combination of these obligations and responsibilities has an impact on financial results, making it an interesting topic to take into account. This study presents an innovative approach that builds upon the existing literature regarding the relationship between emissions and financial performance. By focusing on emission-mitigation instruments, it seeks to address a pivotal gap by exploring the question: How effective are carbon credits in reducing greenhouse gas emissions and enhancing corporate financial performance?

The research has two primary aims: first, to analyse the relationship between emissions and corporate financial performance and, second, to assess how climate finance instruments can improve corporate performance in the context of climate change challenges. Specifically, we assume that carbon emissions have a negative impact on financial outcomes but carbon offsets/credits can moderate their negative effects. We conducted an analysis using a global sample of companies that utilised carbon offsets/credits over a period of five financial years (2018–2022). In order to determine the impact of carbon emissions on financial performance, we conducted a longitudinal analysis using the generalised least squares random-effect model (Guastella et al., 2022; Tuesta et al., 2020; Alsaifi et al., 2020).

The study’s findings confirm that carbon emissions have a detrimental effect on financial performance. However, this negative impact can be mitigated by adopting climate finance tools such as carbon offsets/credits, which can moderate this relationship. This highlights that companies can still have positive outcomes despite reducing carbon emissions. Based on the obtained findings, there are several significant contributions that can be highlighted. The integration of insights from recent studies and our empirical evidence has led us to conclude that investment in the reduction of carbon emissions can significantly enhance financial performance (Meng et al., 2023). In addition, this research delves into the impact of carbon offsets/credits on this relationship, which can further drive positive outcomes for financials. This study aims to contribute towards our understanding of this subject matter.

Our findings provide valuable insights from a management perspective. Our research emphasises the significance of sustainable entrepreneurship over investment in climate finance tools (carbon offsets/credits), which are legally mandatory, leading to an

improvement in financial performance. Also, the study's findings can serve as a valuable tool for companies making informed decisions regarding sustainability practices and carbon credit utilisation. By doing so, companies can promote long-term financial success whilst also contributing to the cause of sustainability. Finally, policymakers can use the research insights to implement effective policies that encourage businesses to adopt sustainable practices. Overall, this study strengthens the evidence of a negative correlation between greenhouse gas (GHG) emissions and corporate financial performance. It also highlights the positive role of carbon credits as a moderator in this relationship. The research opens avenues for further exploration into how climate finance instruments can affect corporate financial performance, which is valuable in the fight against climate change.

2. Literature review

2.1. Carbon emissions and institutional theory

The link between climate management and financial performance is frequently established through mandatory requirements, in addition to social, commercial, and ethical considerations. This is the main reason for this study's emphasis on the theoretical framework of Institutional Theory. In underdeveloped countries, some politicians assert that reducing pollution could impede GDP growth and industrial development (Başar and Tosun, 2021). They posit that a company's higher pollution output could indicate its superior performance, potentially resulting in higher production volume, revenue, and lower costs. However, with the growing emphasis on sustainable business practices, it has become crucial for companies to ensure their sustainability, because of climate change concerns, as well as the increasingly strict regulations that go beyond the behaviour of a single company (Tuesta et al., 2021). It is necessary to analyse the entire supply chain in order to comply with international regulations (Ganda, 2019). For instance, the focus has shifted from the direct carbon emissions faced by a single company to indirect carbon emissions that come from all the companies in the supply chain. Previous research suggested that companies exhibiting less sustainable behaviour, also arising from inaccurate supplier selection, tend to carry higher levels of risk exposure (Cohen, 2023). This higher level of risk often translates into increased costs, including higher debt expenses, greater tax obligations, and amplified raw material expenditures (Gleißner et al., 2022). The increase in costs can be attributed to the national and/or international regulations that focus on promoting the use of renewable sources of energy and sustainable supply chains for raw materials (Qian et al., 2020; Bitat, 2018). This highlights the growing importance of Environmental, Social, and Governance factors (ESG) in financing and investing decisions, as well as the benefits that accrue to national entities, such as taxation.

Prior studies have explored the connection between climate change management, especially in terms of carbon emissions, and company financial performance or value using various samples and methodologies. However, the results have been varied and there is still no agreement on the exact nature of this relationship. Extensive research has been conducted to establish the relationship between carbon emissions and financial performance. This link matches established regulatory best practices and new technologies, even if they are adopted voluntarily (Børing, 2019). Efforts towards emissions reduction, through compliance with international regulations, not only foster innovation but also have an indirect impact on enhancing productivity (Guastella et al., 2022). Several strands of evidence have emerged from previous works, based on many different theoretical frameworks that are highly interconnected.

Previous studies have analysed different theoretical perspectives, either as a single theory or as multiple theories. The prevalent theories are stakeholder theory, institutional theory, resource-based view theory and legitimacy theory. In addition to these primary theories, a number of alternate theories have also been observed and studied. Busch et al. (2022) conducted a study to assess the robustness of a previous study's findings on the relationship between carbon emissions (GHG emissions) and financial performance, specifically the return on assets. However, their results contradicted their hypothesis. In particular, the Delmas et al. (2015) study employed an innovative method that distinctly analysed short-term and long-term performance, which was then taken up by subsequent studies. The results showed a positive correlation in the short-term and a negative correlation in the long-term. Moreover, it is important to highlight that the difference in time orientation for research on carbon emissions was first observed by Slawinski and Bansal (2009). Organisations that are focused on short-term goals tend to be disconnected from the past and future. They are more likely to perceive emerging issues, such as climate change, as trade-offs rather than opportunities for growth. Conversely, companies that take a long-term perspective are more inclined to justify investing more in greenhouse gas reduction efforts with the understanding that this will result in long-term benefits for the organisation.

Furthermore, Ganda (2022) and Siddique et al. (2021) both focused on the stakeholder theory framework. In light of increasing pressures from stakeholders and institutions, businesses are expected to adopt and conform to carbon management strategies. A key differentiation factor for companies, and an opportunity to achieve long-term financial benefits, is to demonstrate and communicate their commitment to addressing climate change issues. This theory underscores the significance of implementing effective carbon management strategies to ensure long-term sustainability and success in a constantly changing business environment. The results of their studies showed positive outcomes over a long time period, while negative outcomes occurred in the short term.

Another important theory is the 'resource-based view' or, more specifically, natural resource-based view, which suggests that firms can gain a competitive edge by utilising their resources and unique attributes. This approach emphasises the importance of leveraging all available resources, investments, and differentiating factors (Tuesta et al., 2021; Alsaifi et al., 2020; Borghei et al., 2018). Other studies are based on legitimacy theory, which states that companies consider implementing carbon management strategies as a means to acquire or maintain legitimacy in the eyes of stakeholders. This will ensure compliance with laws and regulations, thus establishing a reputable image for the company (Siddique et al., 2021). This study highlights a positive relationship between a company's carbon disclosure and carbon performance ratings and its financial performance (Ganda, 2019; He et al., 2016) but a negative relationship between a company's direct and indirect emissions indicators and its financial performance (Tuesta et al., 2021).

Our theoretical framework is based on institutional theory, which suggests that coercive forces, such as regulations and regulatory compliance, drive managerial decisions (Tuesta et al., 2021; Ganda, 2019; Luo and Tang, 2016). The relationship between a company's carbon management and financial performance can be better understood through the lens of institutional theory. This view helps in comprehending how the physical and social environment can affect the development of a company's dynamic capabilities (Sitompul et al., 2023). The argument is that the connection between environmental strategy and competitive advantage depends on how environmental improvement is perceived, as it differs based on the focus, i.e. whether it is pollution prevention, product management or sustainable development.

According to previous studies, corporate sustainable practices are influenced by institutional forces (Moufity et al., 2024; Matten and Moon, 2020; Ansari et al., 2013; Campbell, 2007; DiMaggio and Powell, 1991). In accordance with institutional theory, companies are examined from the perspective of three different types of pressure (Daddi et al., 2020; DiMaggio and Powell, 1991): coercive, normative, and mimetic. Nowadays, institutional theory concentrates on sustainability and scrutinises how institutions exert pressure on firms and how firms respond to such pressure (Scott, 1995). In essence, it is widely accepted that institutions create pressure on firms to adopt specific practices that can enhance their legitimacy (Moufity et al., 2024; Scott, 1995). In addition, institutional theory has demonstrated its effectiveness in elucidating the worldwide dissemination of business practices, including sustainability, and their assimilation by organisations (Brammer et al., 2012; Matten and Moon, 2020; Campbell, 2007). The Institutional theory posits that three categories of institutional forces can exert an influence on a corporation's sustainability practices (Moufity et al., 2024). The first type is called 'coercive' and occurs when those in power and authority force the organisation to implement certain practices. Secondly, 'mimetic' forces result from imitating the best practices, procedures and structures of successful organisations. Finally, 'normative' forces are linked to the pressure of professionalising organisational members, their values, and norms.

The theory posits that firms are active actors who are capable of proactively responding to the pressures exerted on them by their surroundings (Scott, 1995). Institutional theory is commonly employed in the literature, to describe how organisations can establish their legitimacy within their internal, external, and competitive environments. This theory explains the influence of various institutions that can shape the sustainable practices implemented by businesses (Moufity et al., 2024). It can be argued that recognising sustainability practices as key resources that meet the demands of various stakeholders and providing legitimacy to them encapsulates the Institutional theory previously set forth. Summing up, institutional theory argues that the institutional context in which businesses operate influences their sustainability practices (Campbell, 2007). However, previous studies have pointed out that, due to differences in institutional contexts between countries, the sustainable practices developed by firms tend to vary across nations (Moufity et al., 2024; Campbell, 2007).

2.2. Climate finance and carbon credits

According to The Intergovernmental Panel on Climate Change (IPCC) report of 2023, increased availability and access to financing will facilitate the acceleration of climate action. To address the growing climate risks and support investments in emissions reduction, it is imperative to significantly increase both adaptation and mitigation finance. The sources of finance can be diverse, including public or private, local, national, or international, bilateral or multilateral, and alternative sources (IPCC, 2023). One such source is carbon offsets/credits. Climate finance, more specifically carbon finance, is currently the core issue in this context. Due to the absence of a globally recognised definition of climate finance, it can be broadly defined as all funds provided and mobilised by the governments of developed countries (through public or voluntary initiatives) for mitigation actions related to climate change (Michaelowa et al., 2022).

As a climate finance tool, carbon offsets/credits have become popular instruments in global efforts to mitigate climate change (Calel et al., 2021). They work by offering regulated polluters the opportunity to reduce their own emissions by subsidising equivalent emission reductions through other initiatives (Michaelowa et al., 2022). These tools are part of the world's largest carbon offset program, called the Clean Development Mechanism (CDM), established as part of the Kyoto Protocol in 1997. As part of the program, companies that are responsible for polluting can meet their obligation to reduce emissions by financing emission reduction projects that are equivalent in nature, even if they are not directly connected with the company's core business (Calel et al., 2021).

Moreover, the terms 'carbon credits' and 'carbon offsets' are often used interchangeably but they are different products with distinct purposes. A carbon offset refers to the removal of greenhouse gases from the atmosphere to compensate for emissions that have already occurred, while a carbon credit represents a way of buying the right to release carbon (Hume, 2023; Calel et al., 2021). These credits and offsets are commonly used to balance emissions that are difficult to remove and they have become an essential element of corporate sustainability initiatives, directly connected with climate management strategies. More specifically, a carbon credit denotes a reduction of 1 metric ton in greenhouse gas emissions, to offset emissions made elsewhere (Gurgel, 2022). This credit can be bought, sold, or traded until it is retired, signifying that it can no longer be traded. Also, it is important to note that carbon credits are a result of mandatory regulations, while carbon offsets are voluntary measures taken to reduce carbon emissions.

2.3. Hypotheses development

Overall, stakeholder and institutional theories shed light on the substantial influence of stakeholders and institutions on companies, compelling them to adopt and adhere to carbon management strategies. By demonstrating and communicating their unwavering commitment to addressing climate change issues, companies can set themselves apart from their competitors and potentially gain sustainable financial benefits in the long term (Sitompul et al., 2023; Busch et al., 2022). Taking an institutional perspective (Pan et al., 2024), we analyse corporate financial performance as the dependent variable and greenhouse gas emissions, which serve as a proxy for

climate change, as the independent variable. The release of greenhouse gases into the atmosphere can significantly affect climate change. Stakeholders, especially investors, are increasingly focused on climate risk, which subsequently influences corporate financial performance. Based on these considerations we formed the following hypothesis:

Hp1. Carbon emissions have a negative impact on a company's financial outcomes.

The current hypothesis has been divided into three sub-hypotheses as follows:

Hp1a. Carbon emissions have a negative impact on a company's earnings before interest, taxes, depreciation and amortisation.

Hp1b. Carbon emissions have a negative impact on a company's enterprise value.

Hp1c. Carbon emissions have a negative impact on a company's Tobin's q.

In recognition of the negative impact of emissions on companies' financial performance, various financial instruments have been created to help companies offset their emissions. This research takes a broad approach, considering both carbon offsets and credits without making a distinction between the two. The second aim of the study is to investigate how the use of these instruments can reduce or mitigate the adverse effects of emissions on financial performance from an institutional perspective. In light of these considerations, we propose the following hypothesis:

Hp2. Climate finance tools are moderators of the relationship between carbon emissions and company financial outcomes.

3. Methodology

3.1. Sample, data collecting and research design

As stated by [Sitompul et al. \(2023\)](#), carbon emissions have a large negative influence on financial performance; however, implementing carbon management techniques could improve performance. Starting from this point of view, we built our analysis on a worldwide sample of firms ([Siddique et al., 2021](#)). The decision to select a global sample stemmed from the increasing adoption of carbon credits by companies, a trend significantly influenced by the signing of the 2015 Paris Agreement. The number of companies employing carbon credits has seen substantial growth over the years, although conducting a longitudinal analysis for 5–10 years within a specific geographical area or sector remains difficult, due to the relatively small number of companies that have utilised carbon credits for that length of time. The sample includes companies with carbon offsets/credits from 2018 to 2022 (5 financial years), involved in all industries (energy, utilities, industrials, materials, information technology, communication services, health care, real estate, consumer discretionary and consumer staples) except the financials ([Luo, 2019](#)), obtained from the LSEG data and analytics database (Refinitiv), in line with previous empirical studies on the relationship between emissions and financial performance ([Qian et al., 2020](#); [Tuesta et al., 2021](#); [Palea and Santhia, 2022](#)). [Table 1](#) shows the distribution of the companies in the sample, classified by industry sector, following the Global Industry Classification Standard (GICS), and the continent where the headquarters are located. The industrial sector comprises the highest number of firms, with 18.26 % of the sample, followed by the consumer discretionary sector (13.04 %), the energy sector (11.30 %) and the information technology sector (11.30 %). The materials sector has the lowest number of companies in the sample (4.35 %). Europe has the highest number of companies, accounting for 38.26 % of the sample, followed by North America (United States of America and Canada) with 31.30 % of companies in the sample.

To create panel data, the data were collected between 2018 and 2022. Time series and cross-section data were gathered for multiple years and multiple individuals in the panel data analysis.

[Hsiao \(2007\)](#) outlined several advantages of panel data studies over cross-sectional or time series studies: (i) more sample variability and degrees of freedom for a more precise inference of model parameters; (ii) enhanced control of unobserved heterogeneity, the primary cause of bias in omitted variables; (iii) more effective estimation, which allows the application of models with fixed and random effects; (iv) improved dynamic relationship modelling using time-varying variables; and (v) improved ability to deduce the cause of the variation in the variables.

Panel data analysis can be conducted through four different techniques: (i) fixed effect models; (ii) random effect models; (iii) pooled analysis; and (iv) dynamic panel models. The goal of the analysis and the issues surrounding the assumptions of the regression model's error terms are at the core of defining which model is best ([Alsaifi et al., 2020](#)). In order to evaluate our research hypotheses, we employed a generalised least squares random-effects model, as outlined in the results section. This methodology allowed us to account for unobserved variability among firms that could impact both our independent variables (GHG emission) and our dependent variables (proxies for financial performance).

Previous studies on carbon emissions and financial performance based their analysis only on a single country ([Delmas et al., 2015](#); [Alsaifi et al., 2020](#); [Ganda, 2022](#); [Meng et al., 2023](#)), focusing on both non-developing countries and developing countries. As previously mentioned, carbon offsets and credits are still emerging tools in climate finance. Consequently, our analysis focused on a global sample. Moreover, the worldwide sample ensured the homogeneity of the sample. Companies with a market capitalisation of less than 10 billion US dollars were excluded ([Kaplan and Ramanna, 2021](#)). We focused this research on large-capital companies, which are generally well-established and have a solid track record (in terms of performance), which makes them less risky ([Eun et al., 2008](#)). Applying the filters yielded a sample of 115 public companies.

Table 1

Distribution of sample companies by sector and country.

Continent	GICS sector										Total of companies	% of Total
	Energy	Utilities	Industrials	Materials	Information Technology	Communication Services	Health Care	Real Estate	Consumer Discretionary	Consumer Staples		
Europe	7	4	8	2	3	6	4	2	7	1	44	38.26 %
North America	4	4	5	2	7	3	3	1	3	4	36	31.30 %
South America	1	3	2	-	-	-	-	-	-	1	7	6.09 %
Asia	1	-	6	1	2	1	-	2	4	4	21	18.26 %
Australia	-	1	-	-	1	-	1	2	1	-	6	5.22 %
Africa	-	-	-	-	-	-	-	1	-	-	1	0.87 %
Total of companies	13	12	21	5	13	10	8	8	15	10	115	100 %
% of Total	11.30 %	10.43 %	18.26 %	4.35 %	11.30 %	8.70 %	6.96 %	6.96 %	13.04 %	8.70 %	100 %	

3.2. Variable descriptions

In order to test our hypotheses, we followed the methodologies of previous research in carbon management studies and used widely accepted variables from the literature (Sitompul et al., 2023). Prior research adopted different strategies for evaluating the effects of carbon management issues on companies' performance in general (Busch et al., 2022; Ganda, 2022; Siddique et al., 2021), e.g. evaluating the effects of carbon emission disclosure on firms' financial performance. For our analysis, following previous studies, we used the carbon emissions, carbon offsets/credits, and financial performance variables developed by Thomson Reuters. All of our variables are summarised in Table 2.

3.2.1. Dependent variables

The existing studies frequently used accounting and market-based measures interchangeably, to assess the impact of carbon emissions on financial performance (Tuesta et al., 2020; Delmas et al., 2015). Although both approaches could seem similar, they are not completely interchangeable. Accounting measures such as Return on Assets (ROA) and Return on Equity (ROE) are frequently used to evaluate short-term impacts (Busch et al., 2022; Tahat and Mardini, 2021), such as higher operating costs and higher cost of capital (Choi and Luo, 2021). Alternatively, market-based measures, such as Tobin's q, reflect investors' long-term perceptions of a firm's management practices and its performance forecasts (Ganda, 2022; Tuesta et al., 2021). We employed EBITDA, Tobin's q, and Enterprise Value (Guastella et al., 2022; Borghei et al., 2018) because of their ability to effectively capture direct operational results, investor sentiment, and long-term market valuation. This approach offers a well-rounded perspective on the financial implications of greenhouse gas (GHG) emissions. The first variable is from the accounting side and approximates short-term perspectives, whilst the second two variables are from the market-based side, to evaluate long-term perspectives. However, we used both for different objectives: to offer additional insight, to evaluate financial performance; and as a tool for assessing the robustness of the results.

First, EBITDA was used as a profitability measure, in order to evaluate the effect of carbon emissions on companies' operating performance. As suggested by the literature review, carbon emissions could potentially erode performance by deteriorating the contractual conditions or increasing their costs (Guastella et al., 2022). Furthermore, EBITDA offers a clear representation of operational efficiency and profitability, as it eliminates the effects of financing and non-cash items. This makes it especially relevant for evaluating the operational impacts associated with greenhouse gas emissions. Second, Tobin's q is a ratio that compares a company's market value to the cost of replacing its assets. It takes into account intangible attributes that are not captured by accounting-based measures, making it a more accurate reflection of a firm's market value (Ganda, 2022; Delmas et al., 2015). This measure helps analyse how greenhouse gas (GHG) emissions impact a firm's market valuation relative to its physical assets, revealing the premiums or discounts investors assign, based on environmental performance. As Environmental, Social, and Governance (ESG) factors gain importance in investment decisions, Tobin's q has been proven to be a crucial indicator of how GHG emissions influence market expectations. Third, using enterprise value as a variable of financial performance reflects a firm's value and is related to market-based

Table 2
Variables' description.

Variables		Definition	Refs.
Dependent variable	EBITDA	Earnings before interests, taxes, depreciation and amortization	Guastella et al., 2022
Dependent variable	TQ	The ratio of the market value of a firm's assets (as measured by the market value of its outstanding stock and debt) divided by the replacement cost of the firm's assets (book value).	Ganda, 2022
Dependent variable	EV	Enterprise value	Borghei et al., 2018
Independent variable	CO2Em	Report the company emission in tons	Busch et al., 2022
Moderator variable	CC	Carbon offsets/credits of the company tons	Heal, 2022; Betz et al., 2022;
Control variable	MktCap	Market capitalization	Qian et al., 2020
Control variable	Size	The natural logarithm of total assets	Siddique et al., 2021
Control variable	Lev	Ratio between financial debt and total equity	Tuesta et al., 2021
Control variable	inflation	Inflation level of the country where headquarter is located	Agyapong et al., 2024
Control variable	Industry	Dummy variable: 1 manufacturing, 0 services	Nishitani et al., 2017
Control variable	Europe	1 if firm headquarter is located in Europe, 0 otherwise	Tuesta et al., 2020; Fernández-Cuesta et al., 2019
Control variable	Australia	1 if firm headquarter is located in Australia, 0 otherwise	Tuesta et al., 2020; Fernández-Cuesta et al., 2019
Control variable	NorthAmerica	1 if firm headquarter is located in North America, 0 otherwise	Tuesta et al., 2020; Fernández-Cuesta et al., 2019
Control variable	SouthAmerica	1 if firm headquarter is located in South America, 0 otherwise	Tuesta et al., 2020; Fernández-Cuesta et al., 2019
Control variable	Africa	1 if firm headquarter is located in Africa, 0 otherwise	Tuesta et al., 2020; Fernández-Cuesta et al., 2019
Control variable	Asia	1 if firm headquarter is located in Asia, 0 otherwise	Tuesta et al., 2020; Fernández-Cuesta et al., 2019

measures (Borghesi et al., 2018). This measure reflects the responses of markets and investors to greenhouse gas (GHG) management, integrating operational performance, capital structure, and market expectations. It serves as a comprehensive tool for assessing the financial implications of emissions on a firm's valuation in both equity and debt markets.

3.2.2. Independent variables

As independent variables, we used CO₂ emissions, in tonnes, (CO₂Em) from Thomson Reuters (Busch et al., 2022; Tuesta et al., 2021; Tahat and Mardini, 2021; Jayasundara et al., 2019). The measure represents the direct emissions of a company's sources, classified according to the GHG protocol for emission types. The emissions include carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorinated compounds (PFCs), sulphur hexafluoride (SF₆), and nitrogen trifluoride (NF₃), which are owned or controlled by the company. Many previous studies used this variable as a measure of GHG emission reduction, to evaluate the effect of the reduction in emissions on a company's financial performance (Ganda, 2022; Tuesta et al., 2020). Our research aims to evaluate the impact of carbon emissions on financial performance and assess the effectiveness of climate finance tools, such as carbon offsets/credits (our moderator variable) in reducing the impact.

3.2.3. Moderator variables

Carbon offsets/credits (CC) were established by the Kyoto Protocol and are instruments which are widely used to offset emissions, particularly over the last few years, and are a tool for mitigating greenhouse gas emissions (Heal, 2022; Betz et al., 2022). It is our moderator variable. Carbon offsets/credits represent the equivalent of the CO₂ offsets, credits and allowances in tonnes purchased and/or produced by the company during the fiscal year. Some companies, in certain sectors, are regulated to a specific limit of emissions. If they exceed this limit, they can purchase carbon credits to balance it out. Alternatively, if they emit less than their limit, they can sell their remaining allowance. It is important to note that only purchased and produced carbon credits are taken into account (Heal, 2022).

3.2.4. Control variables

By incorporating a range of pertinent control variables, we were able to account for the influence of various firm characteristics and financial variables, thereby avoiding the issue of omitted variables (Smelser and Baltes, 2001). This approach aligns with previous studies and enhances the reliability of our analysis. The chosen control variables are anticipated to significantly affect financial performance indicators. By accounting for these factors, the study isolates the particular impact of GHG emissions on financial performance, leading to a more precise and detailed analysis. It is widely recognised that companies with greater market capitalisation have more resources to invest in carbon reduction strategies. These strategies have the potential to impact on carbon emissions and, consequently, on financial performance. Also, market capitalisation reflects investor expectations of a company's future performance. Effective carbon reduction strategies can increase market capitalisation (Qian et al., 2020). Additionally, larger companies are better equipped to manage the risks associated with carbon emissions, such as regulatory, reputational, and physical risks related to climate change (Palea and Drogo, 2020). First, we controlled for market capitalisation (MktCap), to better isolate the relationship between carbon emissions and financial performance, ensuring reliable and robust findings. We also examined the impact of firm size, which we measured as the natural logarithm of total assets. Larger companies generally have more resources to invest in both carbon emission reduction and carbon offsets or credits (Siddique et al., 2021). While they may achieve higher absolute EBITDA, due to increased revenue, their profit margins can vary based on operating efficiency and GHG costs. Larger operations tend to emit more GHGs and are potentially impacted by significant sustainability concerns. Furthermore, market valuations relative to asset replacement costs may decline if GHG footprints are substantial, especially in sectors sensitive to sustainability issues. Using a logarithmic scale allowed us to reduce the high standard deviation associated with the differences between smaller and larger firms. Furthermore, we considered the leverage ratio (Lev), which indicates the proportion of external financing to a company's equity (Tuesta et al., 2021). High leverage can expose companies to costs from GHG emissions, potentially decreasing EBITDA. Also, excessive debt can undermine investor confidence, especially if GHG emissions lead to regulatory burdens. Furthermore, companies with significant leverage may face lower market valuations (TQ) if investors view their debt as a risk, particularly in environmentally sensitive industries. We also considered the inflation rate (inflation) of the country where the company's headquarters are located, to account for the difference in the size of the economy of each country. This is important because the inflation level could impact the relationship between our independent and dependent variables (Li et al., 2021). Larger economies may have different characteristics than smaller ones, such as a more diverse range of industries, more robust financial markets, and more complex regulatory environments (Choi and Luo, 2021). Moreover, the inflation level can influence companies' operating costs and spending priorities (Agyapong et al., 2024). By controlling for inflation, we isolated the effect of these characteristics and obtained more accurate results. Moreover, as part of our analysis, we looked at the industry sector of the company (Industry) because the sector in which a firm operates influences operational characteristics and exposure to environmental regulations. To do this, we followed the methods used in previous studies (Nishitani et al., 2017) and created a dummy variable with a value of 1 for manufacturing companies and 0 for service companies. Finally, in order to take into account the local context, we incorporated dummy variables that helped identify the geographic locations of company headquarters (Siddique et al., 2021; Tuesta et al., 2020; Fernández-Cuesta et al., 2019), and which determined its exposure to regional environmental regulations, market conditions, and societal expectations. We specifically considered the six continents: Europe, North America, South America, Australia, Asia, and Africa.

4. Results

4.1. Descriptive analysis

The data summary of the sampled companies is shown in Table 3. The dependent variable with the highest mean value is earnings before interest, taxes, depreciation, and amortisation (EBITDA) at $9.32e + 09$, followed by EV at about $1.47e + 11$ and Tobin's Q at 2,183,449. The variables were not normalised, to avoid any influence on the regression results (Siddique et al., 2021). The range for carbon emissions (CO₂Em) is $0.00-1.48e + 0.8$ and for carbon offsets/credits (CC), the range is $0.00-2.09e + 0.7$. Thus, it is essential to highlight the objective of implementing initiatives to reduce carbon emissions. Notably, the maximum value of CC, which represents the total carbon footprint, is higher than CO₂Em, which only reflects direct emissions. This finding demonstrates that there is a collective effort to reduce the carbon footprint beyond the direct emissions of individual companies. However, the mean of the two variables is different. CC has higher CO₂ than CO₂Em, which suggests significant interest in the firms' carbon-reduction initiatives. It is worth noting that the mean carbon emissions stand at 5,150,295. On average, companies undertake 766,029.7 activities aimed at reducing these emissions which, in turn, is reflected in their mean carbon offsets/credits.

4.2. Correlations

In this article, we employed a set of variables that exhibited one-to-one relationships with each other. These relationships are represented in Table 4, the correlation matrix, which is included below. It is clear that there is a negative direct association between carbon emissions (CO₂Em) and the dependent factors (EBITDA, TQ, and EV) in all cases.

According to our research, there is a statistically significant and positive correlation (coefficient = 0.339, p-value = 0.000) between carbon offsets/credits (CC) and direct carbon emissions (CO₂Em). Our analysis suggests that companies with higher carbon emissions tend to have more carbon offsets/credits, which can be attributed to regulatory requirements or private initiatives. Financial performance (EBITDA, TQ and EV) decreases as carbon emissions (CO₂Em) increase (correlation coefficient = -0.2010 , p-value = 0.000 for EBITDA). These findings suggest that ignoring efforts to reduce emissions could have a detrimental impact on financial performance. Furthermore, the finding aligns with the existing literature, which suggests that many firms choose to reduce their carbon emissions voluntarily, as a means to enhance their financial performance (Busch et al., 2022; Tuesta et al., 2021; Tahat and Mardini, 2021; Jayasundara et al., 2019; Nishitani et al., 2017; Rokhmawati et al., 2017). Moreover, the correlation coefficient between carbon offsets/credits and financial performance is positive and significant (e.g. with EBITDA, the correlation coefficient = 0.064, p-value = 0.000), so investing in climate finance tools to reduce carbon emissions has been observed to have a positive impact on a company's overall performance. Companies with headquarters in Europe, North America, Asia, Australia and Africa are negatively correlated with carbon emissions (the correlation coefficient between carbon emissions and Europe = -0.037 , p-value = 0.000), compared with companies with headquarters in South America, which is positively correlated (the correlation coefficient between carbon emissions and South America = 0.258, p-value = 0.000). This difference could be due to variations in regulatory frameworks or less stringent regulations in different geographic areas. However, the correlation between these variables is not really significant.

4.2.1. Regression analysis

To test our research hypotheses, we ran the generalised least squares random-effect model. Despite the propensity for fixed effect models to be employed more frequently in social studies, it has been observed that there has been a marked increase in the utilisation of random effects models (Guastella et al., 2022; Tuesta et al., 2020; Alsaifi et al., 2020).

In contrast to the fixed effect model, the random effect framework posits that the individual-specific effect is a random parameter that is not tied to the independent variables. Yet, when the individual-specific effect is indeed uncorrelated, the random effect

Table 3
Descriptive statistics.

Variable	Obs	Mean	Std. dev.	Min	Max
CC	575	766,209.7	2,520,208	0	2.09e + 07
CO2Em	570	5,150,295	1.59e + 07	0	1.48e + 08
EBITDA	575	9.32e + 09	2.22e + 10	- 7,824,311	1.93e + 11
TQ	570	2,183,449	4,013,615	0.007	4,217,954
EV	575	1.47e + 11	5.57e + 11	7.56e + 08	5.19e + 12
MktCap	570	8.33e + 10	3.00e + 11	1.18e + 07	2.47e + 12
Size	575	23.788	1.499	18.755	27.459
Lev	575	.813	0.334	0.004	1.982
inflation	575	1.92	19.41	- 60.4	66.8
Industry	575	0.313	0.773	0	1
Europe	575	0.383	0.486	0	1
Australia	575	0.052	0.223	0	1
NorthAmerica	575	0.313	0.464	0	1
SouthAmerica	575	0.061	0.239	0	1
Africa	575	0.009	0.093	0	1
Asia	575	0.183	0.387	0	1

Table 4
Correlations matrix.

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(1)	CC	1.000															
(2)	CO2Em	0.339*	1.000														
(3)	EBITDA	0.064	− 0.210*	1.000													
(4)	TQ	0.063	− 0.059	0.065	1.000												
(5)	EV	0.019	− 0.021	0.454*	0.052	1.000											
(6)	MktCap	0.017	− 0.013	0.906*	0.145*	0.502*	1.000										
(7)	Size	0.113*	− 0.376*	0.940*	0.002	0.382*	0.778*	1.000									
(8)	Lev	0.037	− 0.099*	− 0.125*	0.096*	0.006	− 0.123*	− 0.118*	1.000								
(9)	inflation	0.021	− 0.132*	0.077	0.022	− 0.119*	0.029	0.031	0.011	1.000							
(10)	Industry	0.074	0.007	− 0.127*	− 0.161*	0.009	− 0.047	− 0.137*	− 0.027	− 0.209*	1.000						
(11)	Europe	0.128*	− 0.037	− 0.099*	0.084*	− 0.141*	− 0.139*	− 0.084*	0.138*	− 0.139*	− 0.128*	1.000					
(12)	Australia	− 0.070	− 0.076	− 0.094*	0.007	− 0.059	− 0.063	− 0.096*	− 0.031	− 0.511*	0.143*	− 0.185*	1.000				
(13)	NorthAmerica	− 0.106*	− 0.026	0.266*	0.029	0.097*	0.309*	0.229*	− 0.038	0.117*	0.032	− 0.531*	− 0.158*	1.000			
(14)	SouthAmerica	− 0.023	0.258*	− 0.015	− 0.078	0.307*	− 0.059	− 0.003	− 0.051	− 0.537*	0.155*	− 0.201*	− 0.059	− 0.172*	1.000		
(15)	Africa	− 0.028	− 0.030	− 0.038	− 0.020	− 0.000	− 0.026	− 0.049	0.042	− 0.199*	0.125*	− 0.074	− 0.022	− 0.063	− 0.024	1.000	
(16)	Asia	0.028	− 0.033	− 0.121*	− 0.091*	− 0.094*	− 0.114*	− 0.099*	− 0.088*	0.705*	− 0.086*	− 0.372*	− 0.111*	− 0.319*	− 0.121*	− 0.044	1.000

framework is the superior choice over the fixed effect framework (Ganda, 2022).

Moreover, as highlighted by Bell and Jones (2015), if the assumptions of random effect models are correct, then the random effect is the preferred choice due to its increased flexibility and generalisability. The application of the Hausman test is limited to homoscedasticity and is unable to account for fixed effects. So, we performed a Hausman test (Hausman, 1978) to determine the best model for our data. Based on the Hausman test, it is determined that the optimal model for our study is the random effects model. By employing this methodology, we utilised a random effects model to accommodate unobserved variability between firms that could influence our independent and dependent variables. This approach helped to direct the focus of the investigation. Furthermore, this model assumes that these unobserved differences are random and do not correlate with the independent variables. Our hypotheses were examined through the application of the regression models outlined below.

$$EBITDA_t = \beta_0 + \beta_1 CO2Em_t + \sum_i \beta \text{ Control} + u_i + e_{it} \quad (\text{Model 1})$$

$$TQ_t = \beta_0 + \beta_1 CO2Em_t + \sum_i \beta \text{ Control} + u_i + e_{it} \quad (\text{Model 2})$$

$$EV_t = \beta_0 + \beta_1 CO2Em_t + \sum_i \beta \text{ Control} + u_i + e_{it} \quad (\text{Model 3})$$

The results of regression analyses are presented in Table 5. In all four of the previous hypotheses, we suggested that carbon emissions (CO₂Em) have a negative impact on financial outcomes. Model 1 presents the random effects estimated using EBITDA as the dependent variable to test Hypothesis Hp1a. As hypothesized, carbon emissions have a negative and significant effect on EBITDA ($p < 0.01$). Specifically, a 1 % increase in emissions leads to a 0.7543 (b1) decrease in EBITDA. Furthermore, for Hypothesis Hp1b, Model 3 found that carbon emissions also have a significant negative effect on EV. A 1 % increase in carbon emissions decreases EV by 11.0033 (b3) ($p < 0.01$). Finally, in Model 4, we confirm Hypothesis Hp1d, which states that carbon emissions have a negative impact on the company's Tobin's q (TQ). The coefficient is significant ($p < 0.1$). More precisely, a 1 % increase in carbon emissions leads to a decrease in TQ by 0.00022 (b4). Furthermore, when examining the data for specific years, the regression analysis revealed that the COVID-19 pandemic had a significant impact on the accounting variable EBITDA. It showed a reduction in the negative impact of emissions on financial performance during the middle years of the pandemic (2021 and 2022). However, in terms of market indicators EV and TQ, this effect was not observed. Instead, the impact remained relatively consistent across the years surveyed, despite the pandemic's significant effects. Based on the results, Hypotheses 1 and 2 are strongly supported. The regression models indicate significant negative effects (b1 = − 0.7542; b2 = − 0.6208; b3 = − 11.0033) with p-values less than 0.01 for all three models. As a result, we can confirm all of our hypotheses.

In terms of the control variables, we obtained positive and significant outcomes for market capitalisation (b1 = 0.00031, $p < 0.01$; b2 = 0.00942, $p < 0.01$; b3 = 0.01892, $p < 0.01$). Additionally, we observed both positive and negative results for size (b1 = 0.00144,

Table 5
Random effects regression analysis of carbon emissions on EBITDA, EV and Tobin's q.

	Model 1 EBITDA		Model 2 EV		Model 3 TQ	
CO2Em	− 75.426***	(0.005)	− 1100.332***	(0.000)	− 0.022*	(0.075)
CO2Em '19	− 10.201**	(0.041)	− 449.501*	(0.060)	− 0.002***	(0.006)
CO2Em '20	− 21.190**	(0.012)	− 338.827**	(0.035)	− 0.082**	(0.054)
CO2Em '21	− 8.411*	(0.087)	− 289.089**	(0.027)	− 0.009***	(0.003)
CO2Em '22	− 10.922*	(0.072)	− 385.196**	(0.046)	0.005**	(0.037)
inflation	− 0.318*	(0.061)	0.172**	(0.031)	− 0.216**	(0.063)
MktCap	0.031***	(0.000)	0.942***	(0.000)	1.892***	(0.000)
Size	0.144***	(0.000)	− 0.089***	(0.002)	− 5.692***	(0.000)
Lev	− 1.219	(0.250)	− 0.816	(0.206)	1.805***	(0.000)
Sector	− 0.029	(0.118)	0.069	(0.686)	− 0.020	(0.116)
Europe	1.053	(0.145)	0.585	(0.472)	− 1.102**	(0.020)
NorthAmerica	1.472*	(0.072)	1.036	(0.112)	− 0.485	(0.203)
SouthAmerica	1.087**	(0.010)	2.757	(0.110)	− 3.384***	(0.001)
Australia	− 0.144	(0.526)	0.512	(0.775)	− 3.484***	(0.001)
Asia	1.301	(0.275)	− 0.074	(0.548)	− 0.982	(0.141)
Africa	− 0.594	(0.153)	4.185**	(0.023)	− 3.155***	(0.003)
_cons	19.325***	(0.000)	21.080**	(0.043)	1.809*	(0.094)
Observation	564		564		564	
R_squared	0.705		0.371		0.567	
Adjusted R	0.697		0.371		0.556	
Wald chi2	92.37		35.24		50.74	

Values in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

$p < 0.01$; $b_2 = -0.00089$, $p < 0.01$; $b_3 = -0.05692$, $p < 0.01$). These two control variables are directly correlated with our dependent variable. There are no significant results for our dependent variables based on the geographical location of headquarters. In conclusion, there is no consistently significant impact on the other control variables.

Furthermore, in Models 4–6, we examined whether carbon offsets/credits (CC) moderators affect the relationship between carbon emissions and financial performance, as proposed in Hypothesis 2. First of all, Table 6 shows that carbon offsets/credits (CC) have a positive impact on financial performance ($b_1 = 0.3199$; $p < 0.05$; $b_2 = 1.2794$; $p < 0.01$), except for the firm's Tobin's q ($b_3 = -0.0172$; $p < 0.1$). It is interesting to note that, when carbon credits/offsets (CC) are added to the model, the impact of carbon emissions (CO_2Em) is still significant but the effect is weaker ($b_1 = -1.0206$; $p < 0.1$; $b_2 = -13.1012$; $p < 0.01$).

The interaction term between carbon emissions (CO_2Em) and carbon offsets/credits (CC) is positively and significantly related to financial outcomes ($b_1 = 0.0884$; $p < 0.1$; $b_2 = 0.0009$; $p < 0.01$), except for firm's Tobin's q ($b_3 = -0.04501$; $p < 0.1$). Additionally, the interaction term shows that the joint effects of carbon offsets/credits and carbon emissions are positive and significant. This implies that carbon offsets/credits help in reducing the negative impact of carbon emissions on the company's performance. Also, this improvement is sufficient to increase the performance of the company. The analysis was expanded to include the impact of the COVID-19 pandemic. The regression analysis revealed a more pronounced effect in the years leading up to the pandemic (2018–2020), indicating a decline during the pandemic years (2021 and 2022), in terms of EBITDA and EV. In relation to Tobin's q , there was a reduction in the moderating effect of carbon credits/offsets in the pre-pandemic years, while an increased significance was observed in the post-pandemic years. Therefore, considering the positive and significant association between the interaction terms of CO_2Em and CC with financial performance, we can accept Hypothesis 2.

In terms of the accuracy of the models, the main econometric models (including hypotheses 1 and its variations) show an R-squared range of 0.705–0.371 and an adjusted R-squared range of 0.697–0.371. Additionally, the Wald chi test is statistically significant, with a value between 92.37 and 35.24. Finally, in random effects regression analysis with carbon offsets/credits as a moderator (hypothesis 2), which are referred to as models 5–8, the R-squared range is between 0.665 and 0.261, and the adjusted R-squared range is between 0.632 and 0.259. The Wald chi test is significant, with a value between 6288.84 and 35.43. Overall, the model provides a satisfactory level of detail.

5. Discussion of results

In the context of escalating global temperatures, our findings underscore the microeconomic implications of unchecked increases in greenhouse gas emissions, emphasising the critical need for decisive action against climate change. Furthermore, our study demonstrates that the use of carbon credits serves as an effective mechanism for offsetting emissions, thereby managing the gravity of their consequences. The study offers an analysis of carbon credits within a transnational framework, contributing to the existing literature on sustainability practices and climate finance. The research findings align with previous studies and demonstrate that carbon emissions have a statistically significant negative effect on financial performance (Busch et al., 2022; Alsaifi et al., 2020; Borghei et al., 2018). By examining three proxies of financial performance (EBITDA, EV and TQ) through the lens of institutional theory, we found that companies with more sustainable practices and lower carbon emissions generally face fewer economic losses.

In terms of EBITDA, GHG emissions have a detrimental effect on profitability. This impact can be understood through the

Table 6
Random effects regression analysis with carbon offsets/credits as moderator.

	Model 4 EBITDA		Model 5 EV		Model 6 TQ	
CO_2Em	-102.059*	(0.094)	-1310.919**	(0.042)	-1.875*	(0.073)
CO_2EmXCC	8.836**	(0.020)	0.088***	(0.000)	-4.501**	(0.050)
CO_2EmXCC '19	1.232**	(0.032)	0.032***	(0.009)	0.017*	(0.099)
CO_2EmXCC '20	2.258**	(0.019)	0.079**	(0.011)	0.013	(0.110)
CO_2EmXCC '21	1.273*	(0.051)	0.009**	(0.033)	0.141***	(0.001)
CO_2EmXCC '22	1.11*	(0.057)	0.012**	(0.027)	0.297**	(0.012)
inflation	-7.217**	(0.017)	3.208*	(0.074)	0.738*	(0.090)
MktCap	0.031***	(0.000)	0.921***	(0.002)	6.721***	(0.000)
Size	0.143***	(0.000)	-0.098	(0.142)	-1.311***	(0.000)
Lev	6.208	(0.106)	4.539*	(0.051)	1.772***	(0.000)
Sector	-2.720	(0.110)	-6.782	(0.446)	-0.309**	(0.030)
Europe	-3.757	(0.661)	4.031	(0.817)	1.562	(0.171)
NorthAmerica	4.017	(0.973)	2.611	(0.711)	1.176	(0.326)
SouthAmerica	1.159	(0.560)	8.421	(0.225)	1.416	(0.465)
Africa	-1.126	(0.472)	1.521***	(0.000)	1.116	(0.792)
Australia	-3.161	(0.111)	-2.139	(0.935)	2.019	(0.324)
Asia	-4.587	(0.960)	-7.051	(0.260)	-1.407	(0.100)
_cons	2.969*	(0.054)	5.218	(0.261)	1.567	(0.246)
Observation	564		564		564	
R_squared	0.665		0.369		0.261	
Adjusted R	0.632		0.369		0.259	
Wald chi2	1471.31		791.92		35.43	

Values in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

framework of institutional theory, which highlights the influence of coercive pressures on corporate behaviour. In highly regulated environments, companies are compelled to internalise the external costs associated with GHG emissions. This may involve complying with environmental regulations or investing in new technologies, both of which incur costs, referred to as 'compliance costs'. These expenses can diminish profitability by raising operating costs, thereby directly affecting EBITDA. Additionally, from the neo-institutional legitimacy perspective (Suchman, 1995; Pan et al., 2024), elevated emissions can undermine a company's legitimacy in the eyes of consumers, investors, and regulators. This erosion of legitimacy can lead to further declines in profitability due to the resulting costs. Thus, companies that fail to align with institutional expectations regarding emissions reductions risk facing negative financial outcomes.

Greenhouse gas emissions adversely affect company value, as reflected in the financial proxies analysed, enterprise value (EV) and Tobin's Q. This phenomenon stems from both regulatory and cognitive pressures within institutional environments. Investors are placing greater emphasis on ESG performance, resulting in valuation discounts for high-emission companies due to perceived risks and misalignments with market sustainability expectations. This trend towards valuing sustainable companies highlights the significant role that regulations play in shaping market behaviour. High-emission companies tend to experience depreciation in their valuations because they are perceived as being inconsistent with sustainability principles. Institutional theory suggests that organisations with elevated emissions may be regarded as less innovative or future-focused, particularly if they do not adopt strategies that align with stakeholder expectations. This perception can lead to a reduced Tobin's Q, as market participants believe these companies are less likely to thrive in an economy increasingly oriented toward sustainability. As a result, businesses that neglect to address GHG emissions may find themselves facing operational challenges, alongside diminished market confidence and valuation penalties.

Moreover, a strong negative correlation between emissions and financial performance has been observed, particularly in countries with more stringent sustainability regulations. This finding supports the principles of institutional theory, which posits that formal regulations compel firms to adhere to environmental standards, thereby increasing the financial repercussions of noncompliance. Institutional theory further emphasises that the intensity and nature of institutional pressures can differ between countries. As a result, companies operating in highly regulated markets encounter stricter enforcement of environmental standards, leading to significant penalties for noncompliance that directly impact their financial performance.

Finally, we introduced carbon credits as a moderating variable within the relationship we examined. Their role clarifies how institutional innovation can reshape the link between GHG emissions and financial performance. Through a market-based mechanism, carbon credits enable companies to offset their emissions by aligning them with institutional expectations, thereby mitigating the negative impacts these emissions can have on financial results. As a result, companies that leverage carbon credits can demonstrate their observance of social norms and regulatory standards, enhancing their legitimacy and improving their financial performance. This aligns with institutional theory, which posits that legitimacy is a vital driver of organisational success. Furthermore, companies that proactively engage in emission compensation not only cut the adverse financial consequences of their emissions but also indicate that they are pioneers of sustainability.

In conclusion, the findings from our study suggest that the adoption of climate finance instruments, such as carbon credits, not only mitigates the negative effects of carbon emissions but can also convert these effects into a positive and statistically significant impact. Furthermore, our analysis shows that, even during the COVID-19 pandemic, when emissions declined, the observed effects remained consistent, although the levels of impact were different.

6. Conclusions

Organisations face considerable risks due to climate change (Cohen, 2023). It is widely recognised that the unmitigated emissions of greenhouse gases could accelerate increases in temperature, leading to a heightened frequency and severity of extreme weather events that could adversely impact businesses and communities (Palea and Santhia, 2022; Choi and Luo, 2021). In order to ensure the sustainability of businesses, it is crucial to assess their overall profitability, taking into account factors such as CO₂ consumption, which is linked to sustainability practices and financial performance (Wang, 2023; Tuesta et al., 2021; Borghei et al., 2018). A company's management strategies for addressing climate change are particularly important, as greenhouse gas emission levels are a key indicator of its carbon performance (Busch et al., 2022). By analysing both direct and indirect GHG emissions, it is possible to gauge environmental performance (Guastella et al., 2022). It is worth noting that different emissions are subject to regulations that can directly or indirectly impact the types of stakeholders involved, as well as a company's financial performance (Tuesta et al., 2021).

In this landscape, the use of climate finance tools to mitigate the negative effect of companies on the environment, while simultaneously improving financial performance, is becoming increasingly popular (Michaelowa et al., 2022). However, there is a paucity of research on climate finance tools serving business and related sustainability practices. In particular, the literature focuses on the effects of carbon emissions on different levels, mainly economic, environmental and political (Betz et al., 2022; Alsaifi et al., 2020). The number of studies available, with regard to a specific climate finance instrument such as carbon credits/offsets, is significantly lower (Calel et al., 2021; Fan et al., 2021). Many studies have investigated the relationship between financial and environmental performance, with a focus on carbon emissions (Li et al., 2021; Alsaifi et al., 2020; Jayasundara et al., 2019). There are two main approaches to this topic. The first approach analyses how reducing CO₂ emissions affects a company's economic performance and its impact on environmental performance (Başar and Tosun, 2021; He et al., 2016). It also examines the influence of a company's environmental certifications. The second approach looks at regulated environments, such as the Emissions Trading System (ETS), and studies the voluntary participation of companies in such programs (Yan et al., 2020; Borghei et al., 2018).

Our current research explored the relationship between climate finance tools and corporate financial performance. We aimed to investigate and analyse the potential connection between the two and provided insights into the topic. We sought to examine how

climate finance tools, particularly carbon offsets/credits, can influence this relationship. Our hypotheses draw from Institutional Theory (Tuesta et al., 2021; Ganda, 2019; Luo and Tang, 2016), stating that the investment programs of enterprises are intrinsically linked to the mandatory requirements in the sustainability field. Moreover, our proposed theoretical framework is designed to evaluate the efficacy of carbon offset/credit programs in mitigating carbon emissions within the framework of government policies, market dynamics, and societal norms (Trouwloon et al., 2023). The literature has limited evidence on the connection between climate finance tools and the financial benefits of investing in them to improve companies' environmental performance and GHG emission reduction. Our research aimed to bridge the gap in knowledge that existed on this topic. In order to validate our hypotheses, we conducted an empirical analysis of data from nearly 100 companies worldwide, spanning the years 2018–2022, which implemented carbon credits and offsets.

7. Theoretical implications

This study carries important theoretical implications, underscoring the relevance of institutional theory and the institutional framework in the context of sustainability. It opens with a thorough examination of contemporary sustainability theories, with a specific focus on the body of research addressing greenhouse gas emissions, including legitimacy theory (Suchman, 1995; Dowling and Pfeffer, 1975), stakeholder theory (Cornell and Shapiro, 2021; Jones et al., 2017), a resource-based viewpoint (Tuesta et al., 2021; Alsaifi et al., 2019; Borghesi et al., 2018), and institutional theory. Our theoretical framework is grounded in institutional theory, which posits that coercive forces, such as regulatory mandates and compliance pressures, exert a significant influence on managerial decision-making processes (Tuesta et al., 2021; Ganda, 2019; Luo and Tang, 2016). Adopting this theoretical lens enables a nuanced analysis of the interplay between corporate carbon management strategies and financial performance. We emphasise the critical role of climate finance tools and their impacts on both financial and environmental fronts. To meet institutional climate objectives, it is essential to enhance funding for both adaptation and mitigation initiatives. This is because finance, international collaboration, and technology are critical factors in accelerating climate action (IPCC, 2023). The findings of our study reveal that the efficacy of climate action is contingent upon a confluence of factors, namely political commitment, well-aligned multi-level governance and institutional frameworks, laws, policies, and strategies. It requires clearly defined objectives, adequate funding, and financing tools. These findings are in line with the theoretical precepts of institutional theory, which underscores the significance of institutional frameworks and regulatory structures in shaping collective action. In conclusion, institutional theory highlights the dynamic interactions between organisations and their environments, describing how firms must effectively navigate coercive, normative, and cognitive pressures. The findings of this study have implications for institutional theory across three levels. First, the notion of institutional complexity highlights the need for firms to balance multiple, and often competing, institutional pressures. Second, the isomorphism for which firms are increasingly converging towards with respect to lower emissions, to achieve legitimacy and financial stability, is driven by institutional pressures, market mechanisms, and innovation. Finally, the third aspect concerns dependency levels. Firms in less regulated environments may experience these pressures with a delay but are not exempt from them. As global sustainability norms continue to strengthen, institutional pressures are likely to become more uniform, leading to increased costs and ultimately impacting financial performance.

8. Managerial implications

The current study aims to provide a comprehensive outlook on how climate finance instruments, particularly carbon credits, can enhance corporate financial performance, while also addressing environmental concerns and contributing to climate change mitigation actions. The outcome of our research has revealed significant practical implications for managers, investors, and policymakers. In today's business landscape, managers tasked with addressing environmental risks can leverage a range of tools to implement sustainable practices without imposing a financial strain on their company. As a result, sustainability is increasingly recognised as a valuable practice that can enhance both environmental outcomes and overall financial performance. Also, investors enjoy enhanced capabilities to assess investments founded on sustainable practices. They have a wide range of tools for evaluating diverse investments at their disposal and steer clear of companies that engage in greenwashing, i.e. the practice of falsely claiming sustainability for the sole purpose of gaining recognition without implementing sustainable practices. Finally, there is a growing call for policymakers to incentivise companies to adopt sustainable practices. One approach is to establish laws that support environmentally conscious businesses and ensure compliance. These companies can significantly influence the entire system and a more comprehensive set of guidelines and effective monitoring can further encourage their proactive efforts. Government-led initiatives can play a critical role in driving these companies to take necessary action. From a practical perspective, this study emphasises the significance of climate finance instruments, which also support stakeholders in acknowledging a company's commitment to sustainability and climate change concerns. The increasing prominence of carbon credits, in combination with the findings of this research, underscores the considerable financial implications associated with the impacts of climate change and efforts to mitigate them. Overall, these issues are gaining amplified attention and are emerging as important and urgent items on the agendas of each organisation.

9. Limitations and future lines of research

The study provides valuable insights into the relationship between greenhouse gas emissions, financial performance, and the moderating influence of carbon credits. However, several limitations deserve attention. Addressing these limitations could facilitate future research that deepens our understanding of this important topic. Firstly, the analysis focused solely on one moderator: carbon

credits. While our findings indicate that this factor is significant, it may not fully cover the complexity of the various elements affecting the relationship between GHG emissions and financial performance. Future studies could investigate additional potential moderators, such as industry characteristics, corporate governance, stakeholder engagement strategies, and environmental, social, and governance (ESG) ratings. Secondly, our study examined a short time frame of five years, a limitation stemming from the partial use of carbon credits in earlier years. This narrow scope may not totally reflect the long-term financial impacts of GHG emissions or the evolving role of carbon credits. Additionally, short-term data may be influenced by temporary fluctuations due to market trends or policy issues. Extending the analysis over a longer period, as the use of carbon credits becomes more widespread, would be useful. Such an approach would allow for a more comprehensive examination of the cumulative and dynamic effects of GHG emissions on financial performance, as well as the effectiveness of carbon credits in mitigating climate change, while enhancing corporate financial outcomes. Third, we considered carbon credits and offsets as two inter-related components. However, they may not always align seamlessly. Consequently, it would be prudent to differentiate between carbon credits and carbon offsets, to determine whether their effects are actually the same, viewing carbon offsets as the foundational source of carbon credits. Fourth, while employing a global sample of companies provides a broad overview, it may introduce heterogeneity that obscures regional or country-specific dynamics. Differences in regulatory frameworks, market conditions, cultural attitudes toward sustainability, and industry structures across various countries can influence the generalisability of our results. As the use of carbon credits becomes more widespread, conducting regional or country-specific studies would be beneficial for gaining a clearer understanding of the localised effects of greenhouse gas emissions and carbon credits on financial performance. Furthermore, it would be useful to analyse how changes in institutional environments, such as regulatory or investor priorities, shape the relationship between emissions and financial performance. Comparing the effects of GHG emissions and carbon credits in developed (against developing) countries, whilst considering differences in economic structures, resource availability, and regulatory enforcement, would also provide valuable insights. Finally, with the increasing recognition of the impacts of climate change, there has been a notable uptick in the adoption of decarbonisation commitments and the utilisation of climate finance tools. As highlighted by the study, companies are taking swift and decisive action to mitigate greenhouse gas emissions and offset any residual carbon footprints. However, while we have made significant progress so far, it is important to acknowledge that there are still some critical questions that need to be addressed. The primary question is whether companies fund carbon credits/offsets through their marketing or sustainability budgets (Hodgson, 2022). This main question raises a pertinent concern that has gained traction in academic and professional fields, namely the concept of ‘greenwashing’. As novel sustainability practices, such as those pertaining to climate finance tools, continue to gain prominence, there is a potential risk of reduced transparency in sustainability initiatives, culminating in an upsurge of greenwashing in its different forms.

CRedit authorship contribution statement

Salvi Antonio: Validation, Supervision. **Battisti Enrico:** Writing – review & editing, Conceptualization. **Martielli Francesco:** Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Kumar Satish:** Validation, Supervision. **Forliano Canio:** Writing – review & editing.

References

- Agyapong, E.K., Annor, L.D.J., Ohemeng, W., 2024. Corporate social responsibility and performance among rural banks in Ghana: the moderating role of governance structures. *Int. J. Soc. Econ.* 51 (1), 31–45.
- Alsaifi, K., Elnahass, M., Salama, A., 2020. Carbon disclosure and financial performance: UK environmental policy. *Bus. Strategy Environ.* 29 (2), 711–726.
- Ansari, S., Wijen, F., Gray, B., 2013. Constructing a climate change logic: an institutional perspective on the “tragedy of the commons”. *Organ. Sci.* 24 (4), 1014–1040.
- Başar, S., Tosun, B., 2021. Environmental pollution index and economic growth: evidence from OECD countries. *Environ. Sci. Pollut. Res.* 28, 36870–36879.
- Bell, A., Jones, K., 2015. Explaining fixed effects: random effects modeling of time-series cross-sectional and panel data. *Political Sci. Res. Methods* 3 (1), 133–153.
- Betz, R., Michaelowa, A., Castro, P., Kotsch, R., Mehling, M., Michaelowa, K., Baranzini, A., 2022. *The Carbon Market Challenge: Preventing Abuse through Effective Governance*. Cambridge University Press.
- Bitat, A., 2018. Environmental regulation and eco-innovation: the Porter hypothesis refined. *Eurasia Bus. Rev.* 8, 299–321.
- Borghei, Z., Leung, P., Guthrie, J., 2018. Voluntary greenhouse gas emission disclosure impacts on accounting-based performance: Australian evidence. *Australas. J. Environ. Manag.* 25 (3), 321–338.
- Børing, P., 2019. The relationship between firm productivity, firm size and CSR objectives for innovations. *Eurasia Bus. Rev.* 9 (3), 269–297.
- Brammer, S., Jackson, G., Matten, D., 2012. Corporate social responsibility and institutional theory: new perspectives on private governance. *Socio-Econ. Rev.* 10 (1), 3–28.
- Busch, T., Bassen, A., Lewandowski, S., Sump, F., 2022. Corporate carbon and financial performance revisited. *Organ. Environ.* 35 (1), 154–171.
- Cadez, S., Czerny, A., Letmathe, P., 2019. Stakeholder pressures and corporate climate change mitigation strategies. *Bus. Strategy Environ.* 28 (1), 1–14.
- Calel, R., Colmer, J., Dechezleprêtre, A., Glachant, M., 2021. Do Carbon Offsets Offset Carbon? Grantham Research Institute on Climate Change and the Environment (Working Paper No. 371 – ISSN 2515-5717).
- Campbell, J.L., 2007. Why would corporations behave in socially responsible ways? An institutional theory of corporate social responsibility. *Acad. Manag. Rev.* 32 (3), 946–967.
- Choi, B., Luo, L., 2021. Does the market value greenhouse gas emissions? Evidence from multi-country firm data. *Br. Account. Rev.* 53 (1), 100909.
- Cohen, G., 2023. The impact of ESG risks on corporate value. *Rev. Quant. Financ. Account.* 1–18.
- Cornell, B., Shapiro, A.C., 2021. Corporate stakeholders, corporate valuation and ESG. *Eur. Financ. Manag.* 27 (2), 196–207.
- Daddi, T., Bleischwitz, R., Todaro, N.M., Gusmerotti, N.M., De Giacomo, M.R., 2020. The influence of institutional pressures on climate mitigation and adaptation strategies. *J. Clean. Prod.* 244, 118879.
- Daddi, T., Todaro, N.M., De Giacomo, M.R., Frey, M., 2018. A systematic review of the use of organization and management theories in climate change studies. *Bus. Strategy Environ.* 27 (4), 456–474.
- Delmas, M.A., Nairn-Birch, N., Lim, J., 2015. Dynamics of environmental and financial performance: the case of greenhouse gas emissions. *Organ. Environ.* 28 (4), 374–393.
- DiMaggio, P.J., Powell, W.W., 1991. *The New Institutionalism in Organizational Analysis*. University of Chicago Press.
- Dowling, J., Pfeffer, J., 1975. Organizational legitimacy: social values and organizational behavior. *Pac. Sociol. Rev.* 18 (1), 122–136.

- Eun, C.S., Huang, W., Lai, S., 2008. International diversification with large-and small-cap stocks. *J. Financ. Quant. Anal.* 43 (2), 489–524.
- Fan, H., Peng, Y., Wang, H., Xu, Z., 2021. Greening through finance? *J. Dev. Econ.* 152, 102683.
- Fernández-Cuesta, C., Castro, P., Tascón, M.T., Castaño, F.J., 2019. The effect of environmental performance on financial debt. European evidence. *J. Clean. Prod.* 207, 379–390.
- Ganda, F., 2019. Carbon emissions, diverse energy usage and economic growth in South Africa: Investigating existence of the environmental Kuznets curve (EKC). *Environmental Progress & Sustainable Energy* 38 (1), 30–46.
- Ganda, F., 2022. Carbon performance, company financial performance, financial value, and transmission channel: an analysis of South African listed companies. *Environ. Sci. Pollut. Res.* 29 (19), 28166–28179.
- Gleißner, W., Günther, T., Walkshäusl, C., 2022. Financial sustainability: measurement and empirical evidence. *J. Bus. Econ.* 92 (3), 467–516.
- Gross, A., 2020. Carbon offset market progresses during coronavirus. *Financ. Times*, 29 September 2020.
- Guastella, G., Mazzarano, M., Pareglio, S., Spani, R.C., 2022. Do environmental and emission disclosure affect firms' performance? Evidence from sectorial micro data. *Eurasia Bus. Rev.* 12 (4), 695–718.
- Gurgel, A., 2022. Carbon Offsets. Massachusetts Institute of Technology (8 November 2022).
- Harvey, F., 2021. What is carbon offsetting and how does it work? *Guardian*, 4 May 2021.
- Hausman, J.A., 1978. Specification tests in econometrics. *Econometrica* 46 (6), 1251.
- Hodgson, C., 2022. Carbon credits face scrutiny as a corporate path to 'net zero'. *Financial Times*.
- He, Y., Tang, Q., Wang, K., 2016. Carbon performance versus financial performance. *China J. Account. Stud.* 4 (4), 357–378.
- Heal, G., 2022. The Economics of Carbon Accounting and Carbon Offsets (No. w30649). National Bureau of Economic Research.
- Hsiao, C., 2007. Panel data analysis—advantages and challenges. *Test* 16 (1), 1–22.
- Hume, M., 2023. Carbon offsets vs. carbon credits: what's the difference? *Morningstar*, 7 August 2023.
- IPCC (Intergovernmental Panel on Climate Change). 2023. *Climate Change 2023, Summary for Policymaker. A Report of the Intergovernmental Panel on Climate Change*. Available online: https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf (accessed on 15 February 2024).
- Jayasundara, S., Worden, D., Weersink, A., Wright, T., VanderZaag, A., Gordon, R., Wagner-Riddle, C., 2019. Improving farm profitability also reduces the carbon footprint of milk production in intensive dairy production systems. *J. Clean. Prod.* 229, 1018–1028.
- Jones, T.M., Wicks, A.C., Freeman, R.E., 2017. Stakeholder theory: the state of the art. *Black Guide Bus. Ethics* 17–37.
- Kaplan, R.S., Ramanna, K., 2021. Accounting for climate change. *Harv. Bus. Rev.* 99 (6), 120–131.
- Kaplan, R.S., Ramanna, K., Roston, M., 2023. Accounting for carbon offsets—establishing the foundation for carbon-trading markets. *Harv. Bus. Rev.*
- Li, S., Siu, Y.W., Zhao, G., 2021. Driving factors of CO2 emissions: further study based on machine learning. *Front. Environ. Sci.* 9, 721517.
- Luo, L., 2019. The influence of institutional contexts on the relationship between voluntary carbon disclosure and carbon emission performance. *Account. Financ.* 59 (2), 1235–1264.
- Luo, L., Tang, Q., 2016. Determinants of the quality of corporate carbon management systems: an international study. *Int. J. Account.* 51 (2), 275–305.
- Matten, D., Moon, J., 2020. Reflections on the 2018 decade award: the meaning and dynamics of corporate social responsibility. *Acad. Manag. Rev.* 45 (1), 7–28.
- Meng, X., Gou, D., Chen, L., 2023. The relationship between carbon performance and financial performance: evidence from China. *Environ. Sci. Pollut. Res.* 30 (13), 38269–38281.
- Michaelowa, K., Namhata, C., Michaelowa, A., Sacherer, A.K., 2022. Climate finance as development aid. *Handb. Int. Clim. Financ.* 62–82.
- Moufry, S., Al-Najjar, B., Ibrahim, A., 2024. Communications of sustainability practices in the banking sector: evidence from cross-country analysis. *Int. J. Financ. Econ.* 29 (1), 135–161.
- Niranjana, A., 2023. 'Era of global boiling has arrived,' says UN chief as July set to be hottest month on record. *Guardian*, 27 July 2023.
- Nishitani, K., Jannah, N., Kaneko, S., 2017. Does corporate environmental performance enhance financial performance? An empirical study of Indonesian firms. *Environ. Dev.* 23, 10–21.
- Palea, V., Drogo, F., 2020. Carbon emissions and the cost of debt in the eurozone: the role of public policies, climate-related disclosure and corporate governance. *Bus. Strategy Environ.* 29 (8), 2953–2972.
- Palea, V., Santhia, C., 2022. The financial impact of carbon risk and mitigation strategies: insights from the automotive industry. *J. Clean. Prod.* 344, 131001.
- Pan, J., Hunjra, A.I., Bruna, M.G., Zhao, S., Bourri, E., 2024. Shaping sustainability: how corporate reputation can be enhanced under climate change conditions. *Financ. Res. Lett.* 62, 105174.
- Peterson, T., 2022. Utility environmental commitments and shareholder performance. *J. Sustain. Financ. Invest.* 1–15.
- Qian, W., Suryani, A.W., Xing, K., 2020. Does carbon performance matter to market returns during climate policy changes? Evidence from Australia. *J. Clean. Prod.* 259, 121040.
- Rokhmawati, A., Gunardi, A., Rossi, M., 2017. How powerful is your customers' reaction to carbon performance? Linking carbon and firm financial performance. *Int. J. Energy Econ. Policy* 7 (6), 85.
- Scott, W.R., 1995. *Institutions and Organizations*. Sage Publications.
- Shrestha, P., Choi, B., Luo, L., 2023. Carbon management system quality and corporate financial performance. *Int. J. Account.* 58 (01), 2350001.
- Siddique, M.A., Akhtaruzzaman, M., Rashid, A., Hammami, H., 2021. Carbon disclosure, carbon performance and financial performance: international evidence. *Int. Rev. Financ. Anal.* 75, 101734.
- Sitompul, M., Suroso, A.I., Sumarwan, U., Zulfainarni, N., 2023. Revisiting the impact of corporate carbon management strategies on corporate financial performance: a systematic literature review. *Economies* 11 (6), 171.
- Slawinski, N., Bansal, P., 2009. Short on time: the role of time in business sustainability. In: *Academy of Management Proceedings*, 2009. Academy of Management, Briarcliff Manor, NY, pp. 1–6 (August).
- Smelser, N.J., Baltes, P.B. (Eds.), 2001. *International Encyclopedia of the Social & Behavioral Sciences*, 11. Elsevier, Amsterdam.
- Suchman, M.C., 1995. Managing legitimacy: strategic and institutional approaches. *Acad. Manag. Rev.* 20 (3), 571–610.
- Tahat, Y.A., Mardini, G.H., 2021. Corporate carbon disclosure, carbon performance and corporate firm performance. *Int. J. Sustain. Econ.* 13 (3), 219–235.
- Trouwloot, D., Streck, C., Chagas, T., Martinus, G., 2023. Understanding the use of carbon credits by companies: a review of the defining elements of corporate climate claims. *Glob. Chall.* 7 (4), 2200158.
- Tuesta, N.Y., Crespo Soler, C., Ripoll Feliu, V., 2020. The influence of carbon management on the financial performance of European companies. *Sustainability* 12 (12), 4951.
- Tuesta, N.Y., Crespo Soler, C., Ripoll Feliu, V., 2021. Carbon management accounting and financial performance: evidence from the European Union emission trading system. *Bus. Strategy Environ.* 30 (2), 1270–1282.
- Wang, Q., 2023. Financial effects of carbon risk and carbon disclosure: a review. *Account. Financ.*
- Wang, Y., Wu, Z., Zhang, G., 2022. Firms and climate change: a review of carbon risk in corporate finance. *Carbon Neutral.* 1 (1), 6.
- Yan, Y., Zhang, X., Zhang, J., Li, K., 2020. Emissions trading system (ETS) implementation and its collaborative governance effects on air pollution: the China story. *Energy Policy* 138, 111282.