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THE RELATIONSHIPS AMONG CARBON DIOXIDE EMISSIONS, ENVIRONMENTAL PRACTICES, AND FINANCIAL PERFORMANCE: INTERNATIONAL EVIDENCE

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The Relationships among Carbon Dioxide Emissions, Environmental Practices, and Financial Performance: International Evidence

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A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

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ABSTRACT

Accelerated global warming and climate change have encouraged a large number of researchers to investigate the relationship between carbon dioxide (CO_2) emissions and financial performance, but their studies have produced mixed findings. Although previous studies have identified factors related to firm characteristics (e.g., materiality industries) and external influence (e.g., consumer awareness) to explain for the mixed findings, they have neglected the significant role of environmental practices in the relationship between CO_2 emissions and financial performance. Firms that generate CO_2 emissions face legitimacy threats and therefore implement environmental practices with the aim to reduce CO_2 emissions. The implementation of environmental practices has the potential of incurring costs as well as real economic gains, thereby affecting the financial performance of firms. It is therefore important to examine environmental practices that are instrumental in addressing CO_2 emissions to achieve financial performance.

Grounded in the legitimacy theory, this study examines whether integrated environmental practices (i.e., the combined practices of emission reduction, resource use, and environmental innovation) and its individual practices - emission reduction practices (i.e., reducing emission in production and operational processes), resource use practices (e.g., reducing the use of materials, energy or water), and environmental innovation practices (e.g., creating new market opportunities via eco-designed products) mediate the relationships between scopes 1, 2 and 3 CO_2 emissions variations (i.e., increase or decrease) and financial performance (i.e., ROA and Tobin's q). These environmental practices are worth investigating as they contribute to global efforts to reduce CO_2 emissions and mitigate climate change. To achieve this objective, panel data are collected from 122 companies in different industries from the Refinitiv Eikon DataStream database. The data are analyzed by using the causal steps approach and bootstrapping method, which help achieve the research objectives and offer empirical evidence to answer the research questions proposed in this study.

The results show that a decrease (an increase) in each scope of CO_2 emission increases (decreases) the performance in implementing integrated environmental practices and emission reduction practices and implementing integrated environmental practices and emission reduction practices increases ROA. Thus, both types of practices have negative mediating effects on the relationships between each scope of CO_2 emission variation and ROA. The findings indicate implementing integrated

environmental practices and emission reduction practices for CO_2 emission reduction is the legitimacy process/activity that reflects the capabilities of firms to address CO_2 emissions. The legitimacy obtained from implementing such practices is considered to be an operational resource, which helps companies reap profitability. Besides, implementing integrated environmental practices and emission reduction practices is not simply a response to regulatory and stakeholder pressures, but also helps companies transform their legitimacy threats into financial benefits (i.e., profitability). However, neither integrated environmental practices nor emission reduction practices mediate the relationships between each scope of CO_2 emission variation and Tobin's q. Resource use practices and environmental innovation practices do not mediate the relationships between each scope of CO_2 emission variation and financial performance.

Based on the above findings, managers can prioritize integrated environmental practices and emission reduction practices into their strategic plans and consider them as the legitimate process/activity and an operational resource to increase profitability. Policymakers could develop target environmental regulations for reducing each scope of CO_2 emission by considering integrated environmental practices and emission reduction practices, to contribute to the goal of limiting the global average temperature increase to within 1.5°C.

Publications

1. **<u>Pan, X</u>**., Wong, C. W., & Li, C. (2022). Circular economy practices in the waste electrical and electronic equipment (WEEE) industry: A systematic review and future research agendas. *Journal of Cleaner Production*, 365, 132671.

2. **<u>Pan, X</u>**., Wong, C. W., Wong, C. Y., Boon-itt, S., & Li, C. (2024). The influences of Circular Economy practices on manufacturing firm's performance: A meta-analytic structural equation modeling study. *International Journal of Production Economics*, 109267.

Conference presentations

<u>Pan, X</u>., Wong, C. W., Wong, C. Y., Boon-itt, S., & Li, C. (2024). The influences of Circular Economy practices on manufacturing firm's performance: A meta-analytic structural equation modeling study. *EurOMA 30th Annual Conference in Leuven, Belgium, July 2023*

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I have imagined several times how I would write the acknowledgment of my thesis, envisioning it as a moment filled with excitement for finally submitting my thesis, or filled with tears as I reflected on the challenges of my four-year Ph.D. journey. Now that the time has come, I find it's hard to put my thoughts into words. There are so many people to thank for and countless memorable moments to recall. I worry about overlooking someone or something important, but I want to express my heartfelt gratitude to those who have supported me throughout my PhD journey.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

C

CO_2 - Carbon Dioxide

CDP - Carbon Disclosure Project

CDLI - Carbon Disclosure Leaders Index

CPLI - Climate Performance Leadership Index

E

EU ETS - European Union emissions trading scheme

EPS - Earing per share

D

GDP - Gross domestic product

GHG - Greenhouse Gas

Gt - Gigatons

I

IPCC - Intergovernmental Panel for Climate Change

M

MENAT - Middle East, North Africa and Turkey

P

Ppm - Parts per million

R

ROA - Return on assets

ROE - Return on equity

ROI - Return on investment

ROIC - Return on invested capital

ROS - Return on sales

RQ - Research question

T

TSR - Total shareholder return

W

WOS - Web of Science

Chapter 1 Introduction

1.1 Contextual background

1.1.1 Global carbon dioxide emissions

Global warming is driven by increases in greenhouse gas (GHG) emissions that result from human activities (Wu et al., 2021). Statistical data indicate that global carbon dioxide (CO_2) emissions resultant from energy combustion and industrial processes have reached a new all-time high of 36.8 gigatons (Gt) in 2022 (IEA, 2023). In addition, the global average atmospheric CO_2 emission has increased from 290.7 parts per million (ppm) in 1880 to 417.06 ppm in 2022, which is approximately 43.7% higher than pre-industrial (1880-1900) levels (EEA, 2019; NOAA, 2023b). The elevated level of CO_2 emission is the primary contributor to the greenhouse effect, which causes a significant increase in the global average surface temperature. As of 2022, the average surface temperature on Earth is 1.06°C higher than it was during the pre-industrial period (NOAA, 2023a). The global rise of the average surface temperature has triggered shifts in climatic conditions, and thus there is greater frequency and intensity of extreme weather and climate events, such as sea-level rising, floods, droughts, wildfires, and extreme heat events (WHO, 2023). The weather and climate events increase the risk of deaths, infectious disease outbreaks, and noncommunicable diseases, which have both direct and indirect impacts on human health (WHO, 2023).

1.1.2 Status of CO_2 emissions across different sectors

The level of carbon emission emitted by different sectors varies as they use different materials and production methods. For example, the power sector emitted 14.65 Gt of CO_2 in 2022, followed by the industrial sector of 9.15 Gt, transportation sector of 7.89 Gt and building sector of 2.79 Gt (IEA, 2023). Industrial emissions have risen by 70% since 2000 as a result of the increase in global demand for commodities (IEA, 2023). In particular, the fashion industry is one of the most polluting industries globally. Over the past two decades, there has been a substantial increase in textile production and consumption, with production doubling between 2000 and 2014 (Fraser et al., 2023). This trend is due to the emergence of fast fashion, which operates on a business model that offers consumers low-priced and stylish products (Niinimäki et al., 2020). Fast fashion manufacturers produce high volumes of inexpensive clothing which increases consumer spending. As a result, approximately 8-10% of global CO_2 emissions (i.e., roughly 4-5 billion tonnes annually) are generated from the fashion industry (Niinimäki et al., 2020). Specifically, more than 70% of CO_2 emissions are attributed to upstream activities, such as production, preparation, and processing of energy-intensive raw materials; the other 30% of CO_2 emissions are associated with downstream activities, such as packaging, transport, and retail operations (Achi Berg et al., 2020). Without further measures beyond the actions that are already implemented to reduce CO_2 emissions, it is estimated that CO_2 emissions generated from the fashion industry will increase to around 2.7 billion tonnes by 2030 (Achim Berg et al., 2020).

1.1.3 Global CO_2 emission agreements and initiatives

In response to the challenges of CO_2 emission mentioned above, the effective solution is to reduce CO_2 emission levels close to the pre-industrial level as CO_2 emission accounts for a significant portion of GHG emission, which is one of the primary contributors to global warming and climate change. Several significant international agreements and schemes have been enacted to address CO_2 emissions and mitigate the pace of global warming. For example, an international treaty called the Kyoto Protocol was enacted in 1997 to limit and reduce CO_2 emissions. In 2005, the European Union Emissions Trading Scheme (EU ETS) was launched for emission allowance trading, which aimed to promote cost-effective and economically efficient reductions in CO_2 emissions. In 2015, the Paris Agreement set a goal to limit the increase in the global average temperature to well below 2°C above pre-industrial levels and make an effort to limit the increase to within 1.5°C (UN, 2023). In addition, the Intergovernmental Panel for Climate Change (IPCC) suggested that exceeding the 1.5°C threshold would trigger more pronounced climate changes, which would lead to more frequent and severe droughts and rainfall (UN, 2023). To address this, the 27th United Nations Climate Change Conference in November 2022 emphasized that limiting the increase of global average temperature to 1.5°C requires global CO_2 emission to peak before 2025 at the latest and subsequently decreased by 43% by 2030 (United Nations Climate Change, 2022). Companies play a dual role, serving as both major contributors to CO_2 emission and essential entities of the global efforts to mitigate CO_2 emission. The pressures of these agreements and initiatives compel companies to actively engage in reducing their

CO_2 emissions.

1.1.4 Demand for environmental information

Aside from the mentioned regulatory measures, companies face pressure from their stakeholders (e.g., investors). Specifically, stakeholders pressure companies to disclose environmental information (He et al., 2013) related to their CO_2 emissions. A number of initiatives (e.g., Carbon Disclosure Project) are leveraging the influence of institutional investors to demand the disclosure of environmental information as a supplement to traditional financial systems (He et al., 2013). As most environmental information is self-reported by companies, coupled with the absence of regulatory requirements or procedures to verify the disclosed environmental information, there is little reason for the stakeholders to believe the disclosed information (Minutolo et al., 2019). For example, some companies may be diligent in reporting, governance, and using environmental performance systems, but they contribute significantly to pollution and emissions (Delmas et al., 2013; Misani & Pogutz, 2015). Some companies may prioritize changing perceptions of their stakeholders over making actual efforts to minimize environmental damage (Aerts & Cormier, 2009; Luo & Tang, 2014). The situation raises concerns about the credibility of the environmental information provided by companies.

In light of these concerns, various third-party providers have emerged, such as Refinitiv (formerly known as Thomson Reuters) and Bloomberg which specialize in reports and ratings. They have developed their own proprietary metrics and assessment methodology to evaluate the extent of disclosure or environmental performance and practices of companies (Minutolo et al., 2019). The evaluation is ultimately presented as an environmental score (e.g., environmental pillar score), which is a tool that has an important role in assisting various stakeholders to assess the sustainability and risk profile of companies. Specifically, environmental scores reflect environmental practices, which allow investors to compare environmental performances based on the different environmental practices in different companies, evaluate their current portfolios and investments related to the environment, estimate the cost of pollution control, and evaluate the future prospects of such companies (Giannarakis et al., 2017a), and thus give them guidance to make informed investment decisions that align with both ethical behaviors and financial objectives. Companies that are transparent about their environmental practices can better meet the expectations of their stakeholders around their corporate responsibilities (Giannarakis et al., 2017b), which then increases loyalty and satisfaction of consumers, attracts investment interests, and enhances their corporate reputation and brand image, thus ultimately improving their financial performance.

1.1.5 Current issues of CO_2 emission

Even though there is regulatory and stakeholder pressure on companies, the world is currently not on track to maintain a global temperature increase that falls within 1.5°C, with the current plan by countries would lead to a global CO_2 emission increase of roughly 11% by 2030 (United Nations Climate Change, 2022). This indicates that the current endeavors of companies to reduce CO_2 emission have been insufficient to reach the predefined emission reduction target that aimed at limiting global average temperature within 1.5°C. The inability to meet these targets could be that some companies are taking minimal steps to reduce CO_2 emissions, with the aim to only receive positive press coverage or enhance their corporate reputation. This suggests that companies lack the motivation to implement more extensive environmental practices to mitigate CO_2 emissions. While implementing environmental practices can help companies reduce CO_2 emissions, the resulting environmental costs or financial returns are also important aspects that managers and investors take into account. Therefore, investigating the reasons why companies are reluctant to adopt more extensive environmental practices would show why current efforts in reducing CO_2 emissions cannot meet the predefined emission reduction target.

Given that the ultimate goal of companies is to maximize profit, determining the financial benefits of reducing CO_2 emissions is the utmost concern of managers. In addition, shareholders or stakeholders of companies expect their companies to be more concerned with how global warming is associated with their operational emissions (Mahapatra et al., 2021), while still maintaining good financial performance. Thus, research work that has primarily focused on examining the relationship between CO_2 emission and financial performance has produced mixed findings. However, some scholars have neglected the essential role of environmental practices, which may affect both CO_2 emission and financial performance (see *Section 1.2.2.1*).

The following section will present studies that have shown inconsistent findings on the relationship between CO_2 emission and financial performance.

1.2 Conceptual background

1.2.1 Inconsistent findings: relationship between CO_2 emission and financial performance

Studies on the effects of CO_2 emission on financial performance have attracted more attention in recent years. Previous studies have produced mixed findings on the relationship between CO_2 emission and financial performance. Studies have found that firms that reduce their CO_2 emission have better financial performance in terms of return on assets (ROA), return on investment (ROI), return on invested capital (ROIC) (Iwata & Okada, 2011), return on equity (ROE), return on sales (ROS) (Van Emous et al., 2021), earning per share (EPS), and Tobin's q (Adu et al., 2023), and reduce the cost of equity capital (Kim et al., 2015). The positive relationship between CO_2 emission reduction and financial performance motivates firms to reduce their CO_2 emissions, thus contributing to mitigating climate change. However, some studies also find that firms that reduce their CO_2 emissions have a lower ROA (Busch et al., 2022; Delmas et al., 2015) and Tobin's q (Busch et al., 2022; Wang et al., 2014), while others find that CO_2 emission reduction has no relationship with ROA (Gallego-Alvarez et al., 2015), ROE, ROS, and Tobin's q (Iwata & Okada, 2011).

1.2.2 Issues in extant research

1.2.2.1 Mediating role of environmental practices

The mixed findings on the relationship between CO_2 emission and financial performance suggest the performance impacts of CO_2 emission are influenced by other factors. These include corporate growth rate (Ganda, 2018), environmental certification (Tuesta et al., 2020), materiality industries, regional specificities (Ferrat, 2021), pay incentives (Adu et al., 2023), board independence (Kim et al., 2023), and consumer awareness (Sun et al., 2023). These factors are related to the context of the company (e.g., materiality industries, regional specificities), internal attributes (e.g., corporate growth rate, board independence), external recognition (e.g., environmental certification), and external stimuli (e.g., pay incentives, consumer awareness), which provide different insights into explaining the inconsistent findings on the relationship between CO_2 emission and financial performance. However, these factors are primarily focused on firm characteristics or external influence. In reality, the environmental practices of companies play a significant role in the relationship between CO_2 emission and financial performance. Specifically, companies that emit CO_2 will face increased compliance costs, greater risks associated with penalties, fines, and reputation damage, heightened regulatory scrutiny, and growing concerns from stakeholders about their carbon footprint, which are all legitimacy threats. Thus, companies will adopt environmental practices with the aim to reduce their CO_2 emission in response to these threats. The implementation of environmental practices will affect firms' financial performance. As Hart (1995) stated, implementing environmental practices (e.g., reducing material or energy consumption) can help companies reduce compliance and liability costs, and save on costs by reducing the use of energy or materials, and enhance corporate reputation, which will in turn enhance cash flow and profitability, and consequently, improve financial performance. However, environmental practices will also incur environmental expenses, such as green design practices (Tang et al., 2022), which will have a negative impact on financial performance. Based on the above discussion, it can be said that CO_2 emission affects financial performance through environmental practices, which suggests that environmental practices act as mediators[1] in the relationship between CO_2 emission and financial performance.

This study examines the integrated environmental practices and their individual environmental practices (i.e., emission reduction, resource use, and environmental innovation practices). These environmental practices contribute to CO_2 emission

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[1] The variables can be considered as mediators to the extent that they explain the relationships between the independent variables (X) and dependent variables (Y) (Baron & Kenny, 1986). In addition, the variables function as mediators when they meet the three following conditions (Baron & Kenny, 1986): i) the changes in the level of X significantly explain for the changes in the presumed mediating variable (i.e., path a); ii) the changes in the mediating variable significantly explain for the changes in Y (i.e., path b); and iii) a previous significant relationship between X and Y becomes insignificant when paths a and b are controlled, with the direct effect of X on Y (i.e., path c') being zero demonstrating the strongest mediation (see Figure 4-1 in *Section 4.6.2*). In this study, it is expected that i) the changes in the level of CO_2 emission significantly explain for the changes in environmental practices (i.e., path a_1); ii) the changes in environmental practices significantly explain for the changes in financial performance (i.e., path b_1); iii) the significant relationship between CO_2 emission and financial performance becomes insignificant when a_1 and b_1 are controlled, with the direct effect of CO_2 emission on financial performance being zero thus showing the strongest mediation effects of environmental practices.

reduction while affecting financial performance. They are adopted by companies to tackle environmental issues (e.g., CO_2 emissions) along their supply or value chain, and are worth examining as they have the potential to achieve emission reduction targets and combat climate change. Specifically, emission reduction practices include environmental practices of reducing environmental emissions (e.g., CO_2 emissions) during production and operational processes (Refinitiv Eikon, 2023). Resource use practices include environmental practices, including reducing the use of materials, energy, or water, and enhancing eco-friendly solutions by improving supply chain management (Refinitiv Eikon, 2023). Environmental innovation practices include environmental practices, including reducing the environmental costs and burdens for its customers and utilizing innovative environmental technologies and processes or eco-designed products to create new market opportunities (Refinitiv Eikon, 2023). The integrated environmental practices involve combined practices in terms of emission reduction, resource use, and environmental innovation practices (Refinitiv Eikon, 2023).

Based on the above discussion, companies that generate CO_2 emissions may adopt integrated environmental practices and their individual environmental practices with the aim to reduce CO_2 emissions. The implementation of these practices has the potential of incurring costs as well as real economic gains, thus affecting financial performance. Thus, CO_2 emission affects financial performance through integrated environmental practices and their individual environmental practices, which suggests that these practices may act as mediators in the relationship between CO_2 emissions and financial performance. An investigation of the mediating roles of integrated environmental practices and their individual environmental practices is essential, which would clarify the mechanism through which these environmental practices associate CO_2 emission with financial performance, thereby providing researchers with explanations to understand the mixed findings on the relationship between CO_2 emission and financial performance based on different environmental dimensions, including emission reduction, resource use, and environmental innovation. In addition, investigating both integrated environmental practices and their individual environmental practices can provide insights into the synergized or individual effects of environmental practices on the relationship between CO_2 emission and financial performance. Companies with empirical evidence from the investigation can use the information to determine effective environmental practices that contribute to reducing CO_2 emission while improving their financial performance, optimizing investments and resource allocation, and adjusting their environmental strategies to maximize both environmental and financial benefits, thus contributing to strategic decisions. Moreover, policymakers can develop targeted environmental regulations to address CO_2 emissions or design financial incentives (e.g., subsidies) to encourage companies to adopt environmental practices that aim to reduce CO_2 emissions. Thus, it is necessary to examine whether integrated environmental practices and their individual environmental practices have mediating roles in the relationships between CO_2 emission and financial performance, which is the primary objective of this study.

1.2.2.2 Importance of examining Scope 1, 2 and 3 CO_2 emissions

Guided by the primary objective of this study, a review of the literature shows that previous studies have mainly examined the relationships between CO_2 emission and financial performance based on scope 1 CO_2 emission (Desai et al., 2022), total carbon emission (i.e., the sum of scopes 1 and 2) (Palea & Santhia, 2022) and total carbon emission (i.e., the sum of scopes 1, 2 and 3) (Busch et al., 2022). However, they have ignored that CO_2 emission originates from different sources. Specifically, CO_2 emission stems from on-site and internal operations (direct emission), and off-site and external operations, encompassing both upstream and downstream activities of the companies' supply chains (indirect emission). To facilitate efficient management of GHG[2], the World Resources Institute and World Business Council for Sustainable Development developed the Greenhouse Gas Protocol (GHG Protocol) to categorize CO_2 emissions of companies into three different scopes (i.e., scopes 1, 2, and 3). Scope 1 CO_2 emission is the direct emission generated from sources that are owned or managed by the company. Scope 2 is the indirect emission generated from purchased electricity, heat, and/or steam consumed by the company. Scope 3 encompasses other indirect emissions from sources that are not owned or managed by the company, which occur in the upstream and downstream of its supply chain, such as the transport of purchased fuels or utilization of sold products and services, which are often greater than the combined emission of the two other scopes. The GHG Protocol is a widely acknowledged framework for CO_2 emission categorization and is used by companies to comprehensively establish

[2] CO_2 emissions are the primary source of GHG emissions, and account for approximately three-quarters of total GHG emissions. Thus, this study will refer to scopes 1, 2, and 3 GHG emissions simply as scopes 1, 2, and 3 CO_2 emissions.

operational boundaries for both direct (i.e., scope 1 CO_2 emission) and indirect emissions (i.e., scope 2, and 3 CO_2 emissions), thus enabling companies to efficiently manage the risks associated with CO_2 emission (e.g., compliance or reputation risks) and opportunities (e.g., lowering operational costs) throughout the value chain. Therefore, differentiating among scopes 1, 2, and 3 CO_2 emissions could help companies to better manage their CO_2 emission, thus contributing to climate change mitigation efforts. Additionally, all three scopes of CO_2 emissions are related to the activities across the value chain, such as extraction, production, and transportation of materials or products. Since business activities are interconnected, their respective CO_2 emissions are also related. For example, companies that manufacture electronic products contribute to scope 1 CO_2 emission through on-site fuel combustion. The production process requires the use of power or heat, which results in scope 2 CO_2 emissions with the consumption of the purchased energy (e.g., electricity). Following the production process, the transport of the electronic products leads to scope 3 CO_2 emissions. Thus, it is crucial to consider scopes 1, 2, and 3 CO_2 emissions and conduct a detailed investigation of CO_2 emissions across all of these scopes.

In practice, the primary objective of the companies is to maximize profits and increase firm value. Companies that attempt to reduce scope 1, 2, and 3 CO_2 emissions use different environmental practices and incur different environmental expenditures, which in turn have different financial impacts on them. Specifically, i) scope 1 CO_2 emission stems from internal operations, such as combustion or chemical production processes (Greenhouse Gas Protocol, 2023). Companies need to invest in cleaner production technologies to reduce the emission, which will be an additional expense; i) scope 2 CO_2 emission is generated from purchased electricity and heat, but companies can choose to switch to renewable energy. However, doing so means that they will pay both capital and operating costs. iii) scope 3 CO_2 emission is generated from CO_2 emissions across a supply or value chain of companies. To tackle this type of emission, companies need to adopt various environmentally friendly practices, such as green sourcing, green packaging, and green logistics, all of which have their associated costs (Greenhouse Gas Protocol, 2023). Therefore, it is important to examine the real financial impacts of addressing scope 1, 2 and 3 CO_2 emissions, because a realistic picture of the costs can encourage companies to adopt specific environmental practices that address each scope of CO_2 emission and develop clear financial performance targets, all of which contribute to reaching the target reductions of each scope of CO_2 emission while having less financial impact.

In sum, the current issues of CO_2 emission and identified research gaps highlight several research issues that are worthy of research attention. The next section presents the research questions that have guided the development of the research objective of this study.

1.3 Research questions

Based on the aforementioned research gaps, the following set of research questions (RQs) have been developed:

RQ1: Do integrated environmental practices in terms of emission reduction, resource use, and environmental innovation, and their individual environmental practices (i.e., emission reduction, resource use, and environmental innovation practices) act as mediators in the relationships between each scope of CO_2 emission (i.e., scope 1, 2, and 3) and financial performance?

To answer RQ1, the following research questions are proposed:

RQ2: What are the performance implications for each scope of CO_2 emission (i.e., scopes 1, 2, and 3)?

RQ3: What are the effects of each scope of CO_2 emission (i.e., scopes 1, 2, and 3) on integrated environmental practices and their individual environmental practices (i.e., emission reduction, resource use, and environmental innovation practices)?

RQ4: What are the performance implications for integrated environmental practices and their individual environmental practices (i.e., emission reduction, resource use, and environmental innovation practices)?

To answer these research questions, the subsequent research objectives are developed to guide the investigation.

1.4 Research objectives

The main objective of this study is to develop and empirically test a theoretical model that involves the relationships among CO_2 emission, environmental practices, and financial performance based on the legitimacy theory (Suchman, 1995), which states that there is a social contract between businesses or organizations and society. The legitimacy of businesses or organizations to operate in a community depends on whether they respect the expectations and rules of the community. That is, social approval is needed for a company to operate within the community. The legitimacy theory is the most applicable concept to explain the practical observations of the relationships among CO_2 emissions, environmental practices, and financial performance. Specifically, companies that generate CO_2 emissions face legitimacy threats. That is, CO_2 emission negatively affects the community, and thus the community views the companies as socially irresponsible and prohibits them from accessing resources and functioning in the community. Therefore, these companies must adopt environmental practices to mitigate emission threats and ensure their survival in the community. The implementation of environmental practices is a process to seek legitimacy, and the legitimacy obtained is considered to be an operational resource, which helps companies achieve their financial goals (Suchman, 1995) (see details in *Section 3.2.1*). Besides, the legitimacy theory is applicable to explaining the social or moral dimensions of the role of companies in society (Haque & Ntim, 2020). In this study, implementing environmental practices for CO_2 emission reduction is considered as a legitimate action that reflects the social and moral responsibility of a company. Guided by the main research objective, the following specific research objectives are proposed:

Research Objective 1: to empirically explore whether integrated environmental practices and their individual environmental practices (i.e., emission reduction, resource use, and environmental innovation practices) act as mediators in the relationship between each scope of CO_2 emission (i.e., scopes 1, 2, and 3) and financial performance in terms of ROA and Tobin’s q.

To achieve *Research Objective 1*, the following research objectives are developed:

Research Objective 2: to empirically examine the effects of each scope of CO_2

emission on financial performance. This investigation is important since it helps companies to differentiate the financial implications derived from CO_2 emissions across different scopes. In addition, the investigation helps companies to optimize their environmental strategies and promote a well-informed decision-making process when allocating resources to address scope 1, 2, and 3 CO_2 emissions while improving financial performance.

Research Objective 3: to empirically examine the effects of each scope of CO_2 emissions on integrated environmental practices and their individual environmental practices (i.e., emission reduction, resource use, and environmental innovation practices). This investigation will help companies to differentiate the effects of each scope of CO_2 emission on environmental practices, thus providing guidance to companies when they customize their environmental strategies accordingly to address each scope of CO_2 emission and optimize their environmental practices.

Research Objective 4: to empirically examine the impacts of integrated environmental practices and their individual environmental practices (i.e., emission reduction, resource use, and environmental innovation practices) on financial performance. The investigation will help companies differentiate between the financial implications of the different environmental practices, which help managers determine effective environmental practices, manage the potential risks associated with environmental fines, penalties, or reputation damage, and ultimately enhance the financial performance of the firm itself.

Based on the formulated research objectives, this study uses quantitative methods because: i) quantitative methods employ a deductive approach to the research process (Mehrad & Zangeneh, 2019), which enables hypothesis testing (McCusker & Gunaydin, 2015). This approach relies on the collection of large volumes of data through the application of standardized methods that include generalized samples, which emphasize statistical information over individual perceptions; ii) using quantitative methods allows researchers to analyze various factors in how they related to one another, helping to reveal causal relationships of these factors relevant to the research question (McCusker & Gunaydin, 2015); iii) quantitative approach aims to answer “how many” or “how much questions rather than the “what, how or why” questions about a phenomenon that answered by qualitative method (McCusker & Gunaydin, 2015). By relying on statistical analysis instead of real-life scenarios, quantitative methods help researchers minimize emotional and subjective biases that are often present in qualitative research (McCusker & Gunaydin, 2015). This ensures data can be analyzed and interpreted through numerical figures, enhancing neutrality and the validity of findings (McCusker & Gunaydin, 2015); iv) the objective of this study is to empirically examine the relationship between CO_2 emissions, environmental practices and financial performance using panel data. Quantitative methods help test hypotheses proposed in Chapter 3 and identify potential causal relationships.

The quantitative methods used in this study are causal steps approach and bootstrapping methods. This study uses causal steps approach as it includes three steps for mediation test, which help us to achieve research objective 1-4. Specifically, i) dependent variable is regressed on independent variable, which test the effects of CO_2 emission on financial performance, achieving research objective 2; ii) mediator regressed on independent variable, which test the effects of CO_2 emission on environmental practices, achieving research objective 3; iii) dependent variable regressed on both independent variable and mediator, which test the effects of environmental practices on financial performance after controlling for the effect of CO_2 emissions, achieving research objective 4. The achieved research objective 2-4 help to achieve research objective 1. Moreover, this study uses the bootstrapping method as the supplementary method of the causal steps approach (Hayes, 2009) because it employs the resampling technique that used to test the indirect effects of a mediation model, and is one of the more valid and powerful methods to test the mediating effects (MacKinnon et al., 2004; Preacher & Hayes, 2008; Zhao et al., 2010), which can enhance the statistical power of the analysis.

1.5 Research contributions

The research contribution of this thesis is three-fold:

Firstly, this study is, to the best of the knowledge of the author, the first of its kind to investigate the relationships among CO_2 emission, environmental practices, and financial performance in a single model. The investigation i) explains the mixed findings on the relationship between CO_2 emission and financial performance by showing the mechanisms of environmental practices based on different environmental dimensions, including emission reduction, resource use and environmental innovation; ii) provides insights into the synergized and individual effects of environmental practices on the relationships between each scope of CO_2 emission and financial performance, which inform companies on allocating resources and adjusting their environmental strategies to maximize their carbon performance and financial outcomes; iii) sheds light on the pathway among CO_2 emission, environmental practices, and financial performance, which offers insights which companies can use to enhance their profitability by managing their CO_2 emission through environmental practices; and iv) provides explanations of why companies lack motivation to implement more extensive environmental practices to reduce their CO_2 emissions.

Secondly, this study adds value to the existing literature by examining CO_2 emission across the three different scopes. Specifically, this study distinguishes the impacts of scopes 1, 2, and 3 CO_2 emissions on environmental practices, as well as the financial implications of each scope of CO_2 emissions. The empirical evidence helps companies to determine effective environmental practices that correspond to each scope of CO_2 emissions while improving their financial performance. Besides, the findings help companies to make well-informed decisions, be more focused on addressing each scope of CO_2 emission, avoid financial losses, and strategically position themselves in a competitive and sustainable business environment.

Thirdly, this study contributes to existing literature by distinguishing the financial impacts of integrated environmental practices and their individual environmental practices (i.e., emission reduction, resource use and environmental innovation practices). The investigation advances the legitimacy theory by providing nuanced perspectives on the synergized and individual effects of environmental practices on financial performance. Specifically, integrated environmental practices and emission reduction practices improve operational efficiency-aligning with stakeholders' expectation for compliance and cost efficiency, but they fail to increase firm value, indicating a disconnection between internal legitimacy gains and external investor's perception of long-term value. In contrast, environmental innovation practices increase operational efficiency but decrease firm value, suggesting that markets may interpret environmental innovation-driven legitimacy efforts as risky despite their operational benefits. Resource use practices have no significant financial impact. These findings indicate that the financial returns derived from obtained legitimacy depend on how stakeholders interpret specific environmental actions, thereby this study advance legitimacy theory through different environmental dimensions and stakeholder-contingent framework.

1.6 Structure of dissertation

This thesis is structured into seven chapters (see Figure 1-1). Specifically, Chapter 1 provides the research background, motivation, questions, objectives, and contributions of this study. Chapter 2 is a systematic literature review that focuses on the relationship between "CO_2 emission and financial performance", "CO_2 emission and environmental practices", and "environmental practices and financial performance". In Chapter 3, the theoretical foundation, research hypotheses, and theoretical framework of this study are presented. Chapter 4 elaborates on the research methodology, including the data sources, data collection process, econometric models, and analysis methods. In Chapter 5 the results of the analysis and robustness check are presented. Chapter 6 discusses and summarizes the findings of this study. In Chapter 7, both the academic and managerial implications are discussed, future research directions are proposed, the research limitations are discussed, and a conclusive summary of this study is provided.

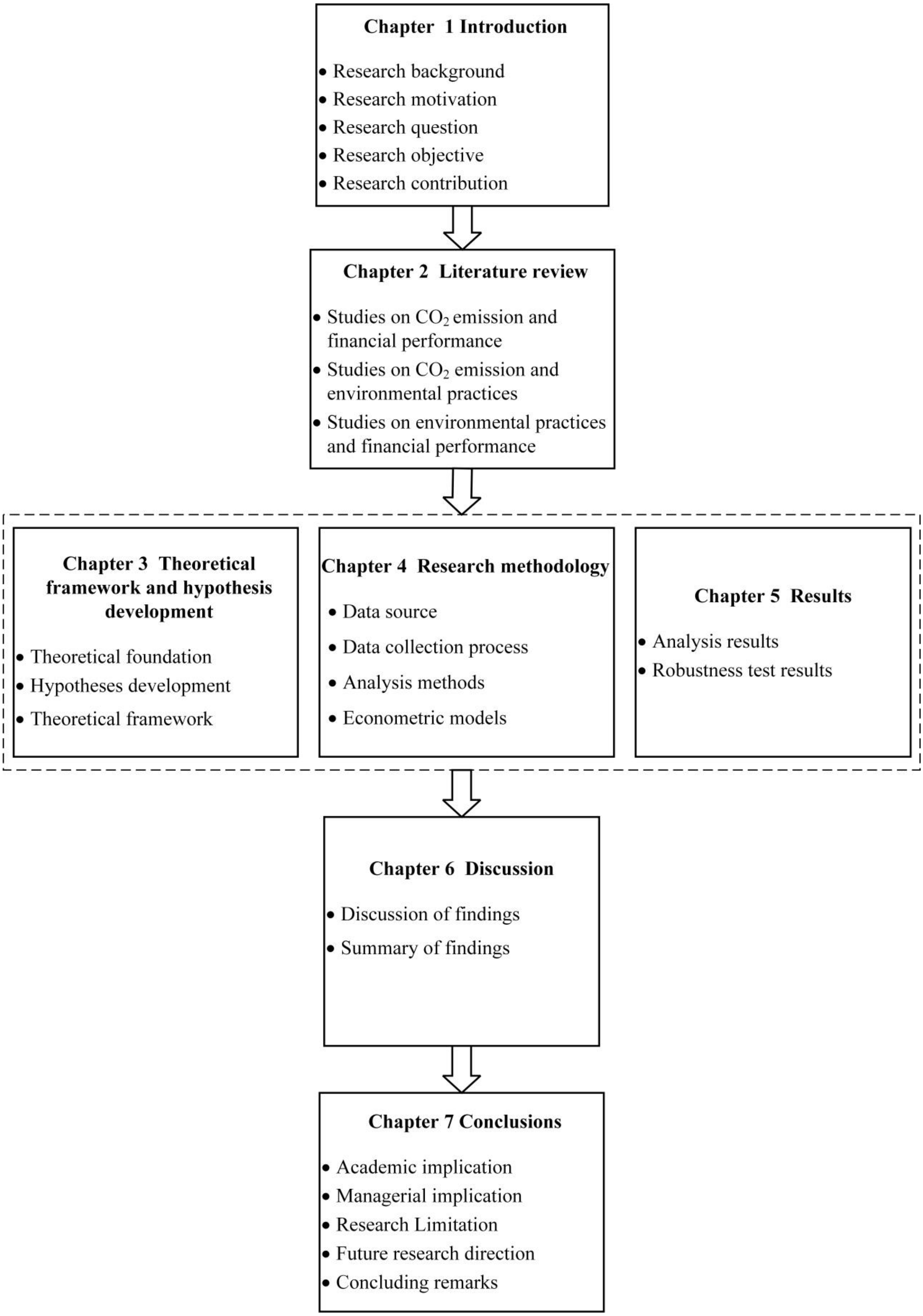

Figure 1-1. Structure of Dissertation

Chapter 2 Literature review

2.1 Introduction

A systematic literature review on the relationships among CO_2 emission, environment practices and financial performance is provided in this chapter. In addition, citation network analysis (CNA) is used to cluster the sample articles and identify research domains. After that, the main path analysis (MPA) is used to capture the important junctures for the historical development of the research domains. As few studies have examined the relationship between CO_2 emission and environmental practices, citation network and main path analyses are not appropriate for analyzing the studies on this relationship. Thus, studies on CO_2 emission and environmental practices are systematically reviewed based on manually collected articles. Finally, the existing literature on CO_2 emission, environment practices, and financial performance is synthesized to identify research gaps, which provides a roadmap for further exploration and research work. The details are discussed in the following sections.

2.2 Methodology

A three-phases method is used to conduct a systematic literature review (Tranfield et al., 2003), including i) planning the review; ii) conducting the review; iii) reporting and disseminating the results. The method helps to gather, synthesize, and evaluate the findings of previous studies in a systematic manner and reduce bias through a comprehensive literature search.

2.2.1 Planning the review

Preliminary research. First, CO_2 emission, environmental practices, and financial performance were identified as areas of interest. Second, a preliminary literature search was conducted and the information available on the published studies assessed in the target topic area to ensure the feasibility of this study (Boland et al., 2017). Third, the literature on CO_2 emission, environmental practices, and financial performance was reviewed to identify research gaps and propose the research questions, as well as ensure the novelty of this study (Ridley, 2012). After the preliminary work, the research topic was finalized to focus on CO_2 emission, environmental practices, and financial performance. To ensure a comprehensive literature search, we divided the process of the literature search was done in three parts because previous studies have separately examined the relationships between "CO_2 emission and financial performance", "environmental practices and financial performance", and "CO_2 emission and environmental practices".

Keyword identification. To ensure that the selected studies are relevant, two criteria were put into place. First, keywords used in previous studies on the three concerned topics "CO_2 emission and financial performance", "environmental practices and financial performance", and "CO_2 emission and environmental practices" were identified. Second, synonyms of the three terms: "CO_2 emission", "environmental practices", and "financial performance" were identified to avoid missing relevant articles and ensure the integrity and comprehensiveness of this study. Three sets of keywords were identified: i) CO_2 emission-related keywords: "carbon emission", "CO_2 emission", "greenhouse gas emission" , "GHG emission" , "carbon performance", and "GHG performance"; ii) environmental practices-related keywords: "Environmental social and governance performance", "ESG performance", "Environmental social and governance score", "ESG score", "environmental pillar score", "E pillar", "E pillar score", "Environmental social and governance disclosure", "ESG disclosure", "Environmental social and governance ratings", and "ESG ratings"; and iii) financial performance-related keywords: "performance", "firm performance", "financial performance", "corporate performance", "business performance", "outcome", "consequence", "benefit", "effect", "return", "profit", "turnover", "revenue", "firm value", "growth", "sales", and "market share".

With regard to CO_2 emission, the keywords "carbon performance" and "GHG performance" were used because previous studies measured "carbon performance" and "GHG performance" based on CO_2 emissions (Lewandowski, 2017). Besides, previous review studies (Galama & Scholtens, 2021) used "carbon performance" and "GHG performance" to examine the relationships between GHG emissions and financial performance. Thus, "carbon performance" and "GHG performance" were included in the CO_2 emission-related keyword list to avoid missing relevant studies that examine the effects of CO_2 emission on financial performance.

For "environmental practices", the keywords "Environmental social and governance score", "ESG score" were used because environmental score is the component score of the ESG score, which reflect the environmental practices of companies, such as energy consumption, waste management, environmental pollution, and conservation of natural resources (Alareeni & Hamdan, 2020). Similarly, the keywords "E pillar" and "E pillar score" were used because they are alternative phrases for "environmental (pillar) score". Based on this, the keywords "Environmental social and governance performance" and "ESG performance" are used because previous studies examine environmental, social and governance (ESG) performance by examining this framework in terms of environmental, social and governance performances, in which environmental performance is measured by using the environmental (pillar) score (Velte, 2017) that reflect environmental practices, such as emission reduction, resource use and environmental innovation (Miralles-Quiros et al., 2019). The keywords "Environmental social and governance disclosure" and "ESG disclosure" were included in the environmental practices related keyword list since previous studies examined ESG disclosure by using the ESG disclosure score and its component score-environmental disclosure score as proxies (Gholami et al., 2022), which reflect the environmental practices. "Environmental social and governance ratings" and "ESG ratings" were included in the environmental practices related keyword list because ESG ratings include environmental rating, which is measured by the environmental score that reflects environmental practices, such as energy and climate changes and resource management (Sandberg et al., 2023). Therefore, the above discussed keywords were incorporated in the environmental related keyword list to avoid missing relevant studies.

2.2.2 Conducting the review

Search criteria. First, journals that focus on the fields of "Business", "Business Finance", "Environment Studies", "Environment Science", "Management", and "Operation Research & Management Science" were searched to ensure that the studies are relevant to this study. Second, the time window of the literature search was set from 1997 to 2023. Third, the studies were limited to those published in English.

Literature search. The literature search was conducted by using the Web of Science (WoS) database for the following reasons: first, the WoS database is the most recognized academic database and has been globally used to measure academic performance (Zhang et al., 2019). Second, the WoS database is the oldest citation database and has a wide coverage with citation and bibliographic data that date back to 1990 (Chadegani et al., 2013). Third, the WoS database is provided by Thomson Reuters (ISI), in which articles are published in journals indexed in the Science Citation Index Expanded, Social Sciences Citation Index, Arts & Humanities Citation Index, and Emerging Source Citation Index, etc. (Chadegani et al., 2013; Clarivate Analytics, 2022). Previous studies suggest that the WoS database is a more scholarly database than Scopus as there are more indexes (Fingerman, 2006). Fourth, in comparison with other databases, such as Scopus, the WoS database retrieves data in a standardized and consistent manner (Falagas et al., 2008). In addition, previous studies have also used the WoS database solely for bibliometric analyses. Therefore, the WoS database is used as the database in this study to conduct the bibliometric analysis (Xu et al., 2022; Zhang et al., 2021).

Two search strings were developed for the identification of studies. First, a search string was developed to search for studies on "CO_2 emission and financial performance": *TS= ("carbon emission" OR "CO_2 emission" OR "greenhouse gas emission" OR "GHG emission" OR "carbon performance" OR "GHG performance") AND TS= ("performance" OR "firm performance" OR "financial performance" OR "corporate performance" OR "business performance" OR "outcome" OR "consequence" OR "benefit" OR "effect" OR "return" OR "profit*" OR "turnover" OR "revenue" OR "firm value" OR "growth" OR "sales" OR "market share").* In total, 8,983 studies were obtained on CO_2 emission and financial performance . Second, a search string was developed to search for studies on "environmental practices and financial performance": *TS=("Environmental social and governance score" OR "ESG score" OR "environmental pillar score" OR "E pillar" OR "E pillar score" OR "Environmental social and governance performance" OR "ESG performance" OR "Environmental social and governance disclosure" OR "ESG disclosure" OR "Environmental social and governance ratings" OR "ESG ratings") AND TS= ("performance" OR "firm performance" OR "financial performance" OR "corporate performance" OR "business performance" OR "outcome" OR "consequence" OR "benefit" OR "effect" OR "return" OR "profit*" OR "turnover" OR "revenue" OR "firm value" OR "growth" OR "sales" OR "market share").* In total, 881 studies were found on environmental practices and financial performance.

To identify studies on CO_2 emission and environmental practices, CO_2 emission and environmental practices related keywords were combined to develop a search string to search for the relevant studies: *TS= ("carbon emission" OR "CO_2 emission" OR* *"greenhouse gas emission" OR "GHG emission" OR "carbon performance" OR "GHG performance") AND TS=("Environmental social and governance score" OR "ESG score" OR "environmental pillar score" OR "E pillar" OR "E pillar score" OR "Environmental social and governance performance" OR "ESG performance" OR "Environmental social and governance disclosure" OR "ESG disclosure" OR "Environmental social and governance ratings" OR "ESG ratings")*. In total, 19 studies were identified on CO_2 emission and environmental practices.

Quality assessment and screening. The inclusion and exclusion criteria were established to assess and screen out studies. Studies were included if they i) examined the relationships between "CO_2/GHG emission and financial performance", "environmental practices and financial performance", and "CO_2/GHG emission and environmental practices", and ii) were published in peer-reviewed journals. In the exclusion process, the title, abstract and full text of the collected studies were read to exclude non-relevant articles. For example, studies that examined the implementation and feasibility of community organic waste composting were excluded. Finally, 53 studies were obtained on the relationship between CO_2 emission and financial performance, and 77 studies on environmental practices and financial performance. No studies were found on CO_2 emission and environmental practices after reviewing the title, abstract and full text of the collected 19 studies. Attempts were made to combine CO_2 emission and environmental practices related keywords in the keyword list and develop different search strings, but no studies were found by using these search strings. Thus, studies that investigated the relationship between CO_2 emission and environmental practices were manually collected and 10 studies were subsequently identified on CO_2 emission and environmental practices.

Data synthesis and analysis. The collected studies were used to conduct a CNA. For the relationship between CO_2 emission and financial performance, 1 cluster and scattered clusters were obtained; For the relationship between environmental practices and financial performance, 1 cluster and scattered clusters were obtained. Using clustering results, the studies in each cluster were reviewed to identify the topics and assign the themes of each cluster. After that, the MPA was used to capture significant paths from the identified clusters.

2.3 Data analysis

The CNA was employed to systematically map the research domains, track the developments, and facilitate the dissemination of the knowledge in an objective manner. After obtaining the research domains, the MPA was used to capture the important moments in the historical progression of the research domains. The details are discussed in the following sections.

2.3.1 Classification of research domains

CitNetExplorer software was used to cluster the collected papers on the relationship between "CO_2 emission and financial performance", and "environmental practices and financial performance".

The clustering was based on the citation relations among publications (Van Eck & Waltman, 2014). In a citation network, publications assigned to the same cluster are more likely to be closely related. Therefore, a cluster can be regarded as the representation of a research topic in scientific literature (Van Eck & Waltman, 2014). CitNetExplorer uses a type of modularity-based clustering that has been widely used in previous studies (Van Eck & Waltman, 2014; Waltman & Van Eck, 2012).

2.3.2 Main path analysis

Following previous studies (Cai & Lo, 2020; Fan et al., 2014; Pan et al., 2022), Pajek software version 5.18 was employed to conduct the MPA. Pajek is a visualization tool, which has been widely used in research fields such as chemistry, genomics, and biomedical (Batagelj & Mrvar, 2004) and for social network analysis. In Pajek, large networks are recursively decomposed into smaller ones (Batagelj & Mrvar, 2004). In addition, MPA is the network analysis technique used in Pajek, which helps to identify the most representative subnetworks by weighing networks based on the importance of network nodes (Barbieri et al., 2016). The MPA offers the following advantages: i) identifying the most relevant papers across different time points; ii) highlighting that the studies are based on prior studies, thus serving as authoritative references for subsequent works; and iii) capturing the essential junctures in the historical development of the research domains (Colicchia & Strozzi, 2012). However, studies without citation relations with the main publications would not appear in the main path (Colicchia & Strozzi, 2012).

2.4 Analysis results

2.4.1 Descriptive analysis

Tables 2-1 to 2-3 show the descriptive analysis results for the number of studies distributed by “publication year”, “research areas”, “published journals”, and “country of origin”.

Table 2-1 shows that the number of published studies on the relationship between CO_2 emission and financial performance is less than or equal to 3 from 2012 to 2019. After 2019, the number of studies started to increase. For example, between 2019 and 2020, the published studies are increased from 3 to 8. Then the number of published papers increased to 11 in 2021, which is the highest number of publications for all years of interest in this study. The increase in the number of studies from 2019 to 2023 is probably in response to the enactment of the Paris Agreement in 2015, with the goal to limit the increase in the global average temperature to well below 2°C above the pre-industrial levels and make an effort to limit the increase to within 1.5°C. As a result, a growing number of companies participated in global efforts to reduce CO_2 emissions, which lead to the increased interest among researchers to explore the relationship between CO_2 emission and financial performance. In terms of research areas, previous studies have focused on “Environmental Sciences”, “Environmental Studies”, and “Business”. With regard to the published journals, the studies on relationship between CO_2 emission and financial performance are mostly published in “Business strategy and the environment”, “Journal of Cleaner Production”, and “Environmental Science and Pollution Research”. As for the country of origin of the publications, the studies are distributed in different geographical regions, including Europe, Asia, and Africa. Most of the studies on CO_2 emission and financial performance are performed in Europe (23), followed by Asia (19) and Africa (3). Therefore, discussions of CO_2 emission and financial performance relationship in other regions are limited.

Table 2-1 Descriptive analysis of studies on relationship between CO_2 emission and financial performance.

Year of publication	No. of articles	Research Areas	No. of articles
2012	3	Environmental Sciences	27
2013	1	Environmental Studies	21
2014	1	Business	15
2015	2	Management	14
2016	1	Green Sustainable Science Technology	13
2017	3	Economics	9
2018	3	Engineering Environmental	9
2019	3	Ecology	3
2020	8	Public Environmental Occupational Health	2
2021	11	Business Finance	1
2022	10	International Relations	1
2023	7	Meteorology Atmospheric Sciences	1
Top 10 Journals		**Top 10 Countries of Origin**	
Business Strategy and the Environment	9	Germany	7
Journal of Cleaner Production	7	China	6
Environmental Science and Pollution Research	5	Spain	6
Sustainability	4	France	4
Ecological Economics	3	Indonesia	4
Journal of Asian Finance Economics and Business	3	India	3
International Journal of Environmental Research and Public Health	2	Italy	3
Journal of Industrial Ecology	2	Scotland	3
Cogent Business Management	1	South Africa	3
E M Ekonomie a Management	1	South Korea	3

Table 2-2 shows that the number of published studies that examine the relationship between environmental practices and financial performance increased from 2019 to 2022, with 2022 having has the highest number of publications (23) for all years of interest in this study. With regard to the research areas, the studies focus on “Environmental Sciences”, “Environmental Studies”, and “Business”. These studies were primarily published in the following journals: “Sustainability”, “Business Strategy and the Environment”, and “Borsa Istanbul Review”, “Cogent Business Management”, and “Finance Research Letters”. As for the country of origin of the study, the studies are performed in different geographical locations: Asia, Europe, and Oceania. Specifically, the most studies are performed in Asia (35), followed by Europe (28) and then Oceania (6). Therefore, there has been limited work done on the relationship between environmental practices and financial performance in other regions.

Table 2-2 Descriptive analysis of studies on relationship between environmental practices and financial performance.

Year of publication	**No. of articles**	**Research Areas**	**No. of articles**
2015	1	Business	25
2018	3	Environmental Studies	25
2019	8	Environmental Sciences	23
2020	8	Business Finance	21
2021	13	Green Sustainable Science Technology	17
2022	23	Management	17
2023	22	Economics	8
		Engineering Environmental	3
		Energy Fuels	1
		Ethics	1
		International Relations	1
		Operations Research Management Science	1
Top 10 Journals		**Top 10 Countries of Origin**	
Sustainability	12	India	13
Business Strategy and the Environment	6	China	11
Borsa Istanbul Review	3	Spain	9
Cogent Business Management	3	Italy	8
Finance Research Letters	3	Malaysia	8
Accounting and Finance	2	Australia	6
Asia Pacific Management Accounting Journal	2	England	4
British Accounting Review	2	France	4
Corporate Governance the International Journal of Business in Society	2	Lebanon	3
Corporate Social Responsibility and Environmental Management	2	Norway	3

As shown in Table 2-3, one or two studies that examine the relationships between CO_2 emission and environmental practices are published each year from 2009 to 2023 with a total of 9 studies. With regard to the country of origin, most of the previous studies are performed in the global context (4) and Europe (4), within only 1 in Asia. The 9 are published in journals related to accounting, finance, business, and social and environmental responsibilities of businesses, such as the China Journal of Accounting

Studies, International Review of Financial Analysis, Business Strategy and the Environment, and Corporate Social Responsibility and Environmental Management.

Table 2-3 Descriptive analysis of studies on relationship between CO_2 emission and environmental practices.

Year of publication	**No. of articles**
2009	1
2013	2
2014	1
2015	1
2017	2
2018	1
2023	1
Country of Origin	
Global	4
Global (Europe)	2
Japan	1
United Kingdom	2
Journal of publication	
China Journal of Accounting Studies	1
Journal of Contemporary Accounting & Economics	1
Management Decision	1
Business Strategy and the Environment	1
International Review of Financial Analysis	1
International Journal of Law and Management	1
Corporate Social Responsibility and Environmental Management	1
Business & Society	1
Sustainability, environmental performance and disclosures	1

2.4.2 CO_2 emission and financial performance

2.4.2.1 Results of citation network analysis for CO_2 emission and financial performance studies

By using the clustering technique in CitNetExplorer, 1 cluster was identified; that is, the effects of CO_2 emission on financial performance” is the research domain with 38 papers. There were 15 publications that did not belong to the cluster. However, studies in this cluster showed mixed results on the relationship between CO_2 emission and financial performance. This is because different studies operationalized CO_2 emission and financial performance differently in different studies. Besides, the studies are conducted in different geographical regions and in different industries.

Focusing on CO_2 emission, the studies in the identified cluster measured CO_2 emission-related variables differently. For example, GHG emission variations (Alvarez, 2012; Gallego-Alvarez et al., 2015), CO_2 emissions (the sum of scopes 1 and 2) divided by sales (Lewandowski, 2017; Misani & Pogutz, 2015), negative total GHG emissions (the sum of scopes 1 and 2) divided by sales (Trumpp & Guenther, 2017), the natural logarithm of carbon emission (the sum of scopes 1 and 2) (Palea & Santhia, 2022), the natural logarithm of scope 1 CO_2 emission (Desai et al., 2022), total greenhouse gas emissions (the sum of scopes 1, 2, and 3), and sales divided by scope 1 GHG emissions (Busch et al., 2022). It can be seen that studies in this cluster examined scope 1 CO_2 emission (Desai et al., 2022), total CO_2 emissions (the sum of scopes 1 and 2) (Palea & Santhia, 2022) and total CO_2 emissions (the sum of scopes 1, 2, and 3) (Busch et al., 2022).

With regard to financial performance, studies in this cluster employed different financial indicators to measure financial performance. For example, ROA, ROE, Tobin's q, EPS (Adu et al., 2023), ROI, ROS, market value (Ganda, 2018), financial debt (Fernández-Cuesta et al., 2019), profit margin (Gomes et al., 2023), share price (Dzomonda & Fatoki, 2020), turnover (Palea & Santhia, 2022), and total shareholder return (TSR; Trumpp & Guenther, 2017). Although some studies used the same financial indicators, these indicators are calculated differently. For example, some studies measured ROA as operating income divided by total assets (Gallego-Alvarez et al., 2015), while others as net income divided by total assets (Trumpp & Guenther, 2017).

In addition, the studies in this cluster were conducted in different geographical regions and various industries. For example, some studies examined the relationship between CO_2 emission and financial performance in one country, such as Japan (Hatakeda et al., 2012), Australia (Wang et al., 2014), and South Africa (Ganda, 2022). Some studies are conducted in an international context (Alvarez, 2012; Lewandowski, 2017). Moreover, researchers use different theories to support their hypothesis development in different studies. For example, resource-based view theory (Gallego-Alvarez et al., 2015), stakeholder theory (Misani & Pogutz, 2015), the meta-theory of the “too-much-of-a-good-thing” effect (Trumpp & Guenther, 2017), pecking order theory and trade-off theory (Fernández-Cuesta et al., 2019), the natural resource-based view of a firm and the instrumental stakeholder theory (Bendig et al., 2023).

2.4.2.2 MPA results for "the effects of CO_2 emission on financial performance"

MPA on the cluster "the effects of CO_2 emission on financial performance" provided 10 of the most related studies. As shown in Figure 2-1 and Table 2-4, the studies cover the period OF 2012 to 2023, which is the most significant historical route of publications in the research domain of "the effects of CO_2 emission on financial performance". Of the 10 studies, 7 papers investigated the relationship between CO_2 emission and financial performance in the global context, while the remaining studies are conducted in Japan, Australia, and South Africa. Besides, some studies find a linear relationship between CO_2 emission and financial performance (Alvarez, 2012), while some find a curvilinear relationship between the two constructs (Misani & Pogutz, 2015). The main path is divided into two streams from 2012-2017. After 2017, the two streams merge into one main path.

The studies in the first branch were first initiated by Alvarez (2012), who investigated the effects of CO_2 emission variations (i.e., increase or decrease) on financial performance in terms of ROA and ROE in international companies during 2007-2010. Alvarez (2012) found that CO_2 emission variations are negatively related to ROA in 2007 but have no impact on either ROE or ROA for other years. This is because firms will adopt a more conservative and defensive stance during the times of economic crisis, and thus stop making investments in sustainable projects and maintain their existing production methods (Alvarez, 2012). Motivated by the mixed results on the relationship between emission variation and financial performance, Wang et al. (2014) conducted a study by using a sample that is consists of 69 Australian public companies in 2010 to test the relationship between the total carbon emissions (i.e., scopes 1 and 2) and Tobin's q. They found that CO_2 emission is positively associated with Tobin's q, which means a higher Tobin's q is associated with higher CO_2 emissions (Wang et al., 2014). Although previous studies have examined CO_2 emission and financial performance using the linear model, a linear model is used to correct or improve previous theories that are based on the same linear models, thereby the application of linear model may prevent the theory development (Trumpp & Guenther, 2017). In this case, Trumpp and Guenther (2017) conducted a study with a non-linear model and the data from 696 international companies with 2,361 firm-year observations from 2008 to 2012 to examine the relationship between carbon performance (i.e., negative total GHG emissions (i.e., the sum of scopes 1 and 2) divided by sales) and financial performance in terms of ROA and TSR (Trumpp & Guenther, 2017). Trumpp and Guenther (2017) found The U-shaped associations between "carbon performance and ROA", and "carbon performance and market performance (TSR)". The findings support the theory framework of the "too-little-of-a-good-thing" effect, which suggests that the positive or negative relationship between carbon and financial performances depends on the level of carbon performance. Specifically, the positive relationship between carbon performance and financial performance with high carbon performance. The negative relationship between carbon performance and financial performance low carbon performance (Trumpp & Guenther, 2017).

The studies in the second branch were initiated by Hatakeda et al. (2012), who investigated the factors that affect GHG emission reduction. They found that companies with certain characteristics, such as low firm-specific uncertainty, high financial flexibility, and a large proportion of large shareholders will mitigate the positive relationship between CO_2 emission and firm profitability. These characteristics are likely to derive positive or at least neutral benefits (Hatakeda et al., 2012). Gallego-Alvarez et al. (2015) observed an increased number of studies that explore corporate GHG emission and firm performance, with Hatakeda et al. (2012) being one of those studies. Considering the mixed results in previous studies on the association between emission reduction and firm performance, Gallego-Alvarez et al. (2015) used the data of 89 firms in different countries during 2006-2009, they found that carbon emission reduction can improve ROE, but not ROA. Similarly, Misani and Pogutz (2015) found that previous studies focus on the accounting measures of the dependent variables such as ROA and ROE. However, Tobin's q has not been used to test the non-linear relationship between carbon emission and financial performance. Besides, measuring financial performance through Tobin's q helps to estimate the future stream of earnings for a firm, and incorporate the expected long-term benefits of enhanced environmental processes and consequences (Misani & Pogutz, 2015). The results show that the inverse U-shaped relationship between carbon performance (i.e., sum of scopes 1 and 2 CO_2 emission divided by sales) and Tobin's q. In other words, firms with high carbon performance that demonstrating firms' endeavors in reducing CO_2 emissions can be rewarded with a higher Tobin's q (Misani & Pogutz, 2015)

These studies (Alvarez, 2012; Hatakeda et al., 2012; Trumpp & Guenther, 2017;

Wang et al., 2014) in the first and second streams are point to the work of Lewandowski (2017). Specifically, Lewandowski (2017) recognized that the curvilinear relationship between corporate carbon and financial performance is increasingly examined in previous studies (Hatakeda et al., 2012). Lewandowski (2017) referred to Alvarez (2012), Trumpp and Guenther (2017) and Wang et al. (2014) primarily in the methodology section. For example, Lewandowski (2017) followed Alvarez (2012) to include carbon intensive industries and adopt the non-linear model used by Trumpp & Guenther (2017) to test the curvilinear relationship between carbon performance (i.e., total CO2 emissions divided by sales) and financial performance. Lewandowski (2017) followed Wang et al. (2014) by incorporating similar control variables, including sales growth and capital intensity, and including firms in the financial service sector when conducting the main analysis.

Lewandowski (2017) indicated that the most important question is to ask what conditions are beneficial to companies to engage in environmental performance management (e.g., CO2 emission reduction) instead of obtaining competitive advantages. Following previous studies and guided by the research questions above, Lewandowski (2017) used both linear and non-linear models to examine the relationship between the (changes in) carbon performance (i.e., total CO2 emissions divided by sales) and financial performance (i.e., ROA, ROE, ROS, ROIC, and Tobin's q), with a sample of 1,640 international companies that include 7625 firm-year observations from 2003-2005. The findings showed a negative linear relationship and positive curvilinear relationship between carbon performance and financial performance. Specifically, carbon performance is negatively related to the ROA, ROE, ROIC, and Tobin's q. The quadratic term of carbon performance has a positive impact on ROA, ROE, ROS, ROIC, and Tobin's q. The changes in carbon performance have positive effects on ROS and negative effects on Tobin's q. The quadratic term of the changes in carbon performance is not associated with financial performance (Lewandowski, 2017).

As focus of previous studies has been to explore the relationship between carbon performance and accounting-based or stock market-based financial performance, and they have failed to consider the influence of environmental policies, climate change, and carbon emission reduction on the capital structure of firms and the impact on indebtedness. In this case, Fernández-Cuesta et al. (2019) examined the effect of carbon performance (i.e., negative total direct carbon emission (Scope 1) divided by sales) on financial debt. The sample dataset consisted of 428 European companies with 4,223 firm-year observations during 2005-2015 (Fernández-Cuesta et al., 2019). The findings indicated that better carbon performance enables companies to obtain more long-term financial debt to fund their environment related investments (Fernández-Cuesta et al., 2019). Previous studies that examine corporate carbon and financial performance have mostly focused on a single period of time, which does not add much value to strategic decision-making. Besides, the assessment of firm value has been neglected in previous studies and few studies have been conducted on the relationship between corporate carbon and financial performance in emerging economies. Thus, Ganda (2022) examined carbon performance (i.e., total carbon emissions divided by sales) and financial performance (i.e., ROA, firm value, and Tobin's q) for 107 South African listed firms by assessing the data in specific time periods (i.e., short run and long run) during 2014-2018. The findings showed that carbon performance can improve the ROA, firm value, and Tobin's q in the short run. However, in the long run, carbon performance will reduce the ROA and firm value, but improve Tobin's q. At the end of the main path, Sitompul et al. (2023) conducted a systematic literature review on the relationship between corporate carbon management (strategies) and financial performance. The findings showed that 59% of the studies reported positive results between the two constructs, in which 50% indicate positive impacts, while 9% indicate mixed results, including both positive and negative impacts in the short- and long-term perspectives (Sitompul et al., 2023). In general, corporate carbon management strategies (e.g., CO_2 emission reduction) predominantly affect financial performance positively (Sitompul et al., 2023).

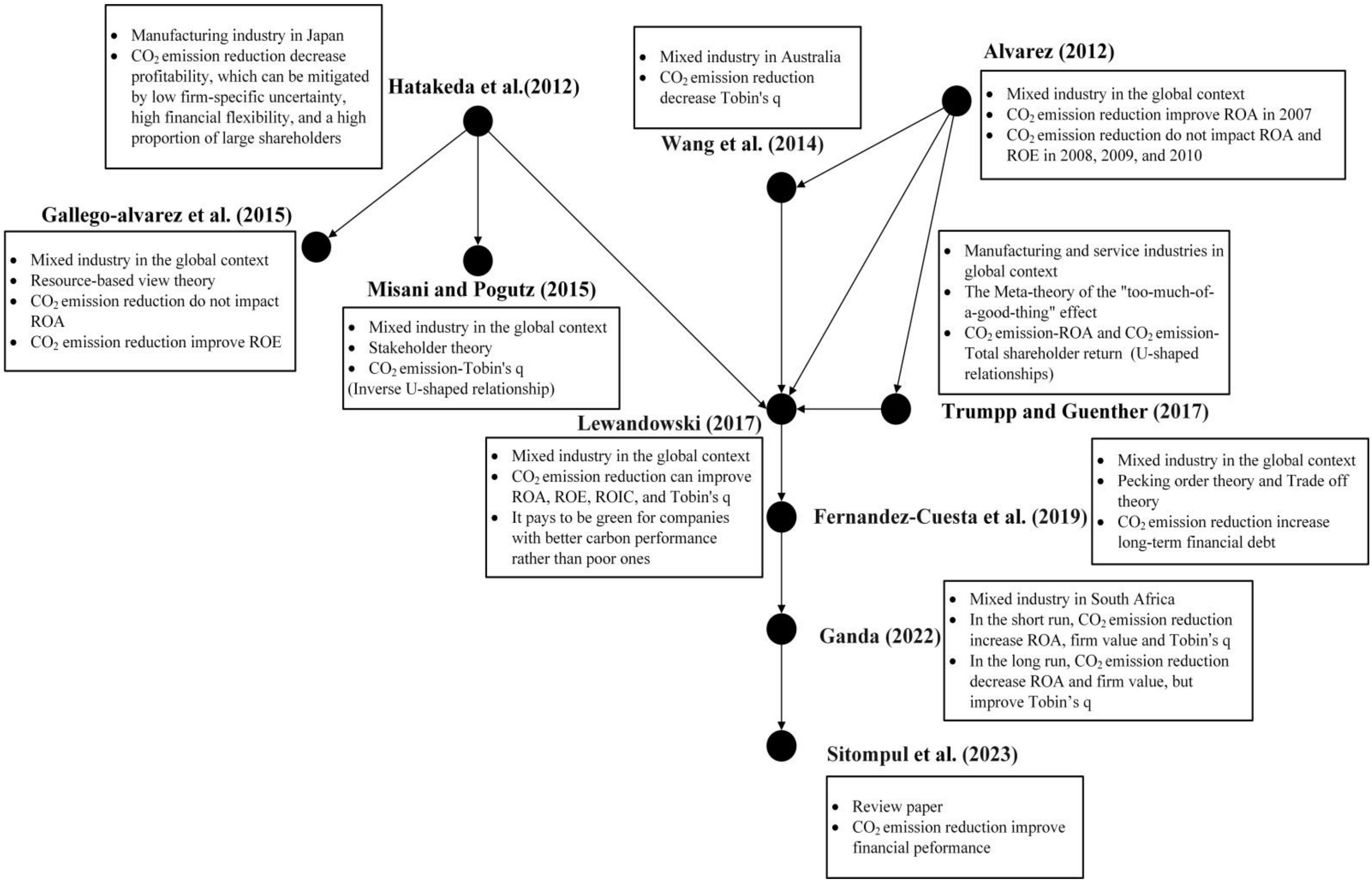

Figure 2-1. Main path of the cluster “the effects of CO_2 emission on financial performance”

Table 2-4 Summary of main path of effects of CO_2 emission on financial performance.

Reference	Theory	Sample size	Industry	Region	Independent Variable		Dependent Variable		Control variable	Finding
					Variable	Indicator	Variable	Indicator		
Alvarez (2012)	-	89	Mixed industry	Global	CO_2 emissions variation	CO_2 emissions variation (increase or decrease)	Financial performance	ROA, ROE	Leverage, size, and activity sector	CO_2 emission variations are negatively related to ROA in 2007, but have no impact on either ROE or ROA for other years (2008-2010)
Hatakeda et al. (2012)	-	1,238	Manufac turing industry	Japan	Environmental performance	GHG emissions×3,00 0 yen[1]	Financial performance	Profitability	Size, Tobin's q, and industry	Low firm-specific uncertainty, high financial flexibility, and a large proportion of large shareholders will mitigate the positive relationship between CO2 emission and firms' profitability
Wang et al. (2014)	-	69	Mixed industrie s	Australi a	Environmental performance	The logarithm of total emissions (Scopes 1 and 2)	Financial performance	Tobin's q	Firm size, sales, capital intensity, growth, leverage, β (i.e., proxies of risk), and industry	A higher Tobin's q is associated with higher GHG emissions across all industry sectors
Gallego-Alvarez et al. (2015)	Resource-based view	89	Mixed industrie s	Global	GHG emission variation	GHG emission reduction	Financial and Operational performances	ROE and ROA	Corporate size, corporate growth rate, Dow Jones Sustainability Index, and legal system	Emissions reduction has a positive impact on ROE, but does not impact ROA

Misani and Pogutz (2015)	Stakeholder theory	127	Mixed industries	Global	Carbon performance	CO_2 emissions (Scopes 1 and 2)/sales	Financial performance	ROA, ROE, ROS, and Tobin's q	Firm size, corporate governance score, UN Global Compact, Climate change innovation, research &development intensity, and firm's risk	Carbon emission affects Tobin's q non-linearly. When their carbon performance is neither low nor high, but intermediate, firms can achieve the highest financial performance
Trumpp and Guenther (2017)	The Meta-theory of the "too-much-of-a-good-thing" effect	696	Manufacturing and service industry	Global	Carbon environmental performance	Negative total GHG emissions (Scopes 1 and 2)/sales	Financial and stock market performances	ROA and TSR	Research and development intensity, capital intensity, leverage, growth, cash flow returns on sales, company size, and legal origin	U-shaped relationship between carbon performance and ROA, but U-shaped relationship between carbon performance and TSR is solely for manufacturing industry
Lewandowski (2017)	-	1,640	Mixed industries	Global	Carbon performance	CO_2 emissions (Scopes 1 and 2)/sales	Financial and stock market performances	ROA, ROE, ROS, ROIC, and Tobin's q	Firm size, firm risk, sales growth, capital intensity, cash flow (liquidity)	Carbon performance (CP) negatively related to ROA, ROE, ROIC, and Tobin's q. The quadratic term of CP has positive impact on ROA, ROE, ROS, ROIC, and Tobin's q. The changes in CP have positive effects on ROS and negative effects on Tobin's q. The quadratic term of the changes in CP

										are not associated with financial performance
Fernandez-Cuesta et al. (2019)	Pecking order theory, Trade off theory	435	Mixed industries	Global	Carbon/environmental performance	Negative total verified direct carbon emission (Scope 1)/sales	Financial Debt	Financial Debt	Profitability, firm size, tangible assets, non-debt tax shields, research and development expenses, firm age, liquidity, corporate tax rate in each country, sales, and investment	Carbon performance enable companies to obtain more long-term financial debt to fund their environmental related investments
Ganda (2022)	-	107	Mixed industries	South Africa	Carbon performance	Total carbon emissions/sales	Financial performance and financial value	ROA, firm value, and Tobin's q	Debt to equity ratio, interest cover ratio, price cash flow ratio, and current ratio	In the short-run, carbon performance can improve ROA, firm value, and Tobin's q. In the long-run, carbon performance will reduce ROA and firm value, but will improve Tobin's q
Sitompul et al. (2023)	-	223 articles	Mixed industries	Global	Corporate carbon management strategies		Corporate financial performance		-	Corporate carbon management strategies have predominantly positive impacts on financial performance

Note: [1]Based on the trade price of 28.73 euro as of March 2008, when emissions data were published, the price of CO2 was equal to approximately 3,000 Japanese yen

2.4.3 Environmental practices and financial performance

2.4.3.1 Results of citation network analysis on environmental practices and financial performance studies

By using the clustering technique in CitNetExplorer, 1 cluster “the effects of environmental practices on financial performance” was identified as a research domain with 42 studies. There were 29 publications that did not belong to the cluster. The studies in this cluster showed mixed findings on the relationship between environmental practices and financial performance because different studies used different indicators to measure environmental practices and financial performance. In addition, studies that examined the relationship between environmental practices and financial performance were conducted in different industries and sectors and geographical locations. The specific details are discussed in the following sections.

With regard to environmental practices, previous studies use different environmental scores that reflecting environmental practices obtained from different databases, such as Thomson Reuters Eikon database (now Refinitiv Eikon) (Ahmad et al., 2023; Kalia & Aggarwal, 2023), Sustainalytics database (Yilmaz, 2021), Bloomberg database (Behl et al., 2022; Fahad & Busru, 2021), MSCI ESG KLD STATS (Brogi & Lagasio, 2019), CSRHub database (Sandberg et al., 2023), and Korean Corporate Governance Service (Yoon et al., 2018). Different databases use different methods and indicators to calculate environmental scores. For example, the environmental score in Thomson Reuters Eikon database (now Refinitiv Eikon) is calculated based on three dimensions, including emission reduction, resource use and environmental innovation (Refinitiv Eikon, 2023). The score ranges from 0 to 100, with 100 being the highest score (Duque-Grisales & Aguilera-Caracuel, 2021). The environmental score in the Bloomberg database relates to emissions, energy, water management, materials, spills, environmental fines, investments/costs, certified sites, and operational policies on environmental impacts, which ranges from 0.1 to 100. The CSRHub environmental score assesses three aspects, including energy and climate change, environment policy and reporting, and resource management, which ranges from 0 to 100 (Sandberg et al., 2023). Thus, researchers use the environmental scores from the different databases which is probably the reason for the mixed results on the relationship between environmental practices and financial performance.

Focusing on financial performance, previous studies use different indicators to measure financial performance. For example, ROA (Brogi & Lagasio, 2019; Duque-Grisales & Aguilera-Caracuel, 2021), Tobin's q (Behl et al., 2022; Mohammad & Wasiuzzaman, 2021), ROE, net and operating profit margin (Yilmaz, 2021), returns on capital employed (Narula et al., 2024), and returns on invested capital (Rahi et al., 2022). Although some studies use the same financial indicators to measure financial performance, the formula to calculate each financial indicator varies. For example, some studies measure ROA as the ratio of net income to total assets, while others measure ROA as the ratio of the company profits before taxes to the average of its total assets (Ortas et al., 2015). Some studies measure Tobin's q as the ratio of market capitalization plus overall debt to the aggregate assets (Al-ahdal et al., 2023), while others measure it as totals assets divided by market capitalization (Narula et al., 2024).

For geographical location, some studies examine the relationship between environmental practices and financial performance in a single country, including Korea (Yoon et al., 2018), Japan (Vuong, 2022), Malaysia (Ahmad et al., 2023; Mohammad & Wasiuzzaman, 2021), Indonesia (Gutiérrez-Ponce & Wibowo, 2023), India (Al-ahdal et al., 2023; Fahad & Busru, 2021; Narula et al., 2024), the United Kingdom (Ahmad et al., 2021; Li et al., 2018), United States (Alareeni & Hamdan, 2020; Brogi & Lagasio, 2019), Germany (Velte, 2019), and Australia (Gholami et al., 2022). Other studies explore the relationship environmental practices and financial performance in Nordic region (i.e., Sweden, Denmark, Finland and Norway) (Rahi et al., 2022), BRICS countries (i.e., Brazil, Russia, India, China and South Africa) (Yilmaz, 2021), Latin America (i.e., Brazil, Chile, Colombia, Mexico and Peru) (Duque-Grisales & Aguilera-Caracuel, 2021) and the global contexts (Abdi et al., 2020). With regard to the industries and sectors, previous studies have examined the relationship between environmental practices and financial performance in the banking (Miralles-Quiros et al., 2019; Shakil et al., 2019), airline (Abdi et al., 2020, 2022), health-care (Kalia & Aggarwal, 2023), financial (Rahi et al., 2022), food (Sandberg et al., 2023), mixed industries (Yoon et al., 2018), and utilities (Remo-Diez et al., 2023), and energy (Behl et al., 2022) sectors.

Therefore, the difference in the measurements of environmental scores and financial performance, countries and regions, industries and sectors, all lead to mixed results for the relationship between environmental practices and financial performance. In addition, different theories are used to examine the relationship between environmental practices and financial performance, including the stakeholder theory and resource-based view (El Khoury et al., 2023a), natural resource-based view of a firm and institutional theory (Duque-Grisales & Aguilera-Caracuel, 2021), stakeholder theory and upper echelons theory (Velte, 2019). The stakeholder theory is the most frequently used theory in this cluster to examine the relationship between environmental practices and financial performance.

2.4.3.2 MPA results for "the effect of environmental practices on financial performance"

The main path depicted in Figure 2-2 and Table 2-5 shows the impacts of environmental practices on financial performance of firms. The studies span from 2018-2023, which is the most significant historical trajectory of publications in the research domain of "the effects of environmental practices on financial performance". The main path is divided into four streams for the period of 2018 to 2020. The four streams merged into one main path in 2022, including two areas of knowledge: the relationship between "environmental practices and accounting-based financial performance" and "environmental practices and market-based financial performance".

The studies in the first streams primarily focus on the relationship between environmental practices and market-based financial performance. Specifically, Yoon et al. (2018) and Miralles-Quiros et al. (2019) examined the effects of environmental practices/scores on stock price of firms. Although conducted in different geographical contexts (i.e., global vs. Korea) and different industries (i.e., banking vs. mixed industries), both studies found environmental practices/scores that reflect environmental practices, including management practices addressing climate change, clean production, pollutants emission, green marketing, and developing eco-friendly products have positive impacts on stock prices (Miralles-Quiros et al., 2019; Yoon et al., 2018). Specifically, Miralles-Quiros et al. (2019) found that more environmental practices in terms of emission reduction, resource use and environmental innovation can improve stock price of firms. Similarly, Yoon et al. (2018) found environmental practices that respond to climate change, clean production, pollutants emission, green marketing, and environmentally friendly production of products can improve stock price of firms. To further investigate the relationship between environmental practices and stock prices, Yoon et al. (2018) investigated the influence of environmentally sensitive industries (i.e., the energy, utility, and material sectors) and family firms (i.e., chaebols-a South Korean word) on this relationship in Korea, and Miralles-Quiros et al. (2019) explored the effects of common law countries and the post-crisis periods (i.e., bankruptcy of Lehman Brothers and subprime mortgage crisis) on this relationship within the global context. The results showed that companies adopt more environmental practices (i.e., emission reduction, resource use and environmental innovation) can improve their stock prices in family firms (Yoon et al., 2018), and common law countries and after the global financial crisis periods (Miralles-Quiros et al., 2019). However, environmental practices will reduce the stock price of a firm in environmentally sensitive industries (Yoon et al., 2018), which means that firms that have better environmental practices will have lower stock prices in environmentally sensitive industries. The finding is consistent with the shareholder expense theory, which emphasizes that environmental practices generate costs (Yoon et al., 2018). In contrast, some scholars find that environmental practices can improve stock prices in environmentally sensitive industries in Europe (Qureshi et al., 2020).Thus, the findings could depend on the context.

In the second stream, studies examine the relationship between environmental practices and accounting-based (i.e., ROA and ROE) and market-based (i.e., Tobin's q) financial performance. To be more specific, Buallay (2019) and Shakil et al. (2019) examined the relationship between environmental practices and financial performance in the global banking industry. The findings showed that improved environmental practices in terms of energy use, waste, pollution, natural resource conservation (Buallay, 2019), and environmental practices in terms of emission reduction, resource use and environmental innovation (Shakil et al., 2019) are associated with a higher ROE, but are not associated with ROA (Buallay, 2019; Shakil et al., 2019). Li et al. (2018) found that environmental practices related to emissions energy, water management, etc., can improve ROA. Companies with more environmental practices will have a higher Tobin's q (Buallay, 2019; Li et al., 2018). This shows that financial and market benefits could be obtained by improving environmental practices (Buallay, 2019). Stakeholders may consider the environmental practices as a main driver of better asset efficiency in their investment decision-making process (Buallay, 2019). Besides, previous studies find that the environmental practices/scores are higher in banks in countries with low gross domestic product (GDP) and governance (i.e., public governance level of the country) (Buallay, 2019). Following Li et al. (2018) and Buallay (2019), Qureshi et al. (2020) examined the effects of environmental practices on market-based financial performance, which is reflected in the third and the fourth streams of the main path. They found that the environmental practices/scores (i.e., emission reduction, resource use and environmental innovation) are positively associated with share price, which means companies with enhanced environmental practices/scores can improve their share prices, which is consistent with findings in previous studies (Miralles-Quiros et al., 2019; Yoon et al., 2018). The positive relationship between the environmental practices/scores and share price is also significant between firms operating in environmentally sensitive industries (i.e., firms with higher ESG requirements) (Qureshi et al., 2020).

Starting in 2022, the four streams merge into one main path. To address the research gap where previous studies have failed to provide the empirical evidence on the relationship between environmental practices and financial performance of banks in the developing countries in the Middle East, North Africa and Turkey (MENAT) region (El Khoury et al., 2023a), El Khoury et al. (2023) examined the effects of environmental practices/scores on financial performance in terms of ROA, ROE, Tobin's q and stock return in the banking industry in the MENAT region. The findings showed that environmental practices/scores in terms of emission reduction, resource use and environmental innovation have a U-shape (convex) relationship with Tobin's q and stock return. Specifically, the negative relationship between the quadratic term of environmental practices/scores and Tobin's q/stock return indicates that firm that invest in environmental practices of emission reduction, resource use and environmental innovation may require a longer time to reap the market benefits (El Khoury et al., 2023a). Besides, environmental practices/scores have no impact on ROA and ROE, thus suggesting that firms that invest in environmental activities are not rewarded with profitability (El Khoury et al., 2023). Gutiérrez-Ponce and Wibowo (2023) conducted a similar investigation and explored the relationship between environmental practices/scores and financial performance in terms of ROA, ROE, and Tobin's q in the banking industry in Indonesia. The findings showed that environmental practices/scores are not associated with financial performance measured by ROA, ROE, and Tobin's q, thus indicating that the firms' environmental practices in terms of emission reduction, resource use and environmental innovation fall short of the mandatory requirements in Indonesia (Gutiérrez-Ponce & Wibowo, 2023). Kong et al. (2023) used the EPS and price to earnings ratio as proxies of market-based financial performance to explain the role of environmental practices/scores in shaping the current and future values of firms in high-tech industries worldwide. The findings showed that environmental practices/scores are not related to EPS and price to earnings ratio (Kong et al., 2023), thus suggesting that environmental practices (i.e., emission reduction, resource use and environmental innovation) do not create the current and future values of a firm in the high-tech industries.

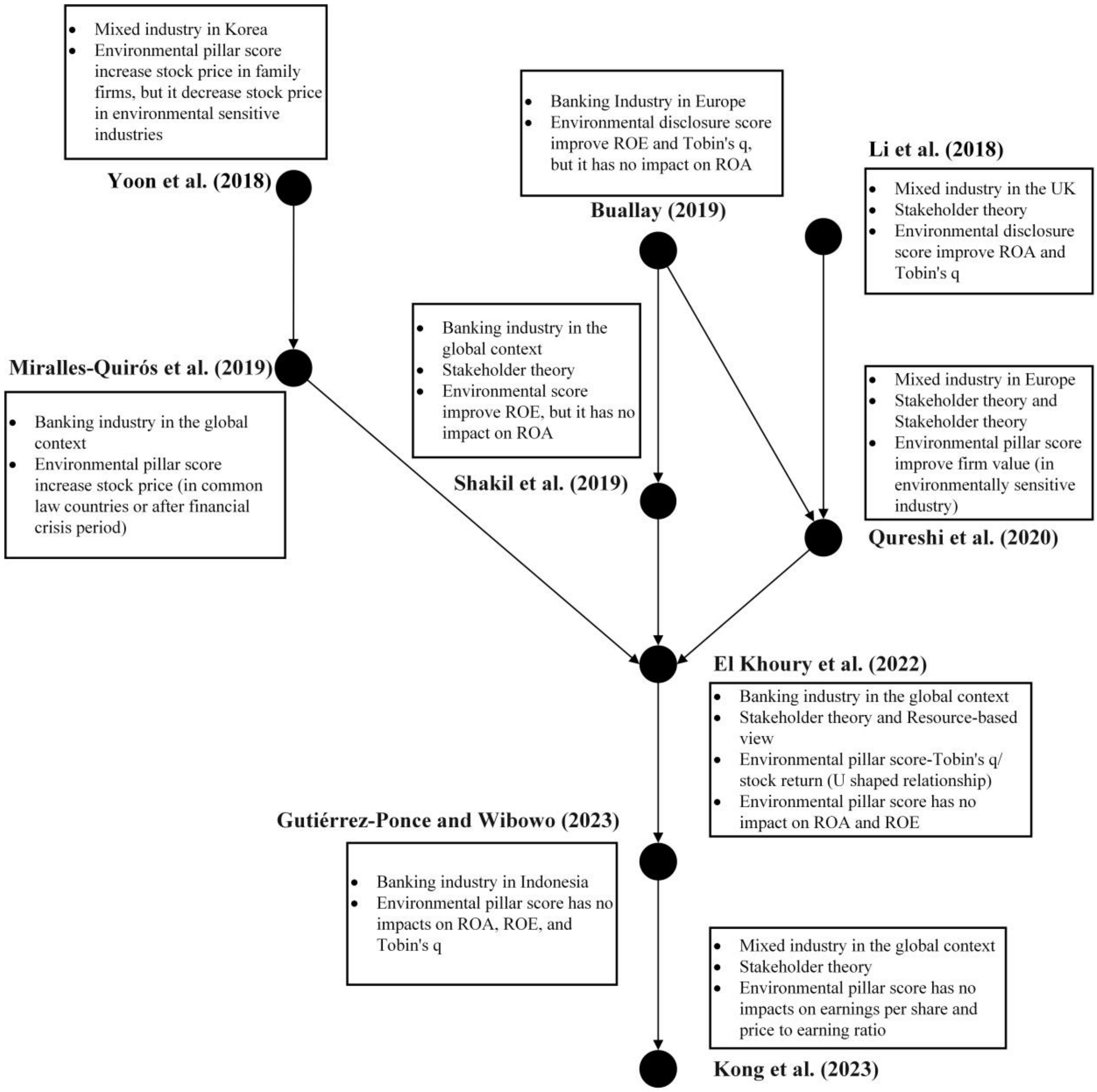

Figure 2-2. Main path of cluster “the effects of environmental practices on financial performance”

Table 2-5 Summary of main path of effects of environmental practices on financial performance.

Reference	Theory	Sample firms	Industry	Region	Independent variable		Dependent variable		Moderator	Control variable	Finding
					Variable	Proxy	Variable	Proxy			
Yoon et al. (2018)	-	705	Mixed industries	Korea	Environmental performance (reflecting environmental practices, including management practices addressing climate change, clean production, pollutant emissions, green marketing, and developing eco-friendly products)	Environmental score provided in Korean Corporate Governance Service	Firm value	Stock price	Environmentally sensitive industries and Family firms (Chaebols)	Book value per share and EPS	Environmental score positively related to stock price (in family firms), but negatively related to stock price in environmentally sensitive industries
Miralles-Quirós et al. (2019)	-	51	Banking Industry	Global	Environmental performance (reflecting environmental practices, including emission reduction, resource use and environmental innovation)	Environmental score provided in Thomson Reuters Eikon database (now Refinitiv Eikon)	Stock price	Stock price	Common law countries and the post-global crisis period	Book value per share and EPS	Environmental score is positively related to stock price (in common law countries and after financial crisis period)

Buallay (2019)	-	235	Banking Industry	Global (Europe)	Environmental disclosure (reflecting environmental practices, including energy consumption, waste management, pollution control, conservation of natural resources etc.)	Environmental score provided in Bloomberg database	Financial, market, operational performance	ROA, ROE, and Tobin's q	-	Financial leverage, total assets, gross domestic product, and governance	Environmental disclosure is positively associated with ROE and TQ, and have no impact on ROA
Shakil et al. (2019)	Stakeholder theory	93	Banking Industry	Global	Environmental performance (reflecting environmental practices, including emission reduction, resource use and environmental innovation)	Environmental score provided in Thomson Reuters Eikon database	Financial, operational performance	ROA, ROE	-	Bank size, leverage ratio, and dividend yield	Environmental score is positively related to ROE, and have no impact on ROA
Li et al. (2018)	Stakeholder theory	367	Mixed industries	UK	Environmental disclosure (reflecting environmental practices, including energy consumption, waste management, pollution control, conservation of natural resources etc.)	Environmental score provided in Bloomberg database	Firm value	ROA and Tobin's Q	CEO power	Plant and equipment, firm size, capital expenditure, leverage, sales growth, and cash	Environmental score positively related to Tobin's Q/ROA. CEO with great power positively moderates the relationship between environmental score and Tobin's q/ROA

Qureshi et al. (2020)	Shareholder theory, Stakeholder theory	812	Mixed industries	Global-Europe	Environmental disclosure (reflecting environmental practices, including emission reduction, resource use and environmental innovation)	Environmental score provided in Thomson Reuters Eikon database	Firm value	Share price	Environmentally sensitive industry	Earnings per share, book value per share, firm size, leverage, inflation, economic growth, banking development, stock market development, and industry sensitivity	Environmental score is positively related to firm value (in the environmentally sensitive industry)
El Khoury et al. (2023)	Stakeholder theory and Resource-based view	46	Banking Industry	The Middle East, North Africa and Turkey region	Environmental pillar score (reflecting environmental practices, including emission reduction, resource use and environmental innovation)	Environmental pillar score provided in Thomson Reuters Eikon database	Financial performance	ROA, ROE, Tobin's q, and stock return	-	Size, capital adequacy ratio, cost to income, liquidity, loans to total deposits ratio, diversification using the income diversity ratio, GDP per capita growth rate, inflation, private credit by deposit banks to GDP, Bank-based or market-based system, and Arab Spring Dummy	Environmental scores have a U-shape (convex) relationship with Tobin's q/ stock return; Environmental scores have no impact on ROA and ROE

Gutiérrez-Ponce and Wibowo (2023)	-	5	Banking Industry	Indonesia	Environmental activities (reflecting environmental practices, including emission reduction, resource use and environmental innovation)	Environmental score provided in Thomson Reuters Eikon database	Financial performance	ROA, ROE, and Tobin's q	-	Size and leverage	Environmental score is not associated with ROA, ROE, and Tobin's q
Kong et al. (2023)	Stakeholder theory	64	Mixed industries (Global hi-tech)	Global	Environment performance (reflecting environmental practices, including emission reduction, resource use and environmental innovation)	Environmental score provided in Thomson Reuters Eikon database	Firm value	Earnings per share and price to earnings ratio	-	Firm size, net profit margin, and leverage	Environmental score is not associated with EPS and price to earnings ratio

2.4.4 CO_2 emission and environmental practices

Studies on CO_2 emission and environmental practices investigate environmental practices primarily focusing on the disclosure of carbon/environmental/climate change information. Environmental scores reflect the environmental practices of firms, which are a tool to assess whether corporate business behaviors are sustainable. The scores are calculated by assessing the information associated with carbon emissions, environmental issues, and climate change actions. For example, some studies have used the indexes, such as a "specific plan to reduce GHG emissions" (Freedman & Jaggi, 2009) or "disclosing scope 3 emissions intensity" (Liu et al., 2023) to computed carbon disclosure score, while other studies use the indexes, such as the indexes of "natural resource conservation", "toxic substances", and "waste management" to calculate the environmental disclosure score (Kuo & Yi-Ju Chen, 2013). Still others use climate change scores to measure the amount of action taken towards climate change mitigation, adaptation, and transparency (Giannarakis et al., 2018). A high climate change score means that companies measure, verify, and manage their carbon footprints. Thus, carbon/environmental/climate change disclosure scores reflect the different environmental practices of firms.

Previous studies have reported mixed results on the relationship between CO_2 emission and environmental practices (see Table 2-6). This is probably because they examine the relationship between CO_2 emission and environmental practices in different geographical regions, such as globally (Freedman & Jaggi, 2009), Japan (Kuo & Yi-Ju Chen, 2013) or the United Kingdom (Liu et al., 2023), as well as in different industries (Giannarakis et al., 2017a; Guenther et al., 2016). Besides, the mixed findings on the relationship between CO_2 emission and environmental practices/scores are probably because CO_2 emissions are calculated in different ways in different studies, and the environmental scores reflect different environmental practices.

For CO_2 emission, previous studies used emission change scaled by revenue (Freedman & Jaggi, 2009), inverse of total carbon emission for each million dollars of net sales turnover (He et al., 2013), scope 1 GHG emissions and scope 2 GHG emissions (Giannarakis, et al., 2017b), total carbon emissions (i.e., sum of scopes 1 and 2) (Liu et al., 2023), CO_2 emissions (i.e., sum of scopes 1 and 2) divided by total assets (Guenther et al., 2016), GHGs divided by sales revenue and sector-adjusted GHG emission (Giannarakis et al., 2018).

As for environmental practices, different environmental scores reflect different environmental practices. First, there is the carbon disclosure score, which is a measure of the transparency of corporate carbon disclosure practices. In different studies, this score in different studies reflects different environmental practices. For example, He et al. (2013) used the carbon disclosure score to reflect how well a company communicates its carbon emission data and strategies related to carbon management. Liu et al. (2023) used carbon disclosure score to reflect three carbon reduction practices: i) engagement and strategy (e.g., companies are actively implementing or planning to implement a specific carbon management scheme), ii) risk and opportunity (e.g., companies improve their business process for carbon emission reduction), and iii) measurement and performance (e.g., companies measure their carbon emissions in accordance with recognized standards for measuring carbon footprint measurement standards). Second, the Carbon Disclosure Leaders Index (CDLI), which measures the extent of carbon disclosure and considers the contents, quality and quantity of the carbon disclosure, reflects the mechanisms that companies use to control carbon, and their carbon strategies, carbon initiatives, carbon communication and engagement, etc. (Luo & Tang, 2014). Third, the Climate Performance Leadership Index (CPLI), which is based on the CDLI approach, assesses corporate practices on climate change mitigation, adaptation as well as transparency, but cannot be considered as a metric to determine whether companies are low carbon (Giannarakis et al., 2018; Giannarakis, et al., 2017b). A high score of CPLI score indicates that the company has a superior performance in integrating climate change strategies and significantly promoting emissions reduction, which show that this company companies measures, verifies, and manages its carbon footprints (Giannarakis et al., 2018; Giannarakis, , et al., 2017b).

There are two main theories used in previous studies to describe the relationship between CO_2 emission and environmental practices/scores, including the legitimacy theory and voluntary disclosure theory. Specifically, He et al. (2013) found that CO_2 emission (i.e., net sales turnover divided by total carbon emission (i.e., the sum of scopes 1, 2 and 3) is negatively related to carbon disclosure score, which indicates companies that have a poorer performance in reducing CO_2 emission will disclose more carbon information. Similarly, Liu et al. (2023) found total carbon emissions (i.e., the sum of scopes 1 and 2) are positively related to carbon disclosure score, which suggests that companies with higher carbon emission are more likely to make strategic disclosures to reduce information gaps and manage legitimacy threats. The findings are consistent with the legitimacy theory that posits that companies threatened with legitimacy tend to create self-serving information (Adams, 2004; He et al., 2013).

However, Kuo and Yi-Ju Chen (2013) found that CO_2 emission reductions are positively associated with carbon disclosure score, which indicate that companies with a better performance in reducing CO_2 emissions will have higher and significant level of environmental disclosure. Other studies also find similar relationships. For example, scope 1 CO_2 emission is negatively related to climate change disclosure score, which suggests that firms with good performance in reducing scope 1 CO_2 emission will disclose more climate change information (Giannarakis et al., 2017b). The reduction in CO_2 emission, for example, CO_2 emission divided by sales revenue (Giannarakis et al., 2017a), CO_2 emission (i.e., the sum of scopes 1 and 2) divided by total assets (Guenther et al., 2016), and GHGs divided by sales revenue minus sector mean (Giannarakis et al., 2018), can increase carbon/climate change disclosure, and thus increase the relevant scores. The findings are consistent with the voluntary disclosure theory, which posits that companies with a superior environmental performance are motivated to increase environmental disclosure practices. in doing so, they ensure their investors and stakeholders are well-informed. This also sets them apart from companies with inferior environmental performance (Giannarakis et al., 2017a; Verrecchia, 1983). In contrast, companies with inferior environmental performance will limit how much they disclose or choose to remain silent about their environmental performance (Giannarakis, et al., 2017a; Verrecchia, 1983). The stakeholder theory also supported a positive relationship between CO_2 emission (i.e., carbon performance) and environmental score (i.e., carbon disclosure score) (Guenther et al., 2016). Specifically, environmental (e.g., CO_2 emission) information disclosure is considered to be a material business issue (Guenther et al., 2016). Due to environmental challenges and climate change, stakeholders (e.g., government, employees, customers and the general public) who have increasing environmental awareness and interests in the carbon performance of firms, influence business practices. For example, the customers environmental awareness of their customers has obliged firms to report on their carbon performance and information (Guenther et al., 2016).

Table 2-6 Summary of main path of effects of CO_2 emission on environmental practices.

Reference	Theory	Samples firms	Industry	Region	Independent Variable		Dependent Variable		Control variable	Finding
					Variable	Indicator	Variable	Indicator		
He et al. (2013)	Voluntary disclosure and legitimacy theories	181	Mixed industries	Global	Carbon performance	Net sales turnover/total carbon emission	Carbon disclosure score (reflecting environmental practices of carbon transparency)	Total score earned/total score available	BETA, earnings quality, firm size, market-to-book ratio, intensity, liquidity, litigation, leverage, ROA, Tobin's q	Carbon performance negatively related to carbon disclosure score
Luo and Tang (2014)	Signaling theory	474	Mixed industries	The United States, the United Kingdom, and Australia	Carbon performance (CP)	CP1:.Emission intensity: scopes 1 and 2 GHG emissions/total sales; CP2: Sector-adjusted CO2 emission intensity=CP1 minus its sector mean; CP3 measures if a firm reduced its emissions relative to historical levels or	Carbon Disclosure Leaders Index/score (CDLI) (reflecting environmental practices of carbon control mechanisms, carbon strategies, carbon initiatives, carbon communication and engagement etc.)	CDLI1:total score earned/total score available; CDLI2: CDLI1 minus its sector mean	Size, ROA, leverage, intensive sector, region	Companies with a large carbon emission reduction will have high carbon disclosure score

						other benchmarks, using different weighted indexes; CP4 is based on an equally weighted index. CP1 and CP2 based on the carbon intensity of emissions and CP3 and CP4 focus on carbon reduction outcomes				
Freedman and Jaggi (2009)	Voluntary disclosure theory, Socio-political theory (stakeholders and legitimacy theories)	282	Mixed industries	Global (Europe)	Change in carbon emission	Emission change/revenue	Global warming disclosure index/score (reflecting environmental practices of disclosing the amount and the cause of CO_2 emission, energy consumption, environmental audit, buy or sell carbon credits etc.)	11 disclosure categories with equal weighting scheme	Size, industry, country	Insignificant relationship between carbon emission and global warming disclosure score
Kuo and Yi-Ju Chen (2013)	Legitimacy theory	208	Mixed industries	Japan	CO2 emission reduction performance	Reduction in CO2 emissions/environmental conservation expenditures	Environmental disclosure score (reflecting environmental practices of pollution	45 items and 8 disclosure categories, using discourse scoring methodology, including	Leverage, ROA, firm size, foreign listings, industry	CO2 emission reduction performance positively related to

							abatement, sustainable development-recycling, environmental management etc.)	quantitative and qualitative measures		environmental disclosure score
Giannarakis et al. (2017b)	Legitimacy and voluntary disclosure theories	119	Mixed industries	The UK	Scopes 1 and 2 GHG emissions	Scopes 1 and 2 GHG emissions	Climate performance leadership index/score (CPLI) (reflecting environmental practices of the climate change mitigation and adaptation as well as carbon transparency)	CPLI reflects the level of company commitment to climate change mitigation, adaptation, and transparency. CPLI participation requires a firm with a minimum CDLI score of 50 , and the scores are groups into bands (A, B, C, D, and E)	Climate change policy, Emission reduction initiatives, firm size, ROA, Number of board meetings, board size	Scope 1 GHG emission negatively related to climate change disclosure score; Scope 2 CO2 emission is not associated with climate change disclosure score
Liu et al. (2023)	Legitimacy theory	100	Mixed industries	UK	Total carbon emissions	Total carbon emissions (scopes 1 and 2)	Carbon disclosure (reflecting environmental practices, including engagement and strategy, risk and opportunity, measurement and performance)	42-item scale with 4 disclosure categories. A score of 1 represent information disclosed.; otherwise, a score of 0 is given	Market value, leverage, capital intensity, intangible assets, MTBV, growth, ROA, sales	Carbon emission positively related to carbon disclosure score

Giannarakis et al. (2017a)	Legitimacy and voluntary disclosure theories	102	Mixed industries	Global	Environmental performance	GHG1: GHG or CO2/sales revenue; GHG2: value of 1 is given to company with good environmental performance; value of 0 is given to company with poor environmental performance	CDLI (reflecting environmental practices of carbon control mechanisms, carbon strategies, carbon initiatives, carbon communication and engagement etc.)	Total attainable score/total available score and standardized to a 100-point scale	Company size, ROA, leverage, CEO duality, board size, independent directors on board	GHG1 negatively related to carbon disclosure score; GHG2 positively related to carbon disclosure score
Giannarakis et al. (2018)	Legitimacy and voluntary disclosure theories	215	Mixed industries	Global (Europe)	Environmental performance	Sector-adjusted GHG emissions:(GHGs/salesrevenue)-sector mean	CPLI reflecting environmental practices of the climate change mitigation and adaptation as well as carbon transparency	Performance points earned/ performance points available, and multiplied by 100	Firm size, profitability, board size, government ownership, verification	GHGE negatively related to climate change disclosure score
Guenther et al. (2015)	Stakeholder theory	1,120	Mixed industries	Global	Carbon performance	CO2 emissions (Scopes 1 and 2)/total assets	Carbon disclosure score (reflecting environmental practices of disclosing carbon information)	Four disclosure categories. The disclosure score ranges from 0 to 100. A score of 0 indicate no answers given, a score of 100 represents complete disclosure	ROE, leverage, volatility, firm size, capital investment, code law, and signatories	Carbon performance positively related to carbon disclosure score

2.5 Summary of literature

Table 2-7 summarize the studies that have examined the relationship between "CO_2 emission and financial performance", "CO_2 emission and environmental practices", and "environmental practices and financial performance".

With regard to CO_2 emission, studies on "CO_2 emission and financial performance" examined scope 1 CO_2 emission (Desai et al., 2022), the sum of scopes 1 and 2 CO_2 emissions (Lewandowski, 2017; Misani & Pogutz, 2015), and the sum of scopes 1, 2, and 3 CO_2 emissions (Busch et al., 2022). Studies on "CO_2 emission and environmental practices" investigated scope 1 CO_2 emission, scope 2 CO_2 emission (Giannarakis, et al., 2017b), and the sum of scopes 1 and 2 CO_2 emissions (Liu et al., 2023).

In terms of environmental practices, previous studies use environmental scores that reflect environmental practices. These scores provided by third party rating agencies (e.g., Refinitiv Eikon, Bloomberg, and MSCI ESG KLD STATS) or calculated based on different scoring approaches (e.g., CPLI approach). The obtained environmental scores can be interpreted in two ways. The first way focuses on the extent of disclosure of environmental information that reflects environmental practices. For example, the Bloomberg environmental scores measure the extent of environmental information disclosure (Yoo & Managi, 2022). The environmental scores calculated based on the amount of publicly disclosed environmental information (Yu et al., 2018). For example, a company that reports direct CO_2 emissions will obtain relevant data points. A higher environmental score means that more environmental information has been disclosed (Yu et al., 2018). The second way of focuses on environmental performance (i.e., actual environmental endeavors). For example, the environmental pillar score provided by Refinitiv Eikon is calculated based on three environmental dimensions, including emission reduction, resource use and environmental innovation

(Refinitiv Eikon, 2023). Emission reduction score measures commitments to emission reduction and effectiveness of doing so during production and operational processes. Resource use score measures the performance and capacity of a company to reduce the use of materials, energy or water and use eco-friendly solutions by improving supply chain management. Finally, environmental innovation score assesses the capacity of a company to reduce environmental costs and burden for its customers and thereby create new market opportunities through new environmental technologies and processes or eco-designed products (Refinitiv Eikon, 2023). In sum, the two interpretations of environmental scores are crucial tools, which can be used to assess the sustainability of the environmental behaviors of companies. However, although the two interpretations of environmental scores reflect environmental practices, previous studies have indiscriminately used the two interpretations of environmental scores to measure environmental information disclosure or the environmental performance, which reflect environmental practices. For example, some studies (Al-ahdal et al., 2023; Qureshi et al., 2020) measured environmental disclosure by using environmental scores that focus on environmental performance instead of environmental information disclosure. This has misleading implications for policymakers, researchers, and practitioners. It is possible that a company has a high environmental score on their environmental performance (i.e., actual environmental practices) but a low environmental score on environmental disclosure. For example, a company makes environmental efforts but discloses little environmental information (Yoo & Managi, 2022). Future studies should therefore differentiate between the two interpretations of environmental scores based on their research objectives.

For the financial performance, previous studies have used ROA, ROE, ROI, ROS, profit margin, turnover, Tobin's q, market value, share price, TSR, EPS, and financial debt, operating profit margin, return on capital employed, and return on invested capital as the proxies of financial performance.

2.6 Identified research gaps

Based on the summarized literature on the relationship between “CO_2 emission and financial performance”, “CO_2 emission and environmental practices”, and “environmental practices and financial performance”, this study identified three research gaps and then propose future research directions (see Table 2-7).

First, previous studies on “CO_2 emission and financial performance” and “CO_2 emission and environmental practices” investigated scope 1 CO_2 emission (Desai et al., 2022; Giannarakis et al., 2017a), scope 2 CO_2 emission (Giannarakis et al., 2017a), the total carbon emission (i.e., the sum of scopes 1 and 2) (Luo & Tang, 2014) or total carbon emission (i.e., the sum of scopes 1, 2 and 3) (He et al., 2013; Palea & Santhia, 2022). However, they ignored that CO_2 emission originates from different sources, and addressing emissions from each source require different environmental practices. These practices will in turn incur different environmental investment and expenditures or generate financial returns, which lead to different financial impacts. Specifically, few studies have separately examined the effects of scopes 1, 2 and 3 CO_2 emissions, which result in the ability to distinguish the financial performance impacts of each scope of CO_2 emission and differentiate which type of environmental practices can reduce CO_2 emissions within the specific scopes. In this case, companies cannot effectively manage their CO_2 emission related risks and opportunities across the value chain, make informed resource allocation decisions and customize their environmental strategies and optimize practices for each scope CO_2 emission, while improving their financial performance. Thus, it is necessary to investigate scopes 1, 2 and 3 CO_2 emissions separately. Future studies could explore the financial impacts of scopes 1, 2 and 3 CO_2

emissions or the effects of each scope of CO_2 emissions on environmental practices.

Secondly, previous studies on "CO_2 emission and environmental practices", and "environmental practices and financial performance" primarily focused on integrated environmental practices (El Khoury et al., 2023; Giannarakis et al., 2017b), but they failed to differentiate them from individual environmental practices. For example, integrated environmental practices (using environmental pillar score provided in Refinitiv Eikon database as proxy) include three types of individual environmental practices, including emission reduction, resource use and environmental innovation practices (Refinitiv Eikon, 2023). However, previous studies have primarily focused integrated environmental practices and examine the effects of CO_2 emission on integrated environmental practices (Giannarakis et al., 2017b), and the effects of integrated environmental practices on financial performance (Miralles-Quirós et al., 2019). They failed to differentiate the effects of CO_2 emission on environmental practices of different dimensions (integrated vs. individual environmental practices), and the financial impacts of environmental practices of different dimensions. Thus, they cannot i) differentiate the effects of CO_2 emission on environmental practices in terms of integrated emission environmental practices and their individual environmental practices, including reduction, resource use and environmental innovation, and ii) distinguish financial performance implications of integrated emission environmental practices and their individual environmental practices separately. It is necessary to i) distinguish the effects of CO_2 emission on environmental practices of different dimensions as the investigation could guide companies to customize environmental strategies accordingly and optimize environmental practices for each scope CO_2 emission reduction; and ii) differentiate the financial impacts of environmental practices of different dimensions as the investigation enable managers to identify effective environmental practices, manage risks like fines or reputation damage, and ultimately enhance firms' financial performance. Without the relevant empirical evidence, some companies may consider implementing environmental practices will incur substantial environmental expenses and decrease their financial performance. This will discourage companies from adopting environmental practices. Carbon neutrality requires the concerted efforts of companies to implement more environmental practices as a means of reducing CO_2 emissions. Thus, future studies could investigate i) the impacts of CO_2 emissions on integrated environmental practices and their individual environmental practices; and ii) investigate how integrated environmental practices and their individual environmental practices influence financial performance, encouraging companies to implement more extensive environmental practices that contribute to reducing CO_2 emissions and enhancing their financial performance.

Thirdly, previous studies have identified corporate growth rate (Ganda, 2018), environmental certification (Tuesta et al., 2020), materiality industries, regional specificities (Ferrat, 2021), pay incentives (Adu et al., 2023), board independence (Kim et al., 2023), and consumer awareness (Sun et al., 2023) to explain the mixed findings on the relationship between CO_2 emission and financial performance. These factors are related to the context of the company (e.g., materiality industries, regional specificities), internal attributes (e.g., corporate growth rate, board independence), external recognition (e.g., environmental certification), and external stimuli (e.g., pay incentives, consumer awareness). Previous studies have ignored the significant role of environmental practices in the relationship between CO_2 emission and financial performance. Specifically, companies that emit CO_2 emission will face legitimate threats, and thus adopt environmental practices with the aim of reducing their CO_2 emissions. However, the implementation of environmental practices will incur environmental expenses or financial returns, which may have different financial impacts. Thus, future studies could explore the role of environmental practices in the relationship between CO_2 emission and financial performance to explain the mixed results for this relationship.

Finally, previous studies have mainly conducted research on the relationship between "CO_2 emission and financial performance" in Europe, Asia, and Africa, and "environmental practices and financial performance" in Asia, Europe, and Oceania. Future studies could explore these relationships beyond the explored areas in the literature.

Table 2-7 Summary of literature, identified research gaps, and future research direction.

Variable/Construct	Studies on CO_2 emission and financial performance	Studies on environmental practices and financial performance	Studies on CO_2 emission and environmental practices
CO_2 emission	Focus: • Scope 1 CO_2 emission • The sum of scopes 1 and 2 CO_2 emission • The sum of scopes 1, 2, and 3 CO_2 emission	-	Focus: • Scope 1 CO_2 emission, • Scope 2 CO_2 emission • The sum of scopes 1 and 2 CO_2 emission
Financial performance	Indicators of financial performance: ROA,ROE, ROI, ROS, profit margin, turnover, Tobin's q, market value, share price, TSR, EPS, and financial debt	Indicators of financial performance: ROA, ROE, net profit margin and operating profit margin, return on capital employed, return on invested capital, and Tobin’s q	

Environmental practices/scores	-	Environmental scores that reflect environmental practices obtained from different sources, including: • Refinitiv Eikon (reflecting Emission reduction, resource use and environmental innovation practices) • Bloomberg (reflecting environmental practices, including energy consumption, waste management, pollution control, conservation of natural resources etc.) • Korean Corporate Governance Service (reflecting environmental practices, including management practices addressing climate change, clean production, pollutant emissions, green marketing, and developing eco-friendly products)	Environmental scores that reflect different environmental practices: • Carbon disclosure score (different studies reflect different environmental practices, see details in *Section 2.4.4*) • Carbon Disclosure Leaders Index (reflecting environmental practices on control carbon, carbon communication and engagement, etc.) • Climate Performance Leadership Index (reflecting environmental practice on climate change mitigation, adaptation and transparency)

		• Sustainalytics (reflecting environmental practices, such as reducing emissions, effluents and waste, management of energy efficiency and GHG emissions of its products and services) • MSCI ESG KLD STATS (reflecting environmental practices, such as climate change, environmental management systems, biodiversity & land use, raw material sourcing etc.)	
		Environmental scores are interpreted in two ways: • focus on the performance of implementing environmental practices • focusing on environmental information disclosure that reflects environmental practices	The environmental score on CO_2 emissions and environmental practices mainly focuses on environmental information disclosure that reflects environmental practices

Identified research gaps	• Previous studies on "CO_2 emission and financial performance" and "CO_2 emission and environmental practices" investigated scope 1 CO_2 emission (Desai et al., 2022), scope 2 CO_2 emission (Giannarakis et al., 2017a), the sum of scopes 1 and 2 emissions (Luo & Tang, 2014) and the sum of scopes 1, 2 and 3 emissions (He et al., 2013). However, they ignored that CO_2 emission originates from different sources (i.e., scopes 1, 2 and 3 emissions). • Previous studies on "CO_2 emission and environmental practices", and "environmental practices and financial performance" primarily focused on integrated environmental practices (El Khoury et al., 2023; Giannarakis et al., 2017b), but they failed to differentiate them from individual environmental practices. • Previous studies investigated the factors related to the company's context (Ferrat, 2021), internal attributes (Ganda, 2018), external recognition (Tuesta et al., 2020), external stimuli (Adu et al., 2023) to explain the mixed findings of the relationship between CO_2 emission and financial performance, but they ignored the significant role of environmental practices in the relationship between CO_2 emission and financial performance. Specifically, companies that emit CO_2 will face legitimate threats, and thus adopt environmental practices with the aim of reducing their CO_2 emissions. Implementing environmental practices will positively (Hart, 1995) or negatively (Tang et al., 2022) affect financial performance. This suggests that CO_2 emission affects financial performance through environmental practices, and thus environmental practices may act as mediators in the relationship between CO2 emission and financial performance

Future research direction	• Future studies could explore the financial impacts of scopes 1, 2 and 3 CO_2 emissions or the effects of each scope of CO_2 emissions on environmental practices. • Future studies could investigate the impacts of CO_2 emissions on integrated environmental practices and their individual environmental practices, as well as the financial impacts of integrated environmental practices and their individual environmental practices. • Future studies could explore the role of environmental practices in the relationship between CO_2 emission and financial performance.

Chapter Summary

This chapter has systematically reviewed studies that examined the relationships between "CO_2 emission and financial performance", "environmental practices and financial performance", and "CO_2 emission and environmental practices". The results of a descriptive analysis, CNA, and MPA are presented to provide an overview of these relationships in the existing literature. Based on the analysis results, the research gaps are identified, and future research directions are proposed. To fill in the research gaps identified in this chapter, the chapters that follow will i) examine the role of environmental practices in the relationships between each scope of CO_2 emission and financial performance, ii) investigate the effects of each scope of CO_2 emission on integrated environmental practices and their individual environmental practices; and iii) the financial impacts of integrated environmental practices and their individual environmental practices. The specific details are discussed in Chapters 3 to 7.

Chapter 3 Theoretical foundation and hypothesis development

3.1 Introduction

This chapter discusses the theoretical foundation of this study, proposes a set of hypotheses, and develops a theoretical model to achieve the research objectives and answer the research questions presented in Chapter 1. Specifically, the legitimacy theory is used to propose hypotheses on the relationships between: i) scopes 1, 2, and 3 CO_2 emissions and financial performance in terms of ROA and Tobin's q, ii) scopes 1, 2, and 3 CO_2 emissions and environmental practices (i.e., integrated environmental practices, emission reduction practices, resource use practices, and environmental innovation practices); and iii) the relationships between environmental practices and financial performance. Finally, a theoretical framework is built to examine whether integrated environmental practices, and their individual practices-emission reduction, resource use, and environmental innovation practices, play mediating roles in the relationships between scopes 1, 2, and 3 CO_2 emission and financial performance. The specific details are provided in the following sections.

3.2 Theoretical foundation

3.2.1 Legitimacy theory

The theoretical foundation of this study is embedded in the legitimacy theory. Legitimacy is defined as a general perception that an organization's actions are appropriate, proper, desirable within the established social system of norms, values, beliefs, and definitions (Suchman, 1995). Legitimacy can also be described as an existence of condition or status which exists when the value system of an organization is consistent with that of the larger social system to which the organization belongs (Lindblom, 1994). Legitimacy is collectively determined by stakeholders (Deegan, 2006) and considered as the one of the conditions that facilitate stakeholders to accept the actions of an organization (Burlea & Popa, 2013). In addition, legitimacy can be viewed as a resource that is essential for the survival of an organization (Deegan, 2006; Dowling & Pfeffer, 1975) since organizations consider legitimacy to be a resource that can be impacted or manipulated through disclosure related strategies (Deegan, 2006).

While organizations aim to ensure that the social value of their activities aligns with the norms of acceptable behavior in the larger social system to which they belong. However, a disparity exists between the two systems, an actual or potential or potential threat of legitimacy will emerge (Deegan, 2006; Dowling & Pfeffer, 1975), which could in the form of legal, economic and social sanctions (Dowling & Pfeffer, 1975). When the legitimacy of a firm is threatened, the firms will legitimize the process primarily by focusing on stakeholder groups who have the necessary characteristics to confer or withdraw legitimacy (O'donovan, 2002). The legitimacy theory posits that organizations will be more inclined to act in a way that maintains or enhances their legitimacy when there is a greater likelihood of negative public perception as a result of their actions (O'donovan, 2002).

Suchman (1995) proposed three types of organization legitimacy. The first type of organizational legitimacy is pragmatic legitimacy, which is based on the self-interested calculation of the most immediate audience of an organization (Suchman, 1995). It is likely that the audience becomes the constituents who scrutinize the behaviors of the organization, which helps to determine the practical outcomes of any given activity line (Suchman, 1995). The constituents will consider the organization as legitimate when they perceive that they will benefit from the activities of the organization (Palazzo &

Scherer, 2006). Therefore, it is difficult for the organization to influence the constituents self-interested calculations of the usefulness of its procedures, structures, and leadership behaviors (Ashforth & Gibbs, 1990; Palazzo & Scherer, 2006). Cognitive legitimacy is the second type of organizational legitimacy, which is based on cognition instead of interest or evaluation (Suchman, 1995). Cognitive legitimacy emerges when the organizational activity is proven to be predictable, meaningful and inviting or based on the take-for-granted assumptions (Suchman, 1995). Cognitive legitimacy primarily works at the subconscious level, which poses challenges for organizations to directly exert strategic influence and manipulate perceptions (Palazzo & Scherer, 2006; Suchman, 1995). The third type of organizational legitimacy is moral legitimacy, which is based on judgements whether an activity of the organization is the right thing to do (Suchman, 1995). Moral legitimacy is based on prosocial logic and resists self-interested manipulation (Suchman, 1995). However, establishing legitimacy can be challenging since the legitimacy of a company is based on social values and perceptions, which can change and do change overtime (Deegan, 2006). Companies can however maintain their legitimacy by observing, anticipating, changing and protecting their previous efforts (Suchman, 1995).

In addition, Suchman (1995) proposed two main approaches to manage legitimacy, including the strategic and the institutional approaches. The former views legitimacy as the "operational resources" that are extracted competitively from their cultural environment and can be used by the organization to achieve its objectives. Strategic endeavors are often symbolic responses to pressure to demonstrate legitimacy, such as managers who prefer the flexibility and economy of symbolism (Ashforth & Gibbs, 1990; Suchman, 1995). Organizations tend to establish symbolic links with the highly respected values, symbols, or individuals that endorse their reputation accordingly (Ashforth & Gibbs, 1990; Palazzo & Scherer, 2006). Unlike a strategic managerial approach, the institutional approach considers legitimacy to be as a set of constitutive beliefs rather than an operational source (Suchman, 1995). Specifically, organizations not only extract legitimacy from the environment, but their legitimacy is constructed and penetrated by institutions external them in all aspects (Suchman, 1995). The organizations therefore obtain legitimacy from their culture environment, which decides how the organizations are established, run, understood and evaluated (Palazzo & Scherer, 2006; Suchman, 1995). Legitimacy is a process that is a continuous and unconscious adaptation, in which the organizations respond to external expectations (Palazzo & Scherer, 2006). The difference between the strategic approach and the institutional approach to legitimacy is that the former adopts the viewpoint that the organization managers of look "out", while the latter sees society as looking "in". Thus, organizations with legitimacy are those that are perceived and acknowledged by their stakeholders and society to have the right to exist and perform moral duties in society (Burlea & Popa, 2013).

3.2.2 Justifying the use of legitimacy theory

The legitimacy theory is used to explain the relationships among scopes 1, 2, and 3 CO_2 emissions, environmental practices, and financial performance, as well as the proposed research hypotheses of this study. The rationale for using the legitimacy theory are as follows：

The legitimacy theory provides reasonable explanations for the practical observations of business operations in relation to CO_2 emissions, environmental practices and financial performance. Specifically, the existence of companies depends on the willingness of a society to allow them to exist (Deegan, 2006; Relch, 1998), and thus companies need to comply with social norms or values to gain or maintain their legitimacy and ensure their continued existence. In this study, companies that generate CO_2 emission will face legitimacy threats, and thus adopt environmental practices with the aim of reducing their CO_2 emission to obtain legitimacy and ensure their continued existence. The implementation of environmental practices is a legitimacy process that helps these companies to meet environmental regulatory requirements, demonstrate their commitment to sustainability and social responsibility, reduce costs (e.g., compliance costs), improve operational efficiency, and enhance corporate reputation, ultimately attracting investment from investors, improving customers' loyalty and satisfaction and increasing sales, which all result in financial benefits (Hart, 1995) and thus positively affecting their financial performance.

Moreover, the legitimacy theory is appropriate for explaining social or moral dimensions of the role of a company in society (Haque & Ntim, 2020). In this study, implementing environmental practices for CO_2 emission reduction is considered as a legitimate action that reflects the social and moral responsibility of a company. In addition, the legitimacy theory involves three types of organizational legitimacy, including pragmatic legitimacy, cognitive legitimacy, and moral legitimacy. Each type of legitimacy is based on distinct behavioral dynamics (Suchman, 1995) (see details in *Section 3.2.1*), which could potentially provide a more nuanced, substantive, and in-depth explanation (Hsu et al., 2022) of the relationships among CO_2 emission, environmental practices, and financial performance. In addition, the legitimacy theory incorporates the strategic and institutional approaches of managing legitimacy (Suchman, 1995). This study focusses on the strategic approaches of managing legitimacy rather than institutional approaches of managing legitimacy since companies the emphasis is on how organizations manage their legitimacy to achieve their goals instead of emphasizing how constitutive social beliefs become embedded in organizations (Deephouse et al., 2017). Based on the above discussion, the legitimacy theory is considered to be appropriate for supporting the development of hypotheses in this study.

3.3 Hypothesis development

3.3.1 Effects of CO_2 emission on financial performance

Companies are social creations, and their existence depends on whether society allows them to exist (Deegan, 2006; Relch, 1998), which explains why long-term profit-maximization can be compatible with almost any socially worthwhile activity rather than those that are socially problematic (Relch, 1998). Reducing CO_2 emission is a socially worthwhile activity as it helps to decrease air pollution, alleviate the effects of GHGs, mitigate climate change, and promote sustainability.

Generally, the values of national legislation and social communities prescribe the action of businesses who view these rules and expectations of stakeholder groups as economic restrictions during their pursuit of profit maximization (Palazzo & Scherer, 2006). Nevertheless, legitimacy plays a crucial role in ensuring the continued existence of companies (Palazzo & Scherer, 2006). The legitimacy theory argues that companies need to consider the political environment in which they operate to gain or maintain legitimacy from a social-political perspective (DiMaggio & Powell, 1983). As environmental policies and regulations are enacted and enforced to reduce CO_2 emissions, environmental awareness is steadily increasing in society, which leads to the development of an established social system of norms and values that emphasize the importance of lowering CO_2 emissions, promoting sustainable practices and mitigating climate change. Thus, reducing scopes 1, 2, and 3 CO_2 emissions is an appropriate, proper, and desirable action of companies, which aligns with the social values or norms of acceptable behaviors for addressing CO_2 emissions in the larger social system, and contributes to the environmental legitimacy of companies, thereby ensuring their ongoing existence.

From the perspective of pragmatic legitimacy, companies that reduce their scopes 1, 2, and 3 CO_2 emissions strategically align with stakeholders self-interested calculations by enhancing their regulatory compliance, avoiding regulatory penalties and fines, mitigating climate-related risks. These tangible benefits help increase investors' confidence by lowering financial and investment risks. Moreover, companies with reduced scopes 1, 2, and 3 CO_2 emissions are perceived as environmentally responsible in their operational process, which will offer products or services that are both safer and healthier for their customers. Furthermore, companies with reduced scopes 1, 2 and 3 CO_2 emissions can achieve cost savings. For example, reducing scopes 1 CO_2 emissions (i.e., direct emissions from owned or controlled sources) by upgrading to energy-efficient facilities and equipment help companies to reduce energy and compliance costs; reducing scope 2 CO_2 emissions (i.e., indirect emissions from consumption of purchased electricity, heat, or steam) by using electricity from renewable sources help companies to reduce electricity expenses; and finally reducing scope 3 CO_2 emissions (i.e., indirect emissions from supply or value chain) by optimizing logistics and transportation routes help companies to reduce fuel and transport costs. These savings enable companies to offer products or services at lower prices, which enhance their market competitiveness and increase their return on investment, benefiting both customers and investors. As a result, companies with reduced scopes 1, 2 and 3 CO_2 emissions are viewed as legitimate. From the perspective of moral legitimacy, the public and company stakeholders perceive companies reducing scopes 1, 2, and 3 CO_2 emissions as doing the right thing (Suchman, 1995) since these practices contribute to reducing the effects of GHGs, mitigating climate change, protecting the ecosystem and biodiversity, and improving air quality. From the perspective of cognitive legitimacy, reducing CO_2 emissions is widely recognized to be an important step for the long-term environmental sustainability behavior of companies nowadays. Many policies and initiatives focus on reducing CO_2 emissions to mitigate global warming and climate change and ensure a sustainable future. Thus, reducing CO_2 emissions is a take-for-granted expectation since it is an inevitable stop for mitigating global warming and climate change, supported by the broad consensus among stakeholders, such as governments, policymakers, and investors, who serve as the most subtle and yet most powerful sources of legitimacy (Suchman, 1995).

The obtained pragmatic legitimacy, moral legitimacy, and cognitive legitimacy by reducing scopes 1, 2, and 3 CO_2 emissions can be regarded as operational resources that companies use to achieve their financial goals, which reflect the strategic view of legitimacy. This will encourage positive feedback of the companies, create the perception that these companies are environmentally responsible among their stakeholders (e.g., regulators, investors, and customers), enhances their corporate reputation, increases satisfaction and loyalty of their customers, attract investment from investors, lower the risks associated with regulation, and reduce financial losses related fines and penalties, ultimately contributing to a better financial performance.

The positive effects of CO_2 emission on financial performance are also discussed in the literature. For example, Yu et al. (2022) found that companies that are covered by the European Union Emissions Trading System (EU ETS) can improve their ROA by reducing CO_2 emissions. Companies can also reduce their cost of equity capital (Kim et al., 2015), ROI, and ROIC (Iwata & Okada, 2011). By improving their carbon performance, companies can increase their ROE and ROS (Ganda, 2018). In addition, companies that are actively participating in CO_2 emission reduction reap competitive advantages and thus have a better financial performance in terms of ROE compared with their competitors who take less proactive measures (Gallego-Álvarez et al., 2015). Therefore, reducing CO_2 emissions can lead to enhanced financial performance. In contrast, companies that emit more CO_2 can face legitimacy threats, such as legal, economic, and social sanctions (Burlea & Popa, 2013; Dowling & Pfeffer, 1975). For example, CO emission from EU ETS covered companies are regulated, scrutinized and priced by the EU ETS (Liu et al., 2023). Companies are mandated to buy carbon credits to compensate for their surplus carbon emissions if they cannot meet the EU ETS requirements to reduce their CO_2 emissions (European Commission, 2023). Otherwise, they will be penalized or fined or find themselves on a publicly disclosed list of penalized companies (European Commission, 2023), which all have adverse effects on corporate reputation, lead to increased compliance or liability costs, and ultimately lead to a poor financial performance (Cek & Eyupoglu, 2020; Gallego-Álvarez et al., 2015; Misani & Pogutz, 2015).

Based on the above discussion, companies reducing scopes 1, 2 and 3 CO_2 emissions can help them obtain legitimacy and thus enhance their financial performance. Therefore, the three following hypotheses, H_1-H_3, are proposed:

H_1: Companies with a reduction in scope 1 CO_2 emission will enhance their financial performance in terms of a) ROA and b) Tobin's q.

H_2: Companies with a reduction in scope 2 CO_2 emission will enhance their financial performance in terms of a) ROA and b) Tobin's q.

H_3: Companies with a reduction in scope 3 CO_2 emission will enhance their financial performance in terms of a) ROA and b) Tobin's q.

3.3.2 Effects of CO_2 emission on environmental practices

Based on the legitimacy theory, companies that generate CO_2 emissions will face legitimate threats, such as legal, economic, and social sanctions, which not only threaten corporate reputation and brand image, but also prompt critical assessment on the role of business in society. In this context, public trust is decreasing in corporate morality (Sethi, 2003), and thus the activities of companies will be closely scrutinized by government bodies and non-government organizations. Once the legitimacy of a company is threatened, the companies need to embark on progress to implement environmental practices that reduce their scopes 1, 2 and 3 CO_2 emissions.

This study examined integrated environmental practices and their individual practices, including emission reduction, resource use, and environmental innovation practices. Specifically, emission reduction practices include the practices of reducing environmental emission during production and operational processes (Refinitiv Eikon, 2023). Resource use practices incorporate practices of reducing the use of materials, energy or water, and enhancing eco-friendly solutions by improving supply chain management (Refinitiv Eikon, 2023). The environmental innovation includes practices that reduce the environmental costs and burden for customers and using innovative environmental technologies and processes or eco-designed products to create new market opportunities (Refinitiv Eikon, 2023). Integrated environmental practices involve the combined practices of emission reduction, resource use, and environmental innovation (Refinitiv Eikon, 2023). These practices and their individual environmental practices contribute to reducing scopes 1, 2 and 3 CO_2 emissions. In response to legitimacy threats resultant of producing CO_2 emissions, companies need to adopt these integrated environmental practices and their individual practices with the aim to reduce their scopes 1, 2 and 3 CO_2 emissions. The implementation of environmental practices for CO_2 emission reduction is the process towards legitimacy as companies can respond to social, environmental, political and economic pressures and obtain or maintain their right to operate (Dowling & Pfeffer, 1975; O'Donovan, 2002).

Companies with reduced scopes 1, 2, and 3 CO_2 emission demonstrate they implement integrated environmental practices and their individual practices aimed at reducing their carbon emissions. From the perspective of pragmatic legitimacy, stakeholders may perceive these companies are adept at implementing integrated environmental practices and their individual practices to reduce their carbon footprint, which enhance firms' legitimacy in the eyes of their stakeholders. For example, investors who value environmental responsibility and financial stability view companies with lower scopes 1, 2, and 3 CO_2 emissions as adept at implementing integrated environmental practices and their individual practices. This reduces regulatory or environmental liability risks, which in turn mitigate financial risks. As a result, companies are considered to have more stable and profitable investment, which leads to potentially higher returns. Consequently, such companies are seen as legitimate by investors. From the perspective of moral legitimacy, stakeholders will perceive that companies with reduced scopes 1, 2, and 3 CO_2 emissions by implementing integrated environmental practices and their individual practices as the right thing to do since these environmental practices contribute to mitigating global warming and climate change, which gives the perception that the companies are environmentally responsible, thus enhancing their legitimacy in the eyes of stakeholders. In this case, companies with reduced CO_2 emissions demonstrate their moral responsibility and their effectiveness in implementing integrated environmental practices and their individual practices for scopes 1, 2, and 3 CO_2 emissions reduction, and thus stakeholders view these companies to be legitimate. From the perspective of cognitive legitimacy, implementing integrated environmental practices and their individual practices is essential for reducing scopes 1, 2, and 3 CO_2 emissions. Cognitive legitimacy arises when organizational activity aligns with the widely acknowledged and taken-for-granted assumptions (Suchman, 1995). For example, several organizations (e.g., United Nations) view implementing environmental practices as a necessary aspect of the operation of a company, which is important for companies to effectively manage their CO_2 emissions. Without environmental practices, companies would struggle to address their scopes 1, 2, and 3 CO_2 emissions, which potentially threatens their legitimacy. Thus, companies with reduced CO_2 emissions demonstrate they can well implement integrated environmental practices and their individual practices for reducing CO_2 emissions, thus gaining or maintaining legitimacy.

From the strategic view of legitimacy, the legitimacy obtained by reducing CO_2 emission could serve as an operational resource to help companies achieve a better performance of implementing integrated environmental practices and their individual practices. Based on legitimacy theory, companies with lower scopes 1, 2, and 3 CO_2 emissions will enhance their performance in implementing integrated environmental practices and their individual practices. Thus, the following hypotheses, H_4-H_6, are proposed:

H_4: Companies with lower scope 1 CO_2 emission will enhance their performance in implementing the a) integrated environmental practices, b) emission reduction practices, c) resource use practices, and d) environmental innovation practices.

H_5: Companies with lower scope 2 CO_2 emission will enhance their performance in implementing the a) integrated environmental practices, b) emission reduction practices, c) resource use practices, and d) environmental innovation practices.

H_6: Companies with lower scope 3 CO_2 emission will enhance their performance in implementing the a) integrated environmental practices, b) emission reduction practices, c) resource use practices, and d) environmental innovation practices.

3.3.3 Effects of environmental practices on financial performance

Companies that generate CO_2 emissions are subjected to social and political pressure under which their legitimacy is monitored and conferred (Liu et al., 2023). In this case, companies will adopt environmental practices for reducing CO_2 emissions to attain legitimacy, improve their financial performance and protect the interests of their shareholders (Haque & Ntim, 2020). As discussed earlier, stakeholders perceive companies that implement integrated environmental practices and their individual environmental practices for CO_2 emission reduction to be doing the right thing (i.e., moral legitimacy), and implementing integrated environmental practices and their individual environmental practices is widely recognized for reducing scopes 1, 2 and 3 CO_2 emission and taken-for-granted as the means of reducing such emissions (i.e., cognitive legitimacy). Besides, stakeholders may view environmental practices of these companies to be beneficial (i.e., pragmatic legitimacy) since the implementation of these environmental practices align with social norms and values and demonstrate that they can effectively address environmental issues. For example, investors consider that their investments will be rewarded with high returns, not only because the implementation of integrated environmental practices and their individual environmental practices is the legitimacy process but also helps to reduce various risks (e.g., penalties, fines, or legal liabilities) that show the effectiveness of companies in addressing environmental issues. As a result, investors perceive these companies to be legitimate. Based on the above discussion, implementing environmental practices is the process towards legitimacy, and the resultant legitimacy from implementing the integrated environmental practices and their individual practices is considered to be an ability of the company (Pfeffer & Salancik, 2015) to address environmental issues. The outcomes associated with firm performance (Dowling & Pfeffer, 1975; Liu et al., 2023).

Based on the strategic view of legitimacy, legitimacy is considered to be an operational resource, which helps companies achieve their goals (Palazzo & Scherer, 2006). In this study, implementing integrated environmental practices and their individual practices can help companies obtain pragmatic, moral and cognitive legitimacy, which can financially benefit companies. Specifically, companies can well implement integrated environmental practices and their individual practices for CO_2 emission reduction demonstrate that they are committed to environmental responsibility and dedicated to mitigating climate change, thus contributing to establishing a positive corporate reputation and brand image among their stakeholders. This positive corporate image that stakeholders have of the company means that they are highly satisfied with the company and its products or services. For example, investors may perceive that companies that can well implement integrated environmental practices and their individual practices to be environmentally responsible, align with global emission reduction targets, and have excellent ability to address environmental issues, thereby they have confidence in the long-term sustainability and growth potential of the company. This perception further attracts other investors who prioritize environmental sustainability during their investment decisions. Environmentally conscious consumers also support companies that align with their values, which encourages them to promote these companies and their brands through positive word of mouth, thus further improving the brand image (Mazzucchelli et al., 2022) and corporate reputation, which cumulates in increased sales of the products and services of the company. As a result, companies will attract investment from investors and enjoy customer satisfaction and loyalty, which then leads to increased profitability and firm value (Hardiyansah et al., 2021). Moreover, companies that perform well in implementing environmental practices for CO_2 emission reduction show higher operational efficiency (e.g., resource or energy use efficiency) to address scopes 1, 2 and 3 CO_2 emissions, which contribute to reduced costs, such as lowering energy or raw material consumption costs, thus ultimately lowering their overall operational expenses. Besides, companies' positive performance in implementing integrated environmental practices and their individual practices helps companies reduce compliance costs so that they do not have to suffer fines, penalties, or related legal expenses, which consequently, contribute to the financial bottom line.

The positive effects of implementing environmental practices on financial performance are also shown in the existing literature. Previous studies find that integrated environmental practices is positively related to ROA (Brogi & Lagasio, 2019; Ortas et al., 2015; Velte, 2017), ROE (Alareeni & Hamdan, 2020; Kalia & Aggarwal, 2023), Tobin's q (Abdi et al., 2020; Mohammad & Wasiuzzaman, 2021; Ortas et al., 2015), stock prices (Miralles-Quiros et al., 2019; Yoon et al., 2018), and EPS (Ahmad et al., 2021). Based on the legitimacy theory, companies that implement integrated environmental practices and their individual practices with the aim to reduce scopes 1, 2 and 3 CO_2 emission will improve their financial performance. Thus, the following hypotheses, H_7-H_{10}, are proposed:

H_7: Companies that implement integrated environmental practices for scope 1, 2 and 3 CO_2 emission reduction will enhance their financial performance in terms of a) ROA and b) Tobin's q

H_8: Companies that implement emission reduction practices for scope 1, 2 and 3

CO_2 emission reduction will enhance their financial performance in terms of a) ROA and b) Tobin's q

H_9: Companies that implement resource use practices for scope 1, 2 and 3 CO_2 emission reduction will enhance their financial performance in terms of a) ROA and b) Tobin's q

H_{10}: Companies that implement environmental innovation practices for scope 1, 2 and 3 CO_2 emission reduction will enhance their financial performance in terms of a) ROA and b) Tobin's q

3.3.4 Mediating role of environmental practices

Previous studies have primarily focused on firms' characteristics (e.g., materiality industries) or external influences (e.g., pay incentives, consumer awareness) to explain the mixed findings on the relationship between CO_2 emission and financial performance, but neglected that environmental practices play a significant role in the relationship between CO_2 emission and financial performance.

Based on the legitimacy theory, firms that generate CO_2 emission will face legitimacy threats and therefore implement integrated environmental practices and their individual practices with the aim to reduce emissions. Thus, companies with reduced scopes 1, 2 and 3 CO_2 emissions show that they are effectively implementing integrated environmental practices and their individual practices to reduce scopes 1, 2, and 3 CO_2 emissions, which result in better performance in implementing integrated environmental practices and their individual environmental practices (see details in *Section 3.3.2*). In contrast, companies that emit more CO_2 show that they are not effective in implementing integrated environmental practices and their individual environmental practices, and the result is a poor performance in implementing such practices. Based on the above discussion, scopes 1, 2, and 3 CO_2 emission variations (i.e., increase or decrease) are negatively related to the performance in implementing integrated environmental practices and their individual environmental practices.

Moreover, based on the legitimacy theory, companies legitimate their carbon behaviors by implementing integrated environmental practices and their individual practices, which suggest that these practices serve as their operational resources and capability to address environmental issues, which have positive impacts on their financial performance (see details in *Section 3.3.3*).

Based on the above discussion, it is proposed in this study that implementing integrated environmental practices and their individual environmental practices represent the legitimacy process of firms, which reflects their capability to address CO_2 emission across all scopes. The legitimacy then enhances the financial performance of these companies. As such, it is predicted that integrated environmental practices and their individual environmental practices are potential mediators in the relationship between each scope of CO_2 emission variation and financial performance. Specifically, i) an increase in each scope of CO_2 emission decreases the performance in implementing integrated environmental practices and their individual practices, while the decrease in each scope of CO_2 emission increases the performance in implementing integrated environmental practices and their individual practices. Thus, it is anticipated that each scope of CO_2 emission variation negatively related to the performance in implementing integrated environmental practices, emission reduction practices, resource use practices and environmental innovation practices, and ii) it is anticipated that the implementation of integrated environmental practices and their individual practices for reducing scopes 1, 2 and 3 CO_2 emissions will have positive impacts on financial performance in terms of the ROA and Tobin's q. In sum, it is anticipated that each scope of CO_2 emission variation affects financial performance through the negative mediating effects of integrated environmental practices and their individual practices. Thus, the following hypotheses, H_{11}-H_{14}, are proposed:

H_{11}: Integrated environmental practices have negative mediating effects on the relationships between a) scope 1 CO_2 emission variation and ROA; b) scope 2 CO_2 emission variation and ROA; c) scope 3 CO_2 emission variation and ROA; d) scope 1 CO_2 emission and Tobin's q; e) scope 2 CO_2 emission variation and Tobin's q; f) scope 3 CO_2 emission variation and Tobin's q

H_{12}: Emission reduction practices have negative mediating effects on the relationships a) scope 1 CO_2 emission variation and ROA; b) scope 2 CO_2 emission variation and ROA; c) scope 3 CO_2 emission variation and ROA; d) scope 1 CO_2 emission and Tobin's q; e) scope 2 CO_2 emission variation and Tobin's q; f) scope 3 CO_2 emission variation and Tobin's q

H_{13}: Resource use practices have negative mediating effects on the relationships between a) scope 1 CO_2 emission variation and ROA; b) scope 2 CO_2 emission variation and ROA; c) scope 3 CO_2 emission variation and ROA; d) scope 1 CO_2 emission and Tobin's q; e) scope 2 CO_2 emission variation and Tobin's q; f) scope 3 CO_2 emission variation and Tobin's q

H_{14}: Environmental innovation practices have negative mediating effects on the relationships between a) scope 1 CO_2 emission variation and ROA; b) scope 2 CO_2 emission variation and ROA; c) scope 3 CO_2 emission variation and ROA; d) scope 1

CO_2 emission and Tobin's q; e) scope 2 CO_2 emission variation and Tobin's q; f) scope 3 CO_2 emission variation and Tobin's q

Figure 3-1 shows the theoretical framework of this study.

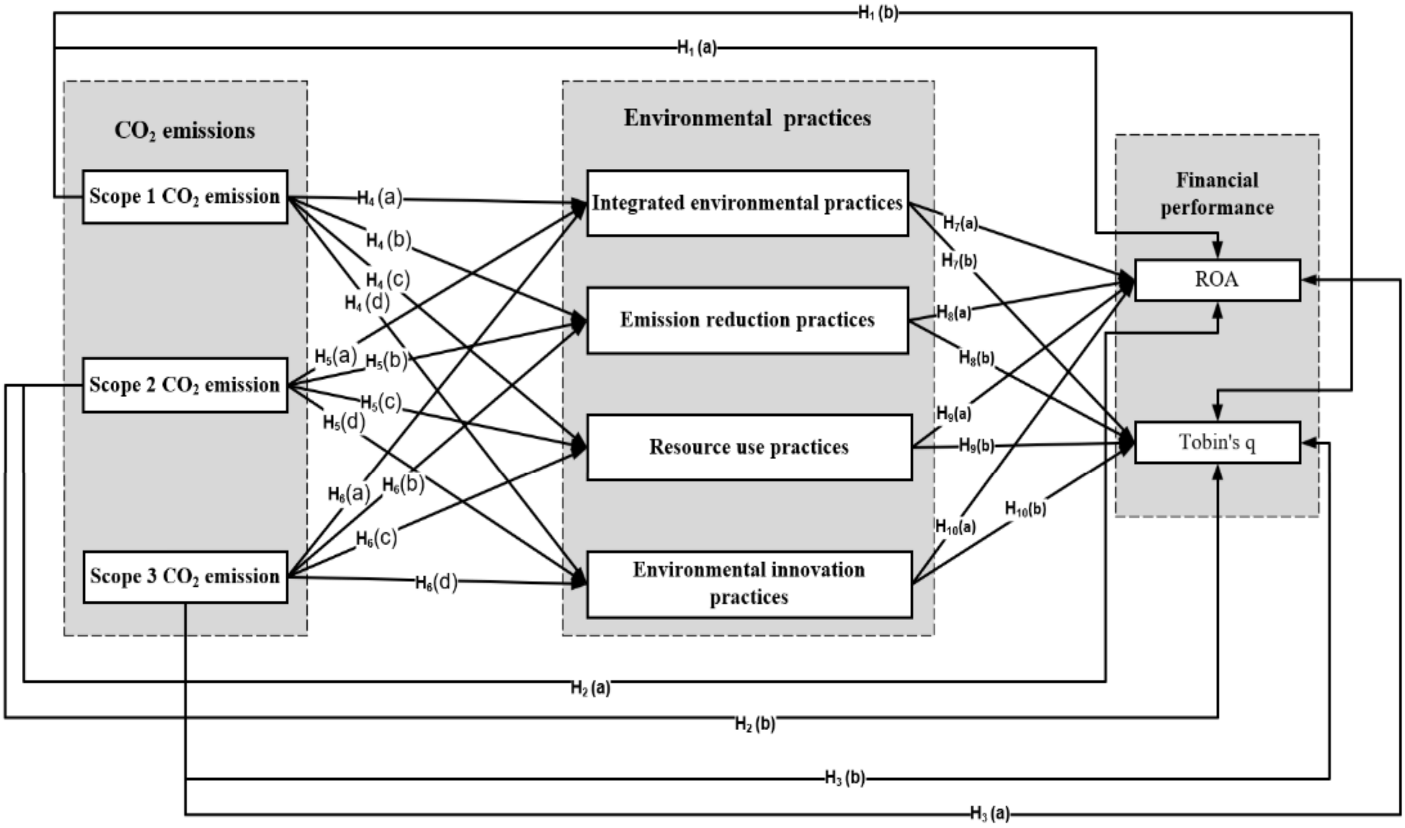

Figure 3-1. Theoretical framework of the relationship between CO_2 emission, environmental practices and financial performance

Chapter summary

Based on the legitimacy theory, the following are developed in the chapter: i) H_1-H_3 on the relationships between "each scope of CO_2 emission (i.e., scopes 1, 2 and 3) and financial performance in terms of ROA and Tobin's q", which help to achieve *Research Objectives 2* that proposed in Chapter 1; ii) H_4-H_6 on the relationship between "each scope of CO_2 emission and environmental practices in terms of integrated environmental practices, emission reduction practices, resource use practices and environmental innovation practices", which help to achieve *Research Objectives 3* as stated in Chapter 1; iii) H_7-H_{10} on the relationship between environmental practices (i.e., integrated environmental practices, emission reduction practices, resource use practices and environmental innovation practices) and financial performance in terms of ROA and Tobin's q, which help to achieve *Research Objectives 4* proposed in Chapter 1; and iv) H_{11}-H_{14} for the negative mediating effects of environmental practices in the relationship between each scope of CO_2 emission variation and financial performance, which help to achieve *Research Objectives 1* as stated in Chapter 1. In Chapter 4, this study describes the research methodology and establishes econometric models for testing the proposed hypotheses.

Chapter 4 Research methodology

4.1 Introduction

In this chapter, the research methodology is discussed, which is designed to test the hypotheses proposed in Chapter 3 and accomplish Research Objectives 1-4 outlined in Chapter 1. With regard to the research methodology, the empirical background of this study is discussed, the selection of sample firms is justified, the sources of the data and the process to form the final dataset are elaborated. In addition, the definitions and measurements of all the variables examined in this study are provided. Moreover, descriptive statistical and correlation analyses of all of the variables examined in this study are conducted by using data collected from 122 companies in different industries worldwide. Furthermore, the analysis methods used are outlined, the model selection is justified, and econometric models are established. Finally, the process for conducting the robustness test to validate the results is elaborated. The specific details are given in the following sections.

4.2 Selection of sample firms and data collection

4.2.1 Empirical context

The current plan of the United Nations to reduce CO_2 emissions by 43% by 2030 is at risk and may not be successfully realized, with the projection instead indicating an approximately 11% increase in CO_2 emissions by 2030 (United Nations Climate Change, 2022). This shows that the current endeavors to reduce CO_2 emissions are insufficient to reach the predefined emission reduction target. Companies play a key role in reducing CO_2 emissions since they are the producers of CO_2 emissions and also are participants in the global efforts to mitigate CO_2 emissions. Although a growing number of companies are participating in reducing CO_2 emissions under pressure from regulatory bodies and stakeholders, their efforts are not sufficient enough to achieve the predefined CO_2 emission reduction goals. This indicates that these companies lack motivation to adopt extensive environmental practices that reduce their CO_2 emissions. Therefore, it is necessary to investigate the reasons why companies lack motivation to adopt extensive environmental practices to reduce CO_2 emissions, which can show why current efforts of companies cannot reach the predefined CO_2 emission reduction target.

To address this, firms that have participated in reducing CO_2 emissions are selected as the sample firms in this study (see justification of selection of sample firms in *Section 4.3*). This enables us to explore why companies participating in CO_2 emissions lack willingness to take extensive environmental practices to reduce CO_2 emission, which provide empirical insights that can guide them to adapt their environmental strategies, as well as policymakers to develop or refine environmental regulations accordingly.

4.2.2 Sample firms

As stated earlier, firms that are engaged in reducing CO_2 emissions are selected for the sample in this study, particularly those that have participated in carbon credit/offset practices since they have made the efforts in reducing CO_2 emission reduction already. Specifically, carbon credit and carbon offset are financial instruments used to encourage firms to reduce their CO_2 emissions and be more environmentally responsible. Carbon credit refers to a reduction in CO_2 emissions from the atmosphere. One carbon credit is equivalent to one metric tons of CO_2 (or other GHG) released to the atmosphere (Gupta, 2011). Companies in certain sectors (e.g., manufacturing sector) have quotas on their CO_2 emissions. If they exceed this limit, they can purchase carbon credit to balance their emissions. Besides, companies could keep the remainder of the credits to use them in the future or sell them (Gupta, 2011) if they reduce their emissions through environmental practices. However, if companies have excessive emissions but do not buy carbon credits to balance their emissions, they will be penalized or fined. Using carbon credit can motivate companies to be more environmentally friendly so that firms can increase their earnings by selling their remaining credits (Gupta, 2011). Carbon offset means removal of CO_2 emissions from the atmosphere. One carbon offset credit equals 1 metric ton of CO_2 (or other GHG) reduction in the atmosphere (Gupta, 2011). Carbon offsets contribute to promoting renewable or green energy options (e.g., wind farms), and supporting projects on natural conservations (e.g., planting trees to offset carbon emissions (Gupta, 2011). Companies that implement carbon offset practices can contribute to reducing their CO_2 emissions. Based on the above discussion, companies that implement carbon credit/offset practices are firms that have participated in reducing CO_2 emissions, and thus they can be included as sample firms in this study.

4.2.3 Data source

The data of all of the variables examined were collected from the Refinitiv Eikon DataStream database (hereafter DataStream). This study uses DataStream as the primary source of data for the following reasons. First, DataStream is a historical financial database that consists of 35 million indicators that cover all major asset classes, including 8.5 million economic indicators that are currently active (Refinitiv, 2023). Second, DataStream not only offers data on equities, equity indices, fixed income, interest rates and other financial, accounting and macroeconomics indicators, but also provides access to environmental, social and corporate governance data (Refinitiv, 2023). Third, DataStream has unique contents, including point-in-time data, Worldscope fundamentals, I/B/E/S estimates aggregates and Reuters Polls. Fourth, DataStream is frequently used by researchers as it provides data with transparency and high quality (Shakil et al., 2019). Most importantly, this study examines the relationships among CO_2 emission, environmental practices, and financial performance. The data that pertain to CO_2 emissions (i.e., scopes 1, 2, and 3 CO_2 emissions), environmental practices (e.g., environmental pillar score that reflect integrated environmental practices of emission reduction, resource use, and environmental innovation), and financial performance (i.e., ROA, Tobin's q) can be obtained from DataStream. Therefore, the DataStream database is appropriate for this study.

4.2.4 Data collection process

The data collection process of this study is divided into four steps. First, firms that participated in reducing CO_2 emissions were selected as the sample firms based on whether they have data on carbon credit/offset practices in the DataStream database. In other words, if a company has carbon credit/offset data during the period of 2008-2021, this company was considered for the firm list. Firms in different industries and countries are selected because the empirical evidence obtained from companies that are distributed in various industries and countries can i) reduce biased in the results and ensure that the findings not overly influenced by the specific characteristics of certain industries or countries; ii) increase the external validity of this study, which facilitate more generalizable conclusions about companies that have acted to reduce CO_2 emission, thus making the findings applicable across various industries and countries; and iii) provide insights from companies in different industries and countries to inform practitioners or policymakers to adjust environmental strategies in addressing CO_2

emissions or relevant environmental regulations. Meanwhile, we checked the data availability on scopes 1, 2 and 3 CO_2 emissions, and companies have no CO_2 emissions data were removed. The first step provides a list with 141 firms.

Second, the Refinitiv Instrument Codes (RICs) of these firms were collated based on the list with 141 firms, which were used to collect the data of other variables examined in this study from DataStream. The following data were downloaded: i) mediating variables: environmental practices (i.e., environmental pillar score and its component scores, including emission reduction, resource use and environmental innovation scores); and ii) dependent variables: ROA and Tobin's q. Besides, control variables were incorporated to minimize confounding effects, including firm size, net sales revenue, capital intensity, emission intensity, ISO 14001 or EMS certification, and leverage.

Third, the collected data were merged and companies with missing data on the mediators, dependent variables and control variables were excluded. The final sample size was 122 firms that represented a panel of 972 firm-years observations over a 14-year period of time.

As shown in Table 4-1, the sample firms are distributed in 29 countries worldwide. Specifically, the sample firms are located in different continents and regions, including Europe (39.344%), North America (37.705%), Asia (14.754%), South America (3.279%) and Oceania (4.918%).

Table 4-1 Geographical distribution of sample firms.

Continents and regions	Country	No. of firms	Percentage of total sample firms (%)
Europe	United Kingdom	9	7.377%
	Switzerland	8	6.557%
	France	7	5.738%

	Germany	7	5.738%
	Italy	4	3.279%
	Netherlands	3	2.459%
	Belgium	2	1.639%
	Spain	1	0.820%
	Denmark	1	0.820%
	Portugal	1	0.820%
	Finland	1	0.820%
	Norway	1	0.820%
	Sweden	1	0.820%
	Hungary	1	0.820%
	Czech Republic	1	0.820%
Asia	Japan	5	4.098%
	Hong Kong, China	3	2.459%
	Turkey	3	2.459%
	Taiwan, China	2	1.639%
	Thailand	2	1.639%
	Mainland China	1	0.820%
	Singapore	1	0.820%
	United Arab Emirates	1	0.820%
South America	Chile	2	1.639%
	Brazil	1	0.820%
	Colombia	1	0.820%
North America	United States	41	33.607%
	Canada	5	4.098%
Oceania	Australia	6	4.918%
Total		122	

Table 4-2 shows that the sample firms are distributed in eight industry sectors based on the four-digit standard industrial classification (SIC) code. To be more specific, the sample firms are classified into sectors that include finance, insurance, real estate (33.607%), manufacturing (24.590%), transportation and public utilities (17.213%), services (9.836%), retail trade (7.377%), mining (3.279%), wholesale trade

(2.459%), and construction (1.639%) sectors. These sectors are crucial for this study as they contribute to scopes 1, 2 and 3 emissions in different ways, and companies within each sector will adopt different environmental practices to address emissions from different scopes, which in turn have different financial implications. By including sample companies from different industries, this study increases its external validity, allowing more generalizable conclusions and broader applicability of the findings across various industries. The examples of companies in each sector that generate CO_2 emissions across different scopes and adopt relevant environmental practices are shown as follows:

i) Finance, insurance, and the real estate sector contribute to scope 1 emission, (e.g., the operation of office building-heating), scope 2 emissions (e.g., using purchased electricity for offices), and scope 3 emission (e.g., financing fossil fuel projects, insuring for high-emission industries, or transportation of construction materials). Companies in these sectors will adopt different environmental practices to reduce their scope 1 emission (e.g., improving energy efficiency in offices), scope 2 emission (e.g., designing green building), and scope 3 emission (e.g., financing low-carbon projects, developing green insurance products, and implementing sustainable construction practices).

ii) Manufacturing industry contributes to scope 1 emission (e.g., energy-intensive production processes), scope 2 emission (e.g., using purchased electricity for factory operations), and scope 3 emission (e.g., raw material logistics). Manufacturing companies will adopt different environmental practices to reduce scope 1 emission (e.g., using high-efficiency machinery), scope 2 emission (e.g., upgrading factory equipment to more energy-efficient technologies), and scope 3 emission (e.g., transitioning to cleaner vehicles).

iii) Transportation and public utilities industry contributes to scope 1 emission (e.g., fuel combustion in vehicles), scope 2 emission (e.g., using electricity used for operations), and scope 3 emission (e.g., fuel supply chains). Firms in these sectors will adopt different environmental practices to reduce their scope 1 emission (e.g., using electric vehicles), scope 2 emission (e.g., using renewable energy) and scope 3 emission (e.g., using low-carbon fuels).

iv) Service industry contributes to scope 1 emission (e.g., using company owned vehicles), scope 2 emission (e.g., energy for offices or data centers operation), and scope 3 emission (e.g., business travel). Companies in this industry will adopt different environmental practices to reduce their scope 1 emission (e.g., using biofuels), scope 2 emission (e.g., purchasing electricity from renewable energy providers or using energy-efficient models in data center), and scope 3 emission (e.g., using electric and hybrid vehicles).

v) Retail trade industry generates scope 1 emission (e.g., refrigeration and delivery fleets), scope 2 emissions (e.g., energy use in warehouses), and scope 3 emission (e.g., packaging materials). Companies in the retail trade sector will adopt different environmental practices to reduce their scope 1 emission (e.g., transition to natural refrigerants or electrification of delivery fleets), scope 2 emission (e.g., using energy-efficient equipment), and scope 3 emission (e.g., reusable packaging).

vi) Mining industry contributes to scope 1 emission (e.g., using mining equipment that runs on diesel or gasoline), scope 2 emission (e.g., using energy for extraction and processing), scope 3 emission (e.g., transporting mined materials). Mining firms will adopt different environmental practices for reducing their scope 1 emission (e.g., using low-carbon alternative fuels), scope 2 emission (e.g., using renewable energy sources), scope 3 emission (e.g., transitioning to electric or hybrid transportation).

vii) Wholesale trade industry contributes to scope 1 emission (e.g., using the owned trucks or fleets that runs on diesel or gasoline), scope 2 emission (e.g., electricity used in warehouse or distribution centers), scope 3 emission (e.g., transporting goods from suppliers to warehouse). Companies in the wholesale trade industry will adopt different environmental practices to mitigate their scope 1 emission (e.g., using vehicles that run on liquefied natural gas), scope 2 emission (e.g., upgrading heating, ventilation, and air conditioning systems in warehouses or distribution centers), and scope 3 emission (e.g., using electric or hybrid vehicles for transportation).

viii) Construction industry generates scope 1 emission (e.g., using heavy machinery and construction equipment that run on diesel or gasoline), scope 2 emission (e.g., electricity consumption at construction sites), scope 3 emission (e.g., transportation of construction materials). Construction companies will adopt different environmental practices to address their scope 1 emission (e.g., using electric heavy or hybrid machinery), scope 2 emission (e.g., use of renewable energy sources), and scope 3 emission (e.g., using recycled materials).

Table 4-2 Industry sectors of sample firms.

Industry sector	SIC code	No. of observations	No. of firms

Finance, insurance, real estate	6000-6799	367	41
Manufacturing	2000-3999	240	30
Transportation & public utilities	4000-4999	131	21
Services	7000-8999	102	12
Retail trade	5200-5999	76	9
Mining	1000-1499	30	4
Wholesale trade	5000-5199	17	3
Construction	1500-1799	9	2
Total	-	972	122

4.3 Measurements

In this section, the conceptions and measurements of the independent variables, dependent variables, mediating variables, and control variables are discussed (see Table 4-3).

4.3.1 Independent variables

The Greenhouse Gas Protocol Corporate Standard categorized CO_2 emissions of corporate into three scopes (i.e., scopes 1, 2, and 3) for CO_2 accounting and reporting purposes, which help companies to identify direct and indirect sources of CO_2 emissions, increases the transparency of CO_2 emissions, and better manages the risks and opportunities of CO_2 emissions along the value chain effectively (Greenhouse Gas Protocol, 2004). In this study, CO_2 emissions are the independent variable, scope 1, 2 and 3 CO_2 emissions are the focus. Specifically, scope 1 CO_2 emission variation was used as the proxy of scope 1 CO_2 emission, scope 2 CO_2 emission variation was used as the proxy of scope 2 CO_2 emission, and scope 3 CO_2 emission variation was used as the proxy of scope 3 CO_2 emission. Following previous studies (Gallego-Álvarez et al., 2015; Hart & Ahuja, 1996), scope 1, 2 and 3 CO_2 emission variations were determined by calculating the change in percentage in scope 1, 2 and 3 CO_2 emissions for each company. The symbol delta (Δ) represents variations.

Scope 1 CO_2 emission variation ($\Delta CO_2 1$**)**. "Scope 1 CO_2 emission" is the direct CO_2 and CO_2 equivalent emissions (e.g., methane, nitrous oxide, hydrofluorocarbons, perfluorinated compound, sulfur, hexafluoride, nitrogen trifluoride, sulfur hexafluoride, and nitrogen trifluoride), which are generated from sources that are owned or controlled by companies. For example, chemical production emissions generated in owned or controlled process equipment (Greenhouse Gas Protocol, 2004). Scope 1 CO_2 emission variation is calculated the as the change in percentage of annual "scope 1 CO_2 emission" at time *t* compared with annual "scope 1 CO_2 emission" at time *t-1* by using the following equation:

$$\Delta CO_2 1 = \frac{Current\ period\ scope\ 1\ CO_2 emission\ -\ Prior\ period\ CO_2 emission\ scope\ 1}{Prior\ period\ scope\ 1\ CO_2 emission}$$

Scope 2 CO_2 emission variation ($\Delta CO_2 2$**).** "Scope 2 CO_2 emission" refers to the indirect CO_2 and CO_2 equivalent emissions (e.g., methane, nitrous oxide, hydrofluorocarbons, perfluorinated compound, sulfur hexafluoride, nitrogen trifluoride, sulfur hexafluoride, and nitrogen trifluoride), which are emitted by the consumption of purchased electricity, heat or steam in the facility where electricity, heat or steam are produced. Scope 2 CO_2 emission variation is calculated as change in percentage in annual "scope 2 CO_2 emission" at time *t* compared with annual "scope 2 CO_2 emission" at time *t-1* using the following equation:

$$\Delta CO_2 2 = \frac{Current\ period\ scope\ 2\ CO_2 emission\ -\ Prior\ period\ scope\ 2\ CO_2 emission}{Prior\ period\ scope\ 2\ CO_2 emission}$$

Scope 3 CO_2 emission variation ($\Delta CO_2 3$**).** “Scope 3 CO_2 emission” encompasses other indirect emissions from sources that are not owned or managed by the company, which occur in the upstream and downstream of supply chain of a firm. For example, CO_2 emission generated from i) vehicles owned by contractors, employee business travel by air or rail, outsourcing, and waste treatment; and ii) product use of customers, purchased materials production, electricity purchased for resale. Scope 3 CO_2 emission are often higher than scopes 1 and 2 CO_2 emissions combined. Scope 3 CO_2 emission variation is calculated as the change in percentage in annual “scope 3 CO_2 emission” at time *t* compared with annual “scope 3 CO_2 emission” at time *t-1* by using the following equation:

$$\Delta CO_2 3 = \frac{Current\ period\ scope\ 3\ CO_2 emission\ -\ Prior\ period\ scope\ 3\ CO_2 emission}{Prior\ period\ scope\ 3\ CO_2 emission}$$

In sum, scopes 1, 2 and 3 CO_2 emission variations indicate the changes in percentages in scope 1, 2 and 3 CO_2 emissions, with an increase or decrease in CO_2 emissions for each scope.

4.3.2 Dependent variables

Financial performance is used as the dependent variable in this study. ROA and Tobin’s q are used as the proxies of financial performance since they capture different dimensions of financial performance (Busch et al., 2022; Delmas et al., 2015).

Specifically, ROA is an accounting-based indicator of financial performance, while Tobin's q is a market-based indicator of financial performance. Accounting-based indicators are used to measure the profitability of firms in the short-term (Busch et al., 2022; Sun et al., 2023), whereas market-based indicators are used to measure the ability of a company to achieve sustainable development in the long-term (King & Lenox, 2002; Sun et al., 2023) and gauge investors long-term perceptions regarding corporates' future profitability (Delmas et al., 2015). Tobin's q considers the market value of a firm, and thus can reflect intangible attributes that cannot be captured by ROA (Delmas et al., 2015). Therefore, ROA and Tobin's q provide complementary information on financial performance (Delmas et al., 2015), to facilitate a differential evaluation of the relationship among CO_2 emissions, environmental practices, and financial performance in terms of the ROA and Tobin's q. Data on the ROA and Tobin's q were collected from DataStream.

Return on assets. ROA is calculated as the net income of a company before financing costs divided by its total assets, which is a profitability ratio that measures how much profit a company generates per unit of asset and evaluates the profitability of the total assets of a firm (Sun et al., 2023). The formula to calculate ROA is:

$$ROA = \frac{Net\ income\ before\ financing\ costs}{Total\ assets}$$

Tobin's q. The simplified approximation of Tobin's q proposed by Chung and Pruitt (1994) is used in this study. Tobin's q is calculated by dividing the sum of the market value, preferred stock and debt by total assets, which reflect the expected future gains (King & Lenox, 2002) and the expectations of the capital market (Bendig et al., 2023).The formula to calculate Tobin's q is:

$$Tobin's\ q = \frac{Market\ value + Preferred\ stock + Debt}{Total\ assets}$$

where *Market value* is equal to the share price multiplied by the number of ordinary shares issued. *Preferred stock* represents the liquidating value of the outstanding preferred stock of the company. *Debt* is the long-term plus short-term debt and current portion of long-term debt.

4.3.3 Mediating variables

Environmental practices are the mediating variable in this study, which refers to the practices that companies adopt to reduce scopes 1, 2 and 3 CO_2 emissions in their business operations. In this study, the environmental scores are used as the proxies of environmental practices. Specifically, the environmental pillar score is used as the proxy of integrated environmental practices, and its component scores (i.e., emission reduction, resource use and environmental innovation scores) as the proxies of the individual practices, including emission reduction, resource use, and environmental innovation practices. These scores are appropriate for this study for the following reasons.

First, based on the definitions provided by Refinitiv Eikon (2023), they reflect environmental practices and evaluate the environmental performance of firms in implementing environmental practices. Specifically, the *emission reduction score* reflects the commitment and effectiveness of a company in reducing its environmental emissions during production and operational processes, which is calculated by Refinitiv Eikon using 28 metrics that related to emissions, waste, biodiversity and environmental management system (Refinitiv Eikon, 2023). The r*esource use score* measures the performance and ability of a company to decrease use of materials, energy or water, and enhance eco-friendly solutions by improving supply chain management (Refinitiv Eikon, 2023). The score calculated by Refinitiv Eikon is derived using 20 metrics that related to water, energy, sustainable packaging and environmental supply chain. The *environmental innovation score* measures the ability of a company to reduce their environmental expenses and burdens for its customers, as well as create new market opportunities via the use of innovative environmental technologies and processes, or eco-designed products, which is calculated by Refinitiv Eikon using 20 metrics that related to product innovation, Green revenues, research and development and capital expenditures (Refinitiv Eikon, 2023). The e*nvironmental pillar score* is calculated by using the weighted average relative rating of a firm based on its disclosed environmental information and the resultant three environmental category scores, including emission reduction, resource use, and environmental innovation scores (Refinitiv Eikon, 2023). The metrics for calculating emission reduction score, resource use score, and environmental innovation score are shown in the Appendix.

Second, previous studies (Kong et al., 2023; Miralles-Quiros et al., 2019; Ortas et al., 2015; Shakil et al., 2019; Velte, 2017) use the environmental pillar score that obtained from the DataStream as the proxy of environmental performance, which reflects integrated environmental practices.

4.3.4 Control variables

In this study, control variables include the firm size (Nishitani & Kokubu, 2012; Wahba, 2008), net sales revenue (Trinks et al., 2020), capital intensity (Trumpp & Guenther, 2017; Wang et al., 2014), emission intensity (Luo & Tang, 2014), ISO 14001 or EMS certification, and leverage.

Firm size is considered to be a relevant factor that could determine companies' behavior to adopt environmental practices and address CO_2 emission. First, large firms are likely to have more resources that could improve firm's ability to adopt environmental practices for CO_2 emission reduction. Second, a firm's size may reflect to what extent the firm is visible to the public, since a large firm is either seen as industry leader or tends to have more environmental risks. Third, firm size is related to the existence of scale of economies inherent in environmental investment. Thus, firm size is included as a control variable in considering firms resources, the scale of economies and public visibility of a firm (Wahba, 2008).

Net sales revenue. The primary objective of companies is to maximize the direct value of their produced products or services (Trinks et al., 2020). Although net sales revenue reflects the monetary value of products or services, the process of the production of the goods or services involves business activities that may contribute to CO_2 emissions. Thus, net sales revenue is included as a control variable and the natural logarithm of net sales revenues is used in this study.

Capital intensity. Calculated by dividing total assets by operating income. A high capital intensity ratio indicates that companies need a large amount of total assets to generate operating income, which leads to an increase in resource demand and CO_2 emissions. In contrast, a low capital intensity ratio implies that firms use a small part of their assets to generate operating income efficiently, thus suggesting that the companies have better resource management and consume less resources and emit less CO_2. Besides, companies with high capital intensity invest in growth opportunities and profit more than those with lower capital intensity (Lewandowski, 2017). The formula to calculate capital intensity is shown as follows:

$$Capital\ Intensity = \frac{Total\ \ assets}{Operating\ \ income}$$

Emission intensity. Calculated by dividing total CO_2 emissions (i.e., the sum of scopes 1, 2 and 3 CO_2 emissions) by net sales revenue. A high CO_2 emission ratio suggests that the companies are associated with higher CO_2 emissions per unit of net sales revenue, which reflects companies have poor performance in reducing carbon emissions. A low CO_2 emission ratio indicates that the companies emit less emission lower CO_2 emission per unit of net sales revenue, which reflects their better performance in reducing carbon emissions. The formula to calculate emission intensity is as follows:

$$Emission\ Intensity = \frac{Scope\ 1\ CO_2 emission\ +\ Scope\ 2\ CO_2 emission\ +\ Scope\ 3\ CO_2 emission}{Net\ sales\ revenue}$$

ISO 14001 or EMS certification. The aim of ISO 14001 is to improve the environmental management practices of companies (Garrido et al., 2020). To obtain International Organization for Standardization (ISO) 14001 certification, firms are required to formulate and implement an environmental management action plan, establish priorities and objectives for environmental performance, and implement measures to mitigate their environmental impacts, etc. (Garrido et al., 2020). Tackling environmental issues in a systematic manner, encouraging firms to use environmentally friendly inputs and avoiding polluting processes (Garrido et al., 2020) can likely prevent pollution (e.g., CO_2 emission) (Garrido et al., 2020). Thus, ISO 14001 certification contributes to emission reduction among certified companies (Sam & Song, 2022). As ISO 14001 is characterized by the implementation of an environmental management system (EMS) (Sam & Song, 2022), ISO 14001 or EMS certification is considered to be a binary variable, which is equal to 1 if a company claims to have ISO

14001 certification or EMS certification, and 0 otherwise.

Leverage. Calculated by dividing total debt by total assets (Trumpp & Guenther, 2017; Wang et al., 2014). A higher leverage ratio indicates that companies have higher financial risk since they have large proportions of debt relative to their assets, thus increasing their probability of bankruptcy and default risk (Lewandowski, 2017). Conversely, a lower leverage ratio suggests that companies have lower financial risk since they have less debt relative to their assets, which helps them reduce their financial distress during hard times.

Table 4-3 Variables descriptions.

Variable	Formula/Description
Independent variable	
Scope 1 CO_2 emission variation ($\Delta CO_2 1$)	$\Delta CO_2 1 = CO_2 1_t - CO_2 1_{t-1} / CO_2 1_{t-1}$
Scope 2 CO_2 emission variation ($\Delta CO_2 2$)	$\Delta CO_2 2 = CO_2 2_t - CO_2 2_{t-1} / CO_2 2_{t-1}$
Scope 3 CO_2 emission variation ($\Delta CO_2 3$)	$\Delta CO_2 3 = CO_2 3_t - CO_2 3_{t-1} / CO_2 3_{t-1}$
Dependent variable	
Return on assets (ROA)	$ROA = Net\ income\ before\ financing\ costs / Total\ assets$ *ROA* is calculated by Refinitiv Eikon DataStream
Tobin's q	$Tobin's\ q = Market\ value + Preferred\ stock + Debt / Total\ assets$ *Tobin's q* is calculated by Refinitiv Eikon DataStream
Mediating variable	

Environmental pillar score (*Pillars*)	*Pillars* reflect the integrated environmental practices in terms of emission reduction, resource use and environmental innovation practices.
Emission reduction score (*Emissions*)	*Emissions* reflect the emission reduction practices, including reducing environmental emission during production and operational processes.
Resource use score (*Resources*)	*Resources* reflect the resource use practices, including reducing the use of materials, energy or water, and enhancing eco-friendly solutions through the improvement of supply chain management.
Environmental innovation score (*Innovations*)	*Innovations* reflect the environmental innovation practices, including decreasing environmental expenses and burdens for its customers, creating new market opportunities via the use of innovative environmental technologies and processes, or eco-designed products.
Control variables	
Firm size (Fs)	The natural logarithm of *Total number of employees*
Net sales revenue (Nsr)	The natural logarithm of *Net sales revenues*
Capital intensity (CI)	The natural logarithm of $Total\ assets / Operating\ income$
Emission intensity (EI)	The natural logarithm of $\Delta CO_2 1_t + \Delta CO_2 2 + \Delta CO_2 3 / Net\ sales\ revenue$

ISO 14001 or EMS certification (*ISO_EMS*)	"Does the company claim to have an ISO 14000 or EMS certification?" A company claim to have ISO 14000 or EMS certification is 1, and 0 otherwise.
Leverage	*Total debt / Total assets*

4.4 Descriptive statistics

Table 4-4 presents the descriptive statistics of independent variables, dependent variables, mediating variables, and control variables examined in this study. All of the continuous variables were winsorized at the lowest and highest 1st percentiles of their distributions to avoid estimates being affected by outliers (Banker et al., 2021; Fernández-Cuesta et al., 2019). For the independent variables, the mean value of $\Delta CO_2 1$ and $\Delta CO_2 3$ are 0.031 and 0.044, respectively, which reflects positive changes (i.e., increase) in scope 1 and 3 CO_2 emissions on average from 2008 to 2021. The mean value of $\Delta CO_2 2$ is -0.002, which indicates negative changes (i.e., decrease) in scope 2 CO_2 emissions on average from 2008 to 2021. With regard to dependent variables, the mean of ROA is 4.704, indicating that the sample firms have mostly been profitable in the years between 2008 and 2021. Tobin's q exceeds 1, which means that the market value of the sample firms is on average higher than their recorded assets value, thus indicating the sample firms are overvalued by the market (Lewandowski, 2017) between 2008 and 2021. Focusing on the mediators, the mean of the environmental pillar score (75.617), emission reduction score (84.132), and resource use score (83.041) indicates the sample companies (i.e., companies participate in CO_2 emissions) have excellent performance (e.g., reduction in energy/water use) in implementing integrated practices, emission reduction practices, and resource use practices, and high degree of transparency in reporting the relevant environmental data. The average environmental innovation score (54.015) indicates that the sample firms have a good environmental performance/above-average performance in implementing environmental innovation practices。

Table 4-4 Descriptive statistics.

Variables	N	Mean	SD	Minimum	Median	Maximum
Independent variables						
$\Delta CO_2 1$	972	0.031	0.390	-0.723	-0.015	2.707
$\Delta CO_2 2$	972	-0.002	0.386	-0.748	-0.047	2.648
$\Delta CO_2 3$	972	0.044	0.398	-0.724	-0.002	2.774
Dependent variables						
ROA	972	4.704	5.608	-2.750	2.783	23.100
Tobin's q	972	1.258	1.232	0.085	0.847	6.987
Mediators						
Environmental pillar score	972	75.617	15.337	32.350	78.620	97.410
Emission reduction score	972	84.132	13.971	34.470	87.990	99.680
Resource use score	945	83.041	17.330	19.500	88.430	99.730
Environmental innovation score	972	54.015	30.658	0.000	57.260	97.520
Control variables						
LogFirm size	902	10.171	1.501	6.084	10.369	12.892
LogNet sales revenues	972	16.552	1.404	13.140	16.644	19.224
LogCapital intensity	928	3.306	1.271	1.202	3.034	6.923
LogEmission intensity	972	3.154	2.057	-0.968	2.786	8.451
Leverage	909	26.077	15.957	0.040	24.170	72.740
ISO_EMS	972	0.579	0.494	0.000	1.000	1.000

Note: N=No. of observations, SD=standard deviation, $\Delta CO_2 1$=scope 1 CO_2 emission variation, $\Delta CO_2 2$=scope 2 CO_2 emission variation, $\Delta CO_2 3$=scope3 CO_2 emission variation, ISO_EMS= ISO 14001 or EMS certification.

4.5 Correlation matrix

As shown in Table 4-5, the correlation matrix shows the negative and significant correlation coefficients between "$\Delta CO_2$1 and ROA", "$\Delta CO_2$2 and ROA", "$\Delta CO_2$3 and ROA", but the correlation coefficients between "$\Delta CO_2$1 and Tobin's q", "$\Delta CO_2$2 and Tobin's q", "$\Delta CO_2$3 and Tobin's q" are insignificant. In addition, the correlation coefficients are negative and significant between "$\Delta CO_2$1 and environmental pillar score", "$\Delta CO_2$2 and environmental pillar score", and "$\Delta CO_2$3 and environmental pillar score", "$\Delta CO_2$1 and emission reduction score", "$\Delta CO_2$2 and emission reduction score", and "$\Delta CO_2$3 and emission reduction score", $\Delta CO_2$1 and resource use score", "$\Delta CO_2$2 and resource use score", and "$\Delta CO_2$3 and resource use score ", but the correlation coefficients are not significant between "$\Delta CO_2$1 and environmental innovation score", "$\Delta CO_2$2 and environmental innovation score", and "$\Delta CO_2$3 and environmental innovation score". Moreover, the correlation coefficients between "environmental pillar score and ROA", "emission reduction score and ROA", "resource use score and ROA", "environmental innovation score and ROA" are positive and significant. In contrast, the correlation coefficient between ''environmental pillar score and Tobin's q" is negative and significant, while the correlation coefficient between "emission reduction score and Tobin's q", "resource use score and Tobin's q", "environmental innovation score and Tobin's q" are not significant. All of the variance inflation factors are less than 2, and multicollinearity is not a concern in this study.

Table 4-5 Correlation matrix.

	$\Delta CO_2 1$	$\Delta CO_2 2$	$\Delta CO_2 3$	ROA	Tobin's q	Pillars	Emissions	Resources	Innovations	LogFs	LogNsr	LogCI	LogEI	Lev	ISO_EMS
$\Delta CO_2 1$	1.000														
$\Delta CO_2 2$	0.998***	1.000													
$\Delta CO_2 3$	0.976***	0.975***	1.000												
ROA	-0.226***	-0.218***	-0.193***	1.000											
Tobin's q	0.036	0.037	0.028	0.206***	1.000										
Pillars	-0.426***	-0.418***	-0.364***	0.223***	-0.088***	1.000									
Emissions	-0.556***	-0.550***	-0.495***	0.301***	0.015	0.742***	1.000								
Resources	-0.137***	-0.132***	-0.135***	0.103***	0.045	0.401***	0.353***	1.000							
Innovations	-0.009	-0.010	-0.006	0.179***	-0.021	-0.001	-0.009	0.003	1.000						
LogFs	-0.059*	-0.057*	-0.048	0.073**	-0.075**	0.272***	0.173***	0.284***	-0.027	1.000					
LogNsr	-0.088***	-0.085***	-0.076**	0.088***	-0.136***	0.355***	0.249***	0.385***	-0.000	0.791***	1.000				
LogCI	-0.006	-0.006	-0.011	-0.273***	-0.634***	0.088***	-0.058*	-0.006	-0.214***	0.055	0.104***	1.000			
LogEI	0.004	0.003	0.011	0.093***	0.034	0.040	0.036	-0.017	0.401***	-0.105***	-0.080**	-0.310***	1.000		
Lev	-0.042	-0.045	-0.039	0.018	0.159***	0.058*	0.001	0.081**	0.252***	-0.009	-0.082**	-0.147***	0.272***	1.000	
ISO_EMS	-0.008	-0.004	-0.009	0.050	-0.045	0.062*	0.077**	0.211***	0.123***	0.081**	0.124***	-0.067**	0.150***	0.064*	1.000

Note: $\Delta CO_2 1$=scope 1 CO_2 emission variation, $\Delta CO_2 2$=scope 2 CO_2 emission variation, $\Delta CO_2 3$=scope 3 CO_2 emission variation, Pillars=environmental pillar score, Emissions=emission reduction score, Resources=resource use score, Innovations=environmental innovation score, LogFs= natural logarithm of total number of employees, LogNsr=natural logarithm of net sales revenues, LogCI=natural logarithm of capital intensity, LogEI=natural logarithm of emission intensity, Lev=leverage, and ISO_EMS= ISO 14001 or EMS certification.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.6 Justifying of using quantitative method

This study uses quantitative methods in this study for the following reasons:

Firstly, quantitative methods employ a deductive approach to the research process (Mehrad & Zangeneh, 2019), which enables hypothesis testing (McCusker & Gunaydin, 2015). This approach relies on the collection of large volumes of data through the application of standardized methods that include generalized samples, which emphasize statistical information over individual perceptions (McCusker & Gunaydin, 2015).

Secondly, using quantitative methods allows researchers to analyze various factors in how they related to one another, helping to reveal causal relationships of these factors relevant to the research question (McCusker & Gunaydin, 2015).

Thirdly, quantitative approach aims to answer "how many" or "how much questions rather than the "what", "how" or "why" questions about a phenomenon that answered by qualitative method (McCusker & Gunaydin, 2015). By relying on statistical analysis instead of real-life scenarios, quantitative methods help researchers minimize emotional and subjective biases that are often present in qualitative research. This ensures data can be analyzed and interpreted through numerical figures, enhancing neutrality and the validity of findings (McCusker & Gunaydin, 2015).

Fourthly, the objective of this study is to empirically examine the relationship among CO_2 emissions, environmental practices and financial performance using panel data. Quantitative methods help test hypotheses proposed in Chapter 3 and identify potential causal relationships.

Based on the above discussion, the use of quantitative method in this study is appropriate.

4.7 Empirical methods

In this study, the mediating effect model is used to test the proposed hypotheses. Three general approaches have been used for mediation analysis in literature (MacKinnon et al., 2002). First, Judd and Kenny (1981) proposed the causal steps approach, which further extended by (Baron & Kenny, 1986) and subsequently became the most widely adopted mediation analysis method (MacKinnon et al., 2002). The variant of the causal step approach is the joint significance, which is also used by some researchers (Cohen et al., 2013). The second general approach is the difference in coefficients approach, such as the difference in regression coefficients or correlation coefficients (MacKinnon et al., 2002). The product of coefficients approach is the third general approach, which includes the Sobel test and asymmetric confidence interval approaches (i.e., bootstrapping method and distribution of product) (MacKinnon et al., 2002).

4.7.1 Justifying selected method

To achieve the research objectives and address the research questions proposed in Chapter 1, the causal steps approach and bootstrapping method are used to conduct the mediation analysis for the following reasons. First, the causal steps approach proposed by Baron and Kenny (1986) is selected because this method includes three conditions for mediation testing, which is to achieve i) Research Objective 2- to examine the effects of each scope of CO_2 emission on financial performance in terms of ROA and Tobin's q; ii) Research Objective 3- to examine the effects of CO_2 emission on environmental practices (i.e., integrated environmental practices, emission reduction practices, resource use practices, and environmental innovation practices), and iii) Research Objective 4- to examining the effects of environmental practices on financial performance. The Research Objective 2-4 helps to achieve Research Objective 1- to examine whether the integrated environmental practices and its individual practices play mediating roles in the relationships between each scope of CO_2 emission and financial performance, thus contributing to answering Research Questions 1-4.

Second, bootstrapping method is selected since it is considered to be a supplementary method instead of a substitute method in the causal steps approach (Hayes, 2009). Specifically, although the causal steps approach is a commonly used method to test mediating effects, the purpose of the method is to establish the mediation conditions (MacKinnon et al., 2002). The causal steps approach is used to establish causal relationships between variables and test the relationships in a sequential manner for mediating effects. In other words, the causal steps approach relies on the individual test of paths a and b, but does not provide a statistical test for the specific indirect effects of X on Y through M (i.e., ab) (see Figure 4-1) (MacKinnon et al., 2002). In addition, the causal steps approach has a low statistical power for mediation analysis (MacKinnon et al., 2002). Unlike the causal steps approach, the bootstrapping method is a resampling technique used to test the indirect effects of a mediation model. The inference of bootstrapping is based on an estimate of the indirect effects (i.e., ab) itself. The bootstrapping method can generate a significant number of resamples from the original data, which can enhance the statistical power of the analysis. In addition, scholars have suggested the bootstrapping method as a solution to the statistical power problem caused by the asymmetries and nonnormalities in the sampling distribution of the indirect effects (Preacher & Hayes, 2004).

Previous studies consider bootstrapping as a one of the more valid and powerful methods to test the mediating effects (MacKinnon et al., 2004; Preacher & Hayes, 2008; Zhao et al., 2010). For the various mediation analysis methods above mentioned, previous studies indicated the product of coefficients (e.g., bootstrapping) has lower type I error rates than the difference in coefficients (MacKinnon et al., 2002). Among the mediation methods in the product of coefficients, the bootstrapping method is superior to the distribution of product and Sobel test. For example, unlike the Sobel test which requires a large sample size and data with a normal distribution, the bootstrapping method does not rely on large-sample theory and thus small samples can be analyzed confidently (Preacher & Hayes, 2004). Bootstrapping also does not require normality assumption. Based on the above discussion, the bootstrapping method is used as the supplementary method to enhance the validity of the mediation analysis results obtained from using the causal steps approach.

4.7.2 Causal steps approach

This study applies the causal steps approach proposed by Baron and Kenny (1986) to test the mediating effects (Kroes et al., 2012) (Kroes et al., 2012; Lu & Lu, 2022). The variables can be considered as mediators to the extent that they can explain the relationships between the independent variables and dependent variables (Baron & Kenny, 1986). In addition, the variables function as mediators when they meet three following conditions (Baron & Kenny, 1986) as shown in Figure 4-1: i) the changes of the independent variable (X) significantly explain the changes in the presumed mediating variable (M) (i.e., path a); ii) the changes in the mediating variable (M) significantly explain the changes in dependent variable (Y) (i.e., path b); and iii) a previous significant relationship between the independent variable (X) and dependent variable (Y) becomes insignificant when paths a and b are controlled, with path c' being zero demonstrating the strongest mediation. Specifically, there is strong evidence for a single and dominant mediator (M) when path c' becomes zero; in contrast, the multiple mediator factors existed when path c' is not zero (Baron & Kenny, 1986). Three steps are used to test mediation model (Baron & Kenny, 1986). First, dependent variable is regressed on the independent variable, which tests the total effect of X on Y. Second, the mediating variable is regressed on the independent variable, which tests the effect of X on M. Third, the dependent variable is regressed on both the mediating variable and independent variable, which tests the effects of M on Y after controlling for X (Baron & Kenny, 1986).

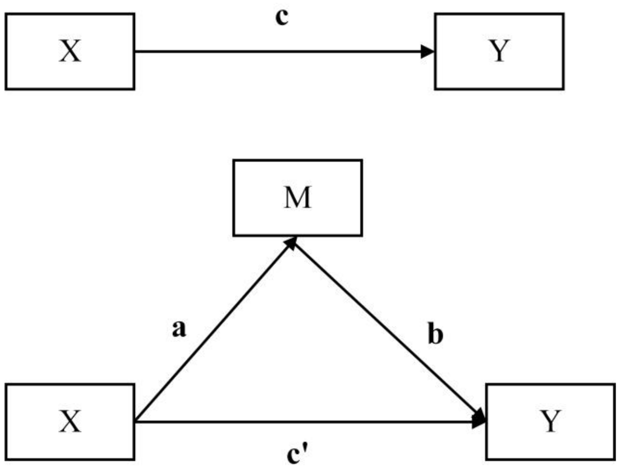

Figure 4-1. Simple mediation model

This study follows three steps described above to test the hypotheses proposed in Chapter 3. To begin with, the effects of each scope of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) on financial performance (i.e., ROA and Tobin's q) are examined. Specifically, the effects of i) $\Delta CO_2 1$ on ROA; ii) $\Delta CO_2 2$ on ROA, iii) $\Delta CO_2 3$ on ROA; iv) $\Delta CO_2 1$ on Tobin's q; v) $\Delta CO_2 2$ on Tobin's q; and vi) $\Delta CO_2 3$ on Tobin's q are investigated.

Secondly, the effects of each scope of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$

and $\Delta CO_2 3$) on environmental practices- integrated environmental practices (in terms of environmental pillar score), emission reduction practices (in terms of emission reduction score), resource use practices (in terms of resource use score), and environmental innovation practices (in terms of environmental innovation score) are investigated. Specifically, the effects of i) $\Delta CO_2 1$ on environmental pillar score; ii) $\Delta CO_2 2$ on environmental pillar score; iii) $\Delta CO_2 3$ on environmental pillar score; iv) $\Delta CO_2 1$ on emission reduction score; v) $\Delta CO_2 2$ on emission reduction score; vi) $\Delta CO_2 3$ on emission reduction score; vii) $\Delta CO_2 1$ on resource use score; viii) $\Delta CO_2 2$ on resource use score; ix) $\Delta CO_2 3$ on resource use score; x) $\Delta CO_2 1$ on environmental innovation score; xi) $\Delta CO_2 2$ on environmental innovation score; and xii)$\Delta CO_2 3$ on environmental innovation score are investigated.

Thirdly, the effects of environmental practices on financial performance are examined after controlling for scopes 1, 2 and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$). Specifically, this study examined the effects of i) environmental pillar score on the ROA after controlling for $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$, respectively; ii) environmental pillar score on Tobin's q after controlling for $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$, respectively; iii) emission reduction score on the ROA after controlling for $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$, respectively; iv) emission reduction score on Tobin's q after controlling for $\Delta\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$, respectively; v) resource use score on the ROA after controlling for $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$, respectively; vi) resource use score on Tobin's q after controlling for $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$, respectively; vii) environmental innovation score on the ROA after controlling for $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$, respectively; viii) environmental innovation score on Tobin's q after controlling for $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$, respectively.

As previously stated, bootstrapping is used as a supplementary method to examine whether integrated environmental practices and their individual practices play the mediating roles in the relationships between scopes 1, 2 and 3 CO_2 emission variations and financial performance. The approach will improve the credibility of the results obtained from the causal steps approach. The discussion of the bootstrapping method is discussed in the following section.

4.7.3 Bootstrapping method

Bootstrapping is a nonparametric method used to estimate the effect sizes and test hypotheses, which offers the most powerful and reasonable means to estimate the confidence interval for specific indirect effect in most conditions (Preacher & Hayes, 2008). Researchers use the bootstrapping method to determine which mediators have a stronger effect (Preacher & Hayes, 2008).

The bootstrapping method constructs the empirical representation of the sampling distribution of indirect effects by using the generated sample size n as the miniature presentations of the population (Hayes, 2009).These miniature presentations are created by repeatedly resampling the sample during the analysis and the resampling of the sample is conducted through replacement. When a resample (i.e., miniature presentation) is created, the point estimates of a and b are derived from the resampled dataset, and the product of the path coefficients (i.e., ab) is recorded (Hayes, 2009). The process can be repeated multiple times, preferably at least 1,000 times, with 5,000 being the recommended number (Hayes, 2009). For example, a study uses a sample size of 500 as the bootstrap population and uses bootstrapping method to resample sampled cases from the population and ensure the sampled cases once drawn are returned, which will help the study to obtain a bootstrap sample with sample size of 500. The process is repeated 1000 times to generate 1000 bootstrap samples (i.e., miniature presentation). Thus, the point estimates of the indirect effects (i.e., ab) indicate that the indirect effects (i.e., ab) are calculated by using the 1000 bootstrap samples (Preacher & Hayes, 2004). The next step involves deriving the bootstrap 95% confidence interval, which can be achieved by sorting the values of ab across the 1000 bootstrap samples from low to high. The 25th and 976th scores are used to define the lower and upper limits of the 95% confidence interval, respectively (Preacher & Hayes, 2004). If the confidence interval excludes zero, the indirect effect is considered statistically significant, otherwise it is nonsignificant (Preacher & Hayes, 2004). In this study, 1,000 bootstrap samples are used as suggested in previous studies. In addition, the bias-corrected bootstrap is adopted since it provides the most accurate confidence limits and highest statistical power compared to other resampling methods, such as percentile bootstrap, bootstrap-t, and bootstrap-Q (MacKinnon et al., 2004b).

4.8 Model specification

To test the proposed hypotheses, panel fixed-effects models with clustered robust standard errors were estimated at the firm level and with year fixed effects (Song et al., 2024). As it is difficult to incorporate various unobservable factors (e.g., potential confounding firm characteristics) into the statistical analysis, the fixed-effects model was used (King & Lenox, 2002). The fixed-effects model allows each firm to have its own intercepts, and thus the model can control unobservable firm characteristics (e.g., management capabilities, founding date of firm) (King & Lenox, 2002), which may correlate with the independent variables and lead to omitted variables issues and biased estimates (Busch et al., 2022). Thus, the fixed effects model was used to deal with the endogeneity issues resulting from unobserved heterogeneity (King & Lenox, 2002). In addition, by using clustered robust standard errors, heteroskedasticity and autocorrelation can be accounted for that cannot be fully accounted for fixed effects

(Cameron & Miller, 2015; Song et al., 2023).

4.8.1 Model specification of effects of CO_2 emission variations on financial performance (H_1-H_3)

To determine the existence of the mediating effects in this study, the first step is to examine the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) and financial performance (i.e., ROA and Tobin's q).

To examine the effects of each scope of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) on financial performance (i.e., ROA and Tobin's q). Models (1)-(6) are established as follows:

$$ROA_{it} = \beta_0 + \beta_1 \Delta CO_2 1_{it} + \beta_2 In\_Firm\ size_{it} + \beta_3 In\_Net sales\ revenues_{it} + \beta_4 Capital\ intensity_{it} + \beta_5 In\_Emission\ intensity_{it} + \beta_6 ISO\_EMS_{it} + \beta_7 Lev_{it} + v_i + \delta_t + m_{0it} \tag{1}$$

$$\text{Tobin's q}_{it} = \alpha_0 + \alpha_1 \Delta CO_2 1_{it} + \alpha_2 In\_Firm\ size_{it} + \alpha_3 In\_Net sales\ revenues_{it} + \alpha_4 Capital\ intensity_{it} + \alpha_5 In\_Emission\ intensity_{it} + \alpha_6 ISO\_EMS_{it} + \alpha_7 Lev_{it} + v_i + \delta_t + m_{1it} \tag{2}$$

$$ROA_{it} = \Upsilon_0 + \Upsilon_1 \Delta CO_2 2_{it} + \Upsilon_2 In\_Firm\ size_{it} + \Upsilon_3 In\_Net sales\ revenues_{it} + \Upsilon_4 Capital\ intensity_{it} + \Upsilon_5 In\_Emission\ intensity_{it} + \Upsilon_6 ISO\_EMS_{it} + \Upsilon_7 Lev_{it} + v_i + \delta_t + \mathrm{m}_{2it} \tag{3}$$

$$\text{Tobin's q}_{it} = \lambda_0 + \lambda_1 \Delta CO_2 2_{it} + \lambda_2 In\_Firm\ size_{it} + \lambda_3 In\_Net sales\ revenues_{it} + \lambda_4 Capital\ intensity_{it} + \lambda_5 In\_Emission\ intensity_{it} + \lambda_6 ISO\_EMS_{it} + \lambda_7 Lev_{it} + v_i + \delta_t + m_{3it}$$

$$ROA_{it} = \theta_0 + \theta_1 \Delta CO_2 3_{it} + \theta_2 In\_Firm\ size_{it} + \theta_3 In\_Net sales\ revenues_{it} + \theta_4 Capital\ intensity_{it} + \theta_5 In\_Emission\ intensity_{it} + \theta_6 ISO\_EMS_{it} + \theta_7 Lev_{it} + v_i + \delta_t + m_{4it} \quad (4)$$

(5)

$$\text{Tobin's } q_{it} = \omega_0 + \omega_1 \Delta CO_2 3_{it} + \omega_2 In\_Firm\ size_{it} + \omega_3 In\_Net sales\ revenues_{it} + \omega_4 Capital\ intensity_{it} + \omega_5 In\_Emission\ intensity_{it} + \omega_6 ISO\_EMS_{it} + \omega_7 Lev_{it} + v_i + \delta_t + m_{5it}$$

(6)

In Models (1)-(6), *i* indexes firm and *t* indexes year. ROA_{it} and Tobin's q_{it} are dependent variables, which indicate ROA and Tobin's q of firm *i* in year *t*, respectively. $\Delta CO_2 1_{it}$, $\Delta CO_2 2_{it}$, and $\Delta CO_2 3_{it}$ denotes the independent variables, which indicate "scope 1 CO_2 emission variation ", "scope 2 CO_2 emission variation", and "scope 3 CO_2 emission variation" that are observed for firm *i* in year *t*. ISO_EMS_{it} denotes ISO 14001 or EMS certification observed for firm *i* in year *t*. Lev_{it} indicate the leverage observed for firm *i* in year *t*. In addition, β_0, α_0, γ_0, λ_0, θ_0, and ω_0 are the constant terms. β_1 is the estimated coefficient of $\Delta CO_2 1$ on ROA, α_1 is the estimated coefficient of $\Delta CO_2 1$ on Tobin's q, γ_1 is the estimated coefficient of $\Delta CO_2 2$ on ROA, λ_1 is the estimated coefficient of $\Delta CO_2 2$ on Tobin's q, θ_1 is the estimated coefficient of $\Delta CO_2 3$ on ROA, and ω_1 is the estimated coefficient of $\Delta CO_2 3$ on Tobin's q. β_2-β_7, α_2-α_7, γ_2-γ_7, λ_2-λ_7, θ_2-θ_6, and ω_2-ω_7 are the estimated coefficients of the control variables; v_i is the firm-fixed effect, δ_t denotes the year-fixed effect, and m_{0it}-m_{5it} are random error terms.

4.8.2 Model specification of effects of CO_2 emission variations on environmental practices (H_4-H_6)

In the second step for mediation test, the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) and environmental practices are investigated. The environmental practices include the integrated environmental practices (in terms of the environmental pillar score), emission reduction practices (in terms of the emission reduction score), resource use practices (in terms of the resource use score), and environmental innovation practices (in terms of the environmental innovation score).

To investigate the relationships between each scope of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) and environmental scores in terms of environmental pillar, emission reduction, resource use, and environmental innovation scores, Models (7)-(18) are developed as follows:

$$Pillars_{it} = a_0 + a_1 \Delta CO_2 1_{it} + a_2 Firm\ size_{it} + a_3 Net\,sales\,revenues_{it} + a_4 Capital\ intensity_{it} + a_5 Emission\ intensity_{it} + a_6 ISO\_EMS_{it} + a_7 Lev_{it} + v_i + \delta_t + \varepsilon_{1it} \quad (7)$$

$$Emissions_{it} = b_0 + b_1 \Delta CO_2 1_{it} + b_2 Firm\ size_{it} + b_3 Net\,sales\,revenues_{it} + b_4 Capital\ intensity_{it} + b_5 Emission\ intensity_{it} + b_6 ISO\_EMS_{it} + b_7 Lev_{it} + v_i + \delta_t + \varepsilon_{2it} \quad (8)$$

$$Resources_{it} = c_0 + c_1 \Delta CO_2 1_{it} + c_2 Firm\ size_{it} + c_3 Net\,sales\,revenues_{it} + c_4 Capital\ intensity_{it} + c_5 Emission\ intensity_{it} + c_6 ISO\_EMS_{it} + c_7 Lev_{it} + v_i + \delta_t + \varepsilon_{3it} \quad (9)$$

$$Innovations_{it} = d_0 + d_1 \Delta CO_2 1_{it} + d_2 Firm\ size_{it} + d_3 Net\,sales\,revenues_{it} + d_4 Capital\ intensity_{it} + d_5 Emission\ intensity_{it} + d_6 ISO\_EMS_{it} + v_7 Lev_{it} + v_i + \delta_t + \varepsilon_{4it} \quad (10)$$

$$Pillars_{it} = e_0 + e_1 \Delta CO_2 2_{it} + e_2 Firm\ size_{it} + e_3 Net\,sales\,revenues_{it} + e_4 Capital\ intensity_{it} + e_5 Emission\ intensity_{it} + e_6 ISO\_EMS_{it} + e_7 Lev_{it} + v_i + \delta_t + \varepsilon_{5it} \quad (11)$$

$$Emissions_{it} = f_0 + f_1 \Delta CO_2 2_{it} + f_2 Firm\ size_{it} + f_3 Net\,sales\,revenues_{it} + f_4 Capital\ intensity_{it} + f_5 Emission\ intensity_{it} + f_6 ISO\_EMS_{it} + f_7 Lev_{it} + v_i + \delta_t + \varepsilon_{6it} \quad (12)$$

$$Resources_{it} = g_0 + g_1 \Delta CO_2 2_{it} + g_2 Firm\ size_{it} + g_3 Net\,sales\,revenues_{it} + g_4 Capital\ intensity_{it} + g_5 Emission\ intensity_{it} + g_6 ISO\_EMS_{it} + g_7 Lev_{it} + v_i + \delta_t + \varepsilon_{7it}$$

(13)

$$Innovations_{it} = h_0 + h_1 \Delta CO_2 2_{it} + h_2 Firm\ size_{it} + h_3 Net sales\ revenues_{it} + h_4 Capital\ intensity_{it}$$
$$+ h_5\ Emission\ intensity_{it} + h_6 ISO\_EMS_{it} + h_7 Lev_{it} + v_i + \delta_t + \varepsilon_{8it}$$

(14)

$$Pillars_{it} = i_0 + i_1 \Delta CO_2 3_{it} + i_2\ Firm\ size_{it} + i_3 Net sales\ revenues_{it} + i_4 Capital\ intensity_{it}$$
$$+ i_5\ Emission\ intensity_{it} + i_6 ISO\_EMS_{it} + i_7 Lev_{it} + v_i + \delta_t + \varepsilon_{9it}$$

(15)

$$Emissions_{it} = j_0 + j_1 \Delta CO_2 3_{it} + j_2 Firm\ size_{it} + j_3 Net sales\ revenues_{it} + j_4 Capital\ intensity_{it}$$
$$+ j_5\ Emission\ intensity_{it} + j_6 ISO\_EMS_{it} + j_7 Lev_{it} + v_i + \delta_t + \varepsilon_{10it}$$

(16)

$$Resources_{it} = k_0 + k_1 \Delta CO_2 3_{it} + k_2 Firm\ size_{it} + k_3 Net sales\ revenues_{it} + k_4 Capital\ intensity_{it}$$
$$+ k_5\ Emission\ intensity_{it} + k_6 ISO\_EMS_{it} + k_7 Lev_{it} + v_i + \delta_t + \varepsilon_{11it}$$

(17)

$$Innovations_{it} = l_0 + l_1 \Delta CO_2 3_{it} + l_2 Firm\ size_{it} + l_3 Net sales\ revenues_{it} + l_4 Capital\ intensity_{it}$$
$$+ l_5\ Emission\ intensity_{it} + l_6 ISO\_EMS_{it} + l_7 Lev_{it} + v_i + \delta_t + \varepsilon_{12it}$$

(18)

In Model (7)-(18), $Pillars_{it}$, $Emissions_{it}$, $Resource_{it}$, *and* $Innovation_{it}$ represent the environmental pillar score, emission reduction score, resource use score, and environmental innovation score observed for firm *i* in year *t*, respectively. a_0, b_0, c_0, d_0, e_0, f_0, g_0, h_0, i_0, j_0, k_0, and l_0 are the constant terms. a_1 is the estimated coefficient of $\Delta CO_2 1$ on environmental pillar score, b_1 is the estimated coefficient of $\Delta CO_2 1$ on emission reduction score, c_1 is the estimated coefficient of $\Delta CO_2 1$ on resource use score, d_1 is the estimated coefficient of $\Delta CO_2 1$ on environmental innovation score, e_1 is the estimated coefficient of $\Delta CO_2 2$ on environmental pillar score, f_1 is the estimated coefficient of $\Delta CO_2 2$ on emission reduction score, g_1 is the estimated coefficient of $\Delta CO_2 2$ on resource use score, h_1 is the estimated coefficient of $\Delta CO_2 2$ on environmental innovation score, i_1 is the estimated coefficient of $\Delta CO_2 3$ on environmental pillar score, j_1 is the estimated coefficient of $\Delta CO_2 3$ on emission reduction score, k_1 is the estimated coefficient of $\Delta CO_2 3$ on resource use score, and l_1 is the estimated coefficient of $\Delta CO_2 3$ on environmental innovation score. In addition, a_2-a_7, b_2-b_7, c_2-c_7, d_2-d_7, e_2-e_7, f_2-f_7, g_2-

g_7, h_2-h_7, i_2-i_7, j_2-j_7, k_2-k_7, *and* l_2-l_7 are the estimated coefficients of the control variables. ε_{1it}-ε_{12it} are random error terms.

4.8.3 Model specification of effects of environmental practices on financial performance (H_7-H_{10})

The third step for mediation test is to examine the relationships between environmental scores (i.e., environmental pillar score, emission reduction score, resource use score, and environmental innovation score) and financial performance (i.e., ROA and Tobin's q) after controlling for $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$.

4.8.3.1 Model specification of effects of integrated environmental practices on financial performance

To explore the effects of the environmental pillar score on financial performance (i.e., ROA and Tobin's q) after controlling for scope 1, 2 and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$), Models (19)-(24) are developed as follows:

$$ROA_{it} = n_0 + n_1 \Delta CO_2 1_{it} + n_2 Pillars + n_3 Firm\ size_{it} + n_4 Net sales\ revenues_{it} + n_5 Capital\ intensity_{it} + n_6 Emission\ intensity_{it} + n_7 ISO\_EMS_{it} + n_8 Lev_{it} + v_i + \delta_t + \varepsilon_{13it} \quad (19)$$

$$Tobin's\ q_{it} = o_0 + o_1 \Delta CO_2 1_{it} + o_2 Pillars + o_3 Firm\ size_{it} + o_4 Net sales\ revenues_{it} + o_5 Capital\ intensity_{it} + o_6 Emission\ intensity_{it} + o_7 ISO\_EMS_{it} + o_8 Lev_{it} + v_i + \delta_t + \varepsilon_{14it} \quad (20)$$

$$ROA_{it} = p_0 + p_1 \Delta CO_2 2_{it} + p_2 Pillars + p_3 Firm\ size_{it} + p_4 Net sales\ revenues_{it} + p_5 Capital\ intensity_{it} + p_6 Emission\ intensity_{it} + p_7 ISO\_EMS_{it} + p_8 Lev_{it} + v_i + \delta_t + \varepsilon_{15it}$$

(21)

$$Tobin's\ q_{it} = q_0 + q_1 \Delta CO_2 2_{it} + q_2 Pillars_{it} + q_3 Firm\ size_{it} + q_4 Net sales\ revenues_{it} + q_5 Capital\ intensity_{it} + q_6 Emission\ intensity_{it} + q_7 ISO\_EMS_{it} + q_8 Lev_{it} + v_i + \delta_t + \varepsilon_{16it}$$

(22)

$$ROA_{it} = r_0 + r_1 \Delta CO_2 3_{it} + r_2 Pillars_{it} + r_3 Firm\ size_{it} + r_4 Net sales\ revenues_{it} + r_5 Capital\ intensity_{it} + r_6 Emission\ intensity_{it} + r_7 ISO\_EMS_{it} + r_8 Lev_{it} + v_i + \delta_t + \varepsilon_{17it}$$

(23)

$$Tobin's\ q_{it} = s_0 + s_1 \Delta CO_2 3_{it} + s_2 Pillars_{it} + s_3 Firm\ size_{it} + s_4 Net sales\ revenues_{it} + s_5 Capital\ intensity_{it} + s_6 Emission\ intensity_{it} + s_7 ISO\_EMS_{it} + s_8 Lev_{it} + v_i + \delta_t + \varepsilon_{18it}$$

(24)

In Model 19, n_1 is the estimated coefficient of $\Delta CO_2 1$ on ROA, and n_2 is the estimated coefficient of the environmental pillar score on ROA. In Model 20, o_1 is the estimated coefficient of $\Delta CO_2 1$ on Tobin's q, and o_2 is the estimated coefficient of the environmental pillar score on Tobin's q. In Model 21, p_1 is the estimated coefficient of $\Delta CO_2 2$ on ROA, and p_2 is the estimated coefficient of the environmental pillar score on ROA. In Model 22, q_1 is the estimated coefficient of $\Delta CO_2 2$ on Tobin's q, and q_2 is the estimated coefficient of the environmental pillar score on Tobin's q. In Model 23, r_1 is the estimated coefficient of $\Delta CO_2 3$ on ROA, r_2 is the estimated coefficient of the environmental pillar score on ROA. In Model 24, s_1 is the estimated coefficient of $\Delta CO_2 3$ on Tobin's q, and s_2 is the estimated coefficient of the environmental pillar score on Tobin's q. In addition, n_0, o_0, p_0, q_0, r_0, and s_0 are the constant terms, n_3-n_8, o_3-o_8, p_3-p_8, q_3-q_8, r_3-r_8, and s_3-s_8 are the estimated coefficients of the control variables, and ε_{13it}-ε_{18it} are random error terms.

4.8.3.2 Model specification of effects of emission reduction practices on financial performance

To explore the effects of the emission reduction score on financial performance (i.e., ROA and Tobin's q) after controlling for scope 1, 2 and 3 CO_2 emission variations (i.e., ΔCO_21, ΔCO_22, and ΔCO_23), we developed Models (25)-(30) as follows:

$$ROA_{it} = t_0 + t_1\Delta CO_2 1_{it} + t_2 Emissions_{it} + t_3 Firm\ size_{it} + t_4 Net sales\ revenues_{it} + t_5 Capital\ intensity_{it} + t_6 Emission\ intensity_{it} + t_7 ISO\_EMS_{it} + t_8 Lev_{it} + v_i + \delta_t + \varepsilon_{19it} \tag{25}$$

$$Tobin's\ q_{it} = u_0 + u_1\Delta CO_2 1_{it} + u_2 Emissions_{it} + u_3 Firm\ size_{it} + u_4 Net sales\ revenues_{it} + u_5 Capital\ intensity_{it} + u_6 Emission\ intensity_{it} + u_7 ISO\_EMS_{it} + u_8 Lev_{it} + v_i + \delta_t + \varepsilon_{20it} \tag{26}$$

$$ROA_{it} = \mathrm{w}_0 + w_1\Delta CO_2 2_{it} + \mathrm{w}_2 Emissions_{it} + \mathrm{w}_3 Firm\ size_{it} + \mathrm{w}_4 Net sales\ revenues_{it} + \mathrm{w}_5 Capital\ intensity_{it} + \mathrm{w}_6 Emission\ intensity_{it} + \mathrm{w}_7 ISO\_EMS_{it} + \mathrm{w}_8 Lev_{it} + v_i + \delta_t + \varepsilon_{21it} \tag{27}$$

$$Tobin's\ q_{it} = x_0 + x_1\Delta CO_2 2_{it} + x_2 Emissions_{it} + x_3 Firm\ size_{it} + x_4 Net sales\ revenues_{it} + x_5 Capital\ intensity_{it} + x_6 Emission\ intensity_{it} + x_7 ISO\_EMS_{it} + x_8 Lev_{it} + v_i + \delta_t + \varepsilon_{22it} \tag{28}$$

$$ROA_{it} = y_0 + y_1\Delta CO_2 3_{it} + y_2 Emissions_{it} + y_3 Firm\ size_{it} + y_4 Net sales\ revenues_{it} + y_5 Capital\ intensity_{it} + y_6 Emission\ intensity_{it} + y_7 ISO\_EMS_{it} + y_8 Lev_{it} + v_i + \delta_t + \varepsilon_{23it} \tag{29}$$

$$Tobin's\ q_{it} = z_0 + z_1\Delta CO_2 3_{it} + z_2 Emissions_{it} + z_3 Firm\ size_{it} + z_4 Net sales\ revenues_{it} + z_5 Capital\ intensity_{it} + z_6 Emission\ intensity_{it} + z_7 ISO\_EMS_{it} + z_8 Lev_{it} + v_i + \delta_t + \varepsilon_{24it} \tag{30}$$

In Model 25, t_1 is the estimated coefficient of ΔCO_21 on ROA, and t_2 is the estimated coefficient of emission reduction score on ROA. In Model 26, u_1 is the estimated coefficient of ΔCO_21 on Tobin's q, and u_2 is the estimated coefficient of emission reduction score on Tobin's q. In Model 27, w_1 is the estimated coefficient of $\Delta CO_2 2$ on ROA, and w_2 is the estimated coefficient of emission reduction score on ROA. In Model 28, x_1 is the estimated coefficient of $\Delta CO_2 2$ on Tobin's q, and x_2 is the estimated coefficient of emission reduction score on Tobin's q. In Model 29, y_1 is the estimated coefficient of $\Delta CO_2 3$ on ROA, y_2 is the estimated coefficient of emission reduction score on ROA. In Model 30, z_1 is the estimated coefficient of $\Delta CO_2 3$ on Tobin's q, and z_2 is the estimated coefficient of emission reduction score on Tobin's q. In addition, $t_0, u_0, w_0, x_0, y_0, z_0$ are the constant terms, t_3-t_8, u_3-u_8, w_3-w_8, x_3-x_8, y_3-y_8, and z_3-z_8 are estimated coefficients of the control variables, and ε_{19it}-ε_{24it} are random error terms.

4.8.3.3 Model specification of effects of resource use practices on financial performance

To examine effects of the resource use score on financial performance (i.e., ROA and Tobin's q) after controlling for CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$), Models (31)-(36) are developed as follows:

$$\begin{aligned} ROA_{it} = {} & \chi_0 + \chi_1 \Delta CO_2 1_{it} + \chi_2 Resources_{it} + \chi_3 Firm\ size_{it} + \chi_4 Net\,sales\,revenues_{it} \\ & + \chi_5 Capital\ intensity_{it} + \chi_6 Emission\ intensity_{it} + \chi_7 ISO\_EMS_{it} + \\ & \chi_8 Lev_{it} + v_i + \delta_t + \varepsilon_{25it} \end{aligned} \tag{31}$$

$$\begin{aligned} Tobin's\ q_{it} = {} & \eta_0 + \eta_1 \Delta CO_2 1_{it} + \eta_2 Resources_{it} + \eta_3 Firm\ size_{it} + \eta_4 Net\,sales\,revenues_{it} \\ & + \eta_5 Capital\ intensity_{it} + \eta_6 Emission\ intensity_{it} + \eta_7 ISO\_EMS_{it} + \\ & \eta_8 Lev_{it} + v_i + \delta_t + \varepsilon_{26it} \end{aligned} \tag{32}$$

$$\begin{aligned} ROA_{it} = {} & \mu_0 + \mu_1 \Delta CO_2 2_{it} + \mu_2 Resources_{it} + \mu_3 Firm\ size_{it} + \mu_4 Net\,sales\,revenues_{it} \\ & + \mu_5 Capital\ intensity_{it} + \mathrm{v}_6 Emission\ intensity_{it} + \mu_7 ISO\_EMS_{it} + \\ & \mu_8 Lev_{it} + v_i + \delta_t + \varepsilon_{27it} \end{aligned} \tag{33}$$

$$\begin{aligned} Tobin's\ q_{it} = {} & \varphi_0 + \varphi_1 \Delta CO_2 2_{it} + \varphi_2 Resources_{it} + \varphi_3 Firm\ size_{it} + \varphi_4 Net\,sales\,revenues_{it} \\ & + \varphi_5 Capital\ intensity_{it} + \varphi_6 Emission\ intensity_{it} + \varphi_7 ISO\_EMS_{it} + \\ & \varphi_8 Lev_{it} + v_i + \delta_t + \varepsilon_{28it} \end{aligned}$$

(34)

$$ROA_{it} = \phi_0 + \phi_1 \Delta CO_2 3_{it} + \phi_2 Resources_{it} + \phi_3 Firm\ size_{it} + \phi_4 Net sales\ revenues_{it} \psi + \phi_5 Capital\ intensity_{it} + \phi_6 Emission\ intensity_{it} + \phi_7 ISO\_EMS_{it} + \phi_8 Lev_{it} + v_i + \delta_t + \varepsilon_{29it}$$

(35)

$$Tobin's\ q_{it} = \gamma_0 + \gamma_1 \Delta CO_2 3_{it} + \gamma_2 Resources_{it} + \gamma_3 Firm\ size_{it} + \gamma_4 Net sales\ revenues_{it} + \gamma_5 Capital\ intensity_{it} + \gamma_6 Emission\ intensity_{it} + \gamma_7 ISO\_EMS_{it} + \gamma_8 Lev_{it} + v_i + \delta_t + \varepsilon_{30it}$$

(36)

In model 31, χ_1 is the estimated coefficient of $\Delta CO_2 1$ on ROA, and χ_2 is the estimated coefficient of resource use score on ROA. In model 32, η_1 is the estimated coefficient of $\Delta CO_2 1$ on Tobin's q, and η_2 is the estimated coefficient of resource use score on Tobin's q. In model 33, μ_1 is the estimated coefficient of $\Delta CO_2 2$ on ROA, and μ_2 is the estimated coefficient of the resource use score on ROA. In model 34, φ_1 is the estimated coefficient of $\Delta CO_2 2$ on Tobin's q, and φ_2 is the estimated coefficient of resource use score on Tobin's q. In model 35, ϕ_1 is the estimated coefficient of $\Delta CO_2 3$ on ROA, ϕ_2 is the estimated coefficient of resource use score on ROA. In model 36, γ_1 is the estimated coefficient of $\Delta CO_2 3$ on Tobin's q, and γ_2 is the estimated coefficient of resource use score on Tobin's q. In addition, χ_0, η_0, μ_0, φ_0, ϕ_0, and γ_0 are the constant terms, χ_3-χ_8, η_3-η_8, μ_3-μ_8, φ_3-φ_8, ϕ_3-ϕ_8, and γ_3-γ_8 are estimated coefficients of the control variables, and ε_{25it}-ε_{30it} are random error terms.

4.8.3.4 Model specification of effects of environmental innovation practices on financial performance

To explore the effects of the environmental innovation score on financial performance (i.e., ROA and Tobin's q) after controlling for scope 1, 2 and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$), Models (37)-(42) are developed as follows:

$$ROA_{it} = \kappa_0 + \kappa_1 \Delta CO_2 1_{it} + \kappa_2 Innovations_{it} + \kappa_3 Firm\ size_{it} + \kappa_4 Net\,sales\,revenues_{it} + \kappa_5 Capital\ intensity_{it} + \kappa_6 Emission\ intensity_{it} + \kappa_7 ISO\_EMS_{it} + \kappa_8 Lev_{it} + v_i + \delta_t + \varepsilon_{31it} \quad (37)$$

$$Tobin's\ q_{it} = \varpi_0 + \varpi_1 \Delta CO_2 1_{it} + \varpi_2 Innovations_{it} + \varpi_3 Firm\ size_{it} + \varpi_4 Net\,sales\,revenues_{it} + \varpi_5 Capital\ intensity_{it} + \varpi_6 Emission\ intensity_{it} + \varpi_7 ISO\_EMS_{it} + \varpi_8 Lev_{it} + v_i + \delta_t + \varepsilon_{32it} \quad (38)$$

$$ROA_{it} = \rho_0 + \rho_1 \Delta CO_2 2_{it} + \rho_2 Innovations_{it} + \rho_3 Firm\ size_{it} + \rho_4 Net\,sales\,revenues_{it} + \rho_5 Capital\ intensity_{it} + \rho_6 Emission\ intensity_{it} + \rho_7 ISO\_EMS_{it} + \rho_8 Lev_{it} + v_i + \delta_t + \varepsilon_{33it} \quad (39)$$

$$Tobin's\ q_{it} = \sigma_0 + \sigma_1 \Delta CO_2 2_{it} + \sigma_2 Innovations_{it} + \sigma_3 Firm\ size_{it} + \sigma_4 Net\,sales\,revenues_{it} + \sigma_5 Capital\ intensity_{it} + \sigma_6 Emission\ intensity_{it} + \sigma_7 ISO\_EMS_{it} + \sigma_8 Lev_{it} + v_i + \delta_t + \varepsilon_{34it} \quad (40)$$

$$ROA_{it} = \psi_0 + \psi_1 \Delta CO_2 3_{it} + \psi_2 Innovations_{it} + \psi_3 Firm\ size_{it} + \psi_4 Net\,sales\,revenues_{it} + \psi_5 Capital\ intensity_{it} + \psi_6 Emission\ intensity_{it} + \psi_7 ISO\_EMS_{it} + \psi_8 Lev_{it} + v_i + \delta_t + \varepsilon_{35it} \quad (41)$$

$$Tobin's\ q_{it} = \upsilon_0 + \upsilon_1 \Delta CO_2 3_{it} + \upsilon_2 Innovations_{it} + \upsilon_3 Firm\ size_{it} + \upsilon_4 Net\,sales\,revenues_{it} + \upsilon_5 Capital\ intensity_{it} + \upsilon_6 Emission\ intensity_{it} + \upsilon_7 ISO\_EMS_{it} + \upsilon_8 Lev_{it} + v_i + \delta_t + \varepsilon_{36it} \quad (42)$$

In Model 37, κ_1 is the estimated coefficient of $\Delta CO_2 1$ on ROA, and κ_2 is the estimated coefficient of the environmental innovation score on ROA. In Model 38, ϖ_1 is the estimated coefficient of $\Delta CO_2 1$ on Tobin's q, and ϖ_2 is the estimated coefficient of the environmental innovation score on Tobin's q. In Model 39, ρ_1 is the estimated coefficient of $\Delta CO_2 2$ on ROA, and ρ_2 is the estimated coefficient of the environmental innovation score on ROA. In Model 40, σ_1 is the estimated coefficient of $\Delta CO_2 2$ on Tobin's q, and σ_2 is the estimated coefficient of the environmental innovation score on Tobin's q. In Model 41, ψ_1 is the estimated coefficient of $\Delta CO_2 3$ on ROA, ψ_2 is the estimated coefficient of the environmental innovation score on ROA. In Model 42, υ_1 is the estimated coefficient of $\Delta CO_2 3$ on Tobin's q, and υ_2 is the estimated coefficient of the environmental innovation score on Tobin's q. In addition, $\kappa_0, \varpi_0, \rho_0, \sigma_0, \psi_0, \upsilon_0$ are constant terms, κ_3-κ_8, ϖ_3- ϖ_8, ρ_3-ρ_8, σ_3-σ_8, ψ_3-ψ_8, and υ_3-υ_8 are estimated coefficients of the control variables, and ε_{31it}-ε_{36it} are random error terms.

4.9 Assessing mediation with bootstrapping

As bootstrapping is considered the supplementary method to the causal steps approach (Hayes, 2009), this method is to test the mediating effects and validate the analysis results of the causal steps approach. Specifically, the bias-corrected bootstrapping method with 1,000 replications (MacKinnon et al., 2004b; Preacher & Hayes, 2008) is used. If the bootstrap 95% confidence interval (CI) of the indirect effects excludes zero, the mediating effect is significant and the proposed mediation hypotheses are established; on the contrary, if the bootstrap 95% CI of the indirect effects includes zero, the mediating effect is not significant, and the proposed mediation hypotheses are rejected (Zhao et al., 2010).

4.10 Robustness check

In this study, several additional analyses were carried out to evaluate the robustness of the results derived from the main analysis.

4.10.1 Alternative measures of financial performance

Following previous studies (Busch et al., 2022; Song et al., 2023; Villena & Dhanorkar, 2020), alternative indicators of financial performance are used to verify if the results derived from the alternative measures of financial performance are consistent with the main analysis findings. Specifically, ROE is used as an alternative measure of ROA for accounting-based financial performance (Busch et al., 2022). ROA and ROE are profitability ratio. ROA is used as a proxy of accounting-based financial performance in the main analysis to evaluate how efficiently a company uses assets to generate profits. Unlike ROA, the ROE measures how effectively a company uses stakeholder equity to generate profits, thus providing a different perspective on profits generation process of companies. ROE is calculated as net income divided by total equity of common shares. Therefore, ROE is used as an alternative measure of accounting-based financial performance in the robustness test.

Moreover, Tobin's q_1 is used as an alternative measure of Tobin's q as for the market-based financial performance for the following reasons. Tobin's q is measured as the sum of the market value, preferred stock and debt divided by total assets, while Tobin's q_1 is measured as enterprise value divided by total assets, where enterprise value is the sum of market capitalization, preferred stock, minority interest, and total debt minus cash. The difference between Tobin's q and Tobin's q_1 is that the latter considers cash and minority interest, which is not true of the former. while Tobin's q does not consider. Cash can be used to pay off debt, and the enterprise value will be reduced if the company has a significant amount of cash on its balance sheet. This is important for potential investors since they would be able to pay less to the company if it has significant cash reserves. Minority interest refers to the portion of equity of the subsidiaries companies that are not owned by the parent company, which means the parent company includes all revenue, expenses, and cash flow in its numbers even though it does not own 100% of the business. Adding minority interests in the calculation of enterprise value provides a more accurate picture of the total value of a company. Since all equity interest within the firms are considered, rather than just the shares that represent common and preferred stocks. Tobin's q_1 is therefore a more comprehensive measure compared to Tobin's q. In this study, ROE and Tobin's q_1 are calculating with the use of and collected from DataStream database.

4.10.2 Omitted variables

To address the concern of omitted variables, previous studies are referenced, and four additional control variables are added to the Models (1)-(42) for the robustness test, including dividend yield, net profit margin, EPS (Liu et al., 2023), and sales revenue (Wang et al., 2014). Dividend yield is defined as dividend per share as a percentage of the share price. Net profit margin is defined as net income divided by sales. EPS is the amount of profits earned by each outstanding share of common stock, which is calculated as net income of company divided by total number of outstanding shares. The four additional control variables are collected from the DataStream database.

Chapter Summary

In Chapter 4, the research methodology is presented to elaborate on how this study is conducted. This study establishes econometric models (1)-(42) to analyze the data collected from 122 companies in different industries worldwide by using the causal steps approach and bootstrapping method. Moreover, the robustness tests are conducted by i) using alternative measures of financial performance in terms of ROE and Tobin's q1; and ii) adding four control variables (i.e., dividend yield, net profit margin, EPS, and sales revenue) to address the issues of omitted variables, which enhance the reliability and credibility of the results obtained from the main analysis. In Chapter 5, the results obtained from Chapter 4 are further explained.

Chapter 5 Results

5.1 Introduction

In this chapter, the empirical results of this study are reported, with the aim of answering Research Questions 1-4 proposed in Chapter 1. Specifically, the results by using causal steps approach and bootstrapping method are reported, including the relationships between i) each scope of CO_2 emission variations on financial performance in terms of ROA and Tobin's q; ii) each scope of CO_2 emission variations and environmental practices in terms of integrated environmental practices, emission reduction practices, resource use practices, and environmental innovation practices; and iii) environmental practices (i.e., integrated environmental practices, emission reduction practices, resource use practices, and environmental innovation practices) and financial performance (i.e., ROA and Tobin's q). This chapter also reports the results of robustness check, including i) using ROE and Tobin's q_1 as alternative measures of financial performance; and ii) adding dividend yield, net profit margin, EPS, and sales revenue as additional control variables in the econometric models (1)-(42) that are established in Chapter 4. The findings provide empirical support for understanding the relationships among CO_2 emissions, environmental practices, and financial performance.

5.2 Results of effects of CO_2 emission variations on financial performance

5.2.1 Results of effects of CO_2 emission variations on ROA

The results in Table 5-1 indicate negative relationships between each scope of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) and ROA.

In Model 1, the results show a negative relationship between $\Delta CO_2 1$ and ROA (β_1=-2.6248, p<0.01). Specifically, a 1% increase in scope 1 CO_2 emission will result in a 2.6248% decrease in ROA, ceteris paribus; conversely, a 1% decrease in scope 1 CO_2 emission, ROA will be increased by 2.6248%, ceteris paribus. The results support H_1 (a).

In Model 3, the results present a negative relationship between $\Delta CO_2 2$ and ROA (γ_1=-2.5606, p<0.01). Specifically, a 1% increase in scope 2 CO_2 emission will result in a 2.5606% decrease in ROA, ceteris paribus; conversely, a 1% decrease in scope 2 CO_2 emission will result in a 2.5606% increase in ROA, ceteris paribus. The results support H_2 (a).

In Model 5, the results indicate a negative relationship between $\Delta CO_2 3$ and ROA (θ_1=-2.2907, p<0.01), Specifically, a 1% increase in scope 3 CO_2 emission will lead to a 2.2907% decrease in ROA, ceteris paribus. In contrast, a 1% decrease in scope 3 CO_2 emission will lead to a 2.2907% increase in the ROA, ceteris paribus. The results support H_3 (a).

Table 5-1 Estimation results: effects of CO_2 emission variations on ROA.

	Dependent variable: ROA			
	Estimate Controls only	Estimate Model 1	Estimate Model 3	Estimate Model 5
$\Delta CO_2 1$		-2.6248^{***}		
		(-4.5253)		
$\Delta CO_2 2$			-2.5606^{***}	
			(-4.5097)	
$\Delta CO_2 3$				-2.2907^{***}
				(-4.4663)
LogFs	-0.6006	-0.0378	-0.0501	-0.1197
	(-0.8821)	(-0.0556)	(-0.0734)	(-0.1767)
LogNsr	1.8534^{**}	1.2624	1.2746	1.3209
	(2.4488)	(1.5459)	(1.5651)	(1.6056)
LogCI	-0.0665	-0.1311	-0.1288	-0.1282
	(-0.2315)	(-0.4348)	(-0.4291)	(-0.4233)

LogEI	0.6988	1.0002*	0.9941*	0.9841*
	(1.1905)	(1.7643)	(1.7512)	(1.7243)
ISO_EMS	-0.6171	-0.4981	-0.4876	-0.4661
	(-0.6861)	(-0.5430)	(-0.5314)	(-0.5113)
Lev	-0.0778***	-0.0642**	-0.0646**	-0.0663**
	(-2.9623)	(-2.4156)	(-2.4310)	(-2.4999)
Cons	-18.4836	-15.3202	-15.4875	-15.4478
	(-1.2990)	(-1.0556)	(-1.0683)	(-1.0620)
Firm-fixed effect	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
N	799	799	799	799
R^2	0.0359	0.0747	0.0721	0.0670
adj. R^2	0.0137	0.0521	0.0494	0.0442
F	2.6504	3.2105	3.2393	3.1899

Note: Cons=Constant, N=Number of observations, R^2=R-squared or the coefficient of determination, adj. R^2= Adjusted R-squared, F=F statistic, t statistics in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.2.2 Results of effects of CO2 emission variations on Tobin's q

As shown in Table 5-2, the results present that each scope of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) are not in relation to Tobin's q.

In Model 2, the result shows that $\Delta CO_2 1$ does not have impact on Tobin's q (α_1=0.0395, p=0.465), which implies that an increase or a decrease in scope 1 CO_2 emission is not linked to Tobin's q. The result rejects H_1 (b).

In Model 4, the effect of $\Delta CO_2 2$ on Tobin's q is not significant (λ_1=0.0433, p=0.425), which indicates an increase or a decrease in scope 2 CO_2 emission is not related to Tobin's q. The result rejects H_2 (b).

In Model 6, the result indicates that $\Delta CO_2 3$ is not associated with Tobin's q (ω_1=0.0509, p=0.362), which suggests that an increase or a decrease in scope 3 CO_2 emission is not in relation to Tobin's q. The results rejected H_3 (b).

Table 5-2 Estimation results: effects of CO_2 emission variations on Tobin's q .

	Dependent variable: Tobin' s q			
	Estimate Controls only	Estimate Model 2	Estimate Model 4	Estimate Model 6
$\Delta CO_2 1$		0.0395		
		(0.7340)		
$\Delta CO_2 2$			0.0433	
			(0.8009)	
$\Delta CO_2 3$				0.0509
				(0.9160)
LogFs	-0.3784***	-0.3869***	-0.3877***	-0.3891***
	(-3.4661)	(-3.5581)	(-3.5538)	(-3.5706)
LogNsr	0.7052*	0.7141*	0.7150*	0.7171*
	(1.7805)	(1.7985)	(1.8007)	(1.7970)
LogCI	-0.1697***	-0.1687***	-0.1686***	-0.1683***
	(-2.8643)	(-2.8697)	(-2.8673)	(-2.8660)
LogEI	-0.1112	-0.1157	-0.1162	-0.1175
	(-0.8411)	(-0.8746)	(-0.8787)	(-0.8890)
ISO_EMS	-0.1589*	-0.1607*	-0.1611*	-0.1623*
	(-1.8397)	(-1.8556)	(-1.8615)	(-1.8625)
Lev	0.0124	0.0122	0.0122	0.0121
	(1.3634)	(1.3365)	(1.3342)	(1.3309)
Cons	-6.2380	-6.2857	-6.2887	-6.3056
	(-0.9705)	(-0.9777)	(-0.9782)	(-0.9800)
Firm-fixed effect	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
N	799	799	799	799
R^2	0.2169	0.2176	0.2177	0.2181
adj. R^2	0.1988	0.1985	0.1986	0.1991
F	5.8340	5.4468	5.4388	5.4440

5.3 Results of effects of CO_2 emission variations on environmental practices

5.3.1 Results of effects of CO_2 emission variations on integrated environmental practices

The results in Tables 5-3 show negative relationships between CO_2 emission variations (i.e., ΔCO_21, ΔCO_22 and ΔCO_23) and the environmental pillar score.

In Model 7, ΔCO_21 are negatively related to environmental pillar score (a_1=-14.2877, p<0.01). Specifically, a 1% increase in scope 1 CO_2 emission will lead to approximately 14.2877% decrease in the environmental pillar score, ceteris paribus. In contrast, an approximately 14.2877% increase in the environmental pillar score is in response to a 1% decrease in scope 1 CO_2 emission, ceteris paribus. The results lend support to H_4 (a).

In Model 11, the result indicates that ΔCO_22 has a negative impact on environmental pillar score (e_1=-14.1018, p<0.01), suggesting that a 1% increase in scope 2 CO_2 emission will lead to approximately 14.1018% decrease in the environmental pillar score, ceteris paribus; and conversely, an approximately 14.1018% increase in the environmental pillar score is in response to a 1% decrease in scope 2 CO_2 emission, ceteris paribus. Thus, the results support H_5 (a).

In Model 15, the result reveals a negative relationship between ΔCO_23 and environmental pillar score (i_1=-12.0366, p<0.01), indicating that a 1% increase in scope 3 CO_2 emission is associated with approximately 12.0366% decrease in the environmental pillar score, ceteris paribus. In contrast, a 1% decrease in scope 3 CO_2 emission is linked to approximately 12.0366% increase in environmental pillar score, ceteris paribus. Therefore, the results provide support for H_6 (a).

Table 5-3 Estimation results: effects of CO_2 emission variations on environmental pillar score.

	Dependent variable: Environmental pillar score			
Variable	Estimate	Variable	Estimate	Variable

	Controls only	Model 7	Model 11	Model 15
$\Delta CO_2 1$		-14.2877***		
		(-4.7296)		
$\Delta CO_2 2$			-14.1018***	
			(-4.7063)	
$\Delta CO_2 3$				-12.0366***
				(-4.6412)
LogFs	-1.4101	1.6533	1.6219	1.1170
	(-0.7700)	(0.9943)	(0.9712)	(0.6697)
LogNsr	3.9561*	0.7391	0.7689	1.1583
	(1.8793)	(0.4538)	(0.4704)	(0.7005)
LogCI	-0.1972	-0.5488	-0.5403	-0.5215
	(-0.2602)	(-0.8488)	(-0.8260)	(-0.7677)
LogEI	-1.2823	0.3581	0.3438	0.2170
	(-0.8191)	(0.3097)	(0.2955)	(0.1750)
ISO_EMS	-1.1025	-0.4548	-0.3896	-0.3093
	(-0.4648)	(-0.1978)	(-0.1689)	(-0.1313)
Lev	0.0803	0.1538*	0.1526*	0.1402
	(0.9019)	(1.8257)	(1.8142)	(1.6095)
Cons	23.4696	40.6885	39.9693	39.4208
	(0.6682)	(1.6173)	(1.5717)	(1.5060)
Firm-fixed effect	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
N	799	799	799	799
R_2	0.0550	0.2548	0.2458	0.2043
adj. R_2	0.0332	0.2367	0.2274	0.1849
F	3.0098	5.2879	5.1397	4.6409

5.3.2 Results of effects of CO_2 emission variations on emission reduction practices

The results Table 5-4 show negative relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) and emission reduction score.

Based on the results in Model 8, $\Delta CO_2 1$ has negative impact on the emission reduction score (b_{1}=-17.1482, p<0.01), thus indicating that a 1% increase in scope 1 CO_2 emission will lead to approximately 17.1482% decrease in the emission reduction score, while a reduction of 1% in scope 1 CO_2 emission will lead to an increase of approximately 17.1482% in the emission reduction score, ceteris paribus. Thus, the results support H_4 (b).

Model 12 indicates that $\Delta CO_2 2$ is negatively associated with the emission reduction score (f_1=-17.1489, p<0.01), which indicates that a 1% increase in scope 2 CO_2 emission will result in an approximately 17.1489% decrease in the emission reduction score, and conversely, a 1% reduction in scope 2 CO_2 emission will result in approximately 17.1489% increase in the emission reduction score, ceteris paribus. Therefore, the results provide support for H_5 (b).

In Model 16, the negative effect of $\Delta CO_2 3$ on the emission reduction score (j_1=-14.9703, p<0.01) suggests that a 1% increase in scope 3 CO_2 emission will lead to approximately 14.9703% decrease in the emission reduction score, while a decrease of 1% in scope 3 CO_2 emission is associated with an approximate 14.9703% increase in the emission reduction score, ceteris paribus. Thus, H_6 (b) is supported.

Table 5-4 Estimation results: effects of CO_2 emission variations on emission reduction score.

	Dependent variable: Emission reduction score			
	Estimate Controls only	Estimate Model 8	Estimate Model 12	Estimate Model 16
$\Delta CO_2 1$		-17.1482^{***}		
		(-10.1682)		
$\Delta CO_2 2$			-17.1489^{***}	
			(-10.2962)	
$\Delta CO_2 3$				-14.9703^{***}
				(-11.3691)
LogFs	-2.9395^{*}	0.7372	0.7477	0.2036
	(-1.6620)	(0.4528)	(0.4561)	(0.1194)
LogNsr	8.2513^{***}	4.3902^{**}	4.3753^{**}	4.7716^{**}

	(3.2020)	(2.4965)	(2.5039)	(2.5673)
LogCI	-0.0261	-0.4480	-0.4433	-0.4293
	(-0.0333)	(-0.6885)	(-0.6773)	(-0.6338)
LogEI	-1.3913	0.5774	0.5861	0.4734
	(-0.9375)	(0.4919)	(0.5001)	(0.3831)
ISO_EMS	-2.1792	-1.4017	-1.3122	-1.1926
	(-1.2539)	(-0.9332)	(-0.8699)	(-0.7416)
Lev	-0.0327	0.0555	0.0553	0.0418
	(-0.3423)	(0.7099)	(0.7065)	(0.5072)
Cons	-20.4111	0.2552	-0.3461	-0.5721
	(-0.4785)	(0.0092)	(-0.0126)	(-0.0191)
Firm-fixed effect	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
N	799	799	799	799
R_2	0.0889	0.3785	0.3727	0.3213
adj. R_2	0.0679	0.3633	0.3574	0.3047
F	2.6497	25.2945	25.2617	24.6519

5.3.3 Results of effects of CO_2 emission variations on resource use practices

The results in Table 5-5 shows non-significant relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) and the resource use score.

As shown in Model 9, $\Delta CO_2 1$ is not associated with the resource use score (c_1=-1.1109, p=0.397), which suggests that an increase or a decrease in scope 1 CO_2 emission is not linked to resource use score. Thus, the result rejects H_4 (c).

As a result of Model 13, $\Delta CO_2 2$ is not related to the resource use score (c_1=-1.0796, p=0.413), indicating that an increase or a decrease in scope 2 CO_2 emission is not in relation to the resource use score. The results reject H_5 (c).

Model 17 shows an insignificant relationship between $\Delta CO_2 3$ and the resource use score (c_1=-1.1707, p=0.344), which implies that an increase or a decrease in scope 3 CO_2 emission is not related to the resource use score. Therefore, H_6 (c) is rejected.

Table 5-5 Estimation results: effects of CO_2 emission variations on resource use score.

	Dependent Variable: Resource use score			
	Estimate	Estimate	Estimate	Estimate
	Controls only	Model 9	Model 13	Model 17
$\Delta CO_2 1$		-1.1109		
		(-0.8501)		
$\Delta CO_2 2$			-1.0796	
			(-0.8220)	
$\Delta CO_2 3$				-1.1707
				(-0.9505)
LogFs	1.9681	2.2063	2.2002	2.2139
	(1.0220)	(1.1454)	(1.1421)	(1.1536)
LogNsr	3.2573	3.0071	3.0133	2.9851
	(1.5153)	(1.3435)	(1.3457)	(1.3427)
LogCI	0.9968	0.9694	0.9705	0.9652
	(0.9890)	(0.9606)	(0.9613)	(0.9566)
LogEI	-0.4677	-0.3402	-0.3433	-0.3219
	(-0.2765)	(-0.2013)	(-0.2030)	(-0.1901)
ISO_EMS	2.6495	2.6999	2.7041	2.7267
	(1.5956)	(1.6138)	(1.6177)	(1.6346)
Lev	-0.0453	-0.0396	-0.0398	-0.0395
	(-0.4140)	(-0.3614)	(-0.3631)	(-0.3607)
Cons	-2.0609	-0.7221	-0.7977	-0.5094
	(-0.0618)	(-0.0213)	(-0.0235)	(-0.0151)
Firm-fixed effect	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
N	799	799	799	799
R_2	0.1668	0.1685	0.1684	0.1688
adj. R_2	0.1475	0.1483	0.1481	0.1486
F	2.6931	2.7813	2.7793	2.7666

5.3.4 Results of effects of CO_2 emission variations on environmental innovation practices

The results in Table 5-6 show insignificant relationships between CO_2 emission variations (i.e., ΔCO_21, ΔCO_22 and ΔCO_23) and the environmental innovation score.

In Model 10, the results show an insignificant relationship between ΔCO_21 and the environmental innovation score (d_1=-1.0247, p=0.684). The result indicates that an increase or a decrease in scope 1 CO_2 emission is not linked to the environmental innovation score, which rejects H_4 (d).

In Model 14, an insignificant relationship between ΔCO_22 and the environmental innovation score (h_1=-1.1084, p=0.663) indicates that an increase or a decrease in scope 2 CO_2 emission is not related to the environmental innovation score. Thus, the result rejects H_5 (d).

The results in Model 18 show the effect of ΔCO_23 on the environmental innovation score (l_1=-0.4059, p=0.857) is not significant, which suggests that an increase or a decrease in scope 3 CO_2 emission is not associated with the environmental innovation score, Therefore, H_6 (d) is rejected.

Table 5-6 Estimation results: effects of CO_2 emission variations on environmental innovation score.

	Dependent Variable: Environmental innovation score			
	Estimate	Estimate	Estimate	Estimate
	Controls only	Model 10	Model 14	Model 18
ΔCO_21		-1.0247		
		(-0.4076)		
ΔCO_22			-1.1084	
			(-0.4375)	
ΔCO_23				-0.4059
				(-0.1801)
LogFs	10.0268***	10.2465***	10.2651***	10.1120***
	(3.4776)	(3.7585)	(3.7626)	(3.6766)
LogNsr	-0.4165	-0.6472	-0.6670	-0.5108

	(-0.0892)	(-0.1409)	(-0.1450)	(-0.1120)
LogCI	-2.7592	-2.7844	-2.7861	-2.7701
	(-1.4557)	(-1.4818)	(-1.4830)	(-1.4725)
LogEI	4.0465	4.1642*	4.1744*	4.0971
	(1.6149)	(1.6857)	(1.6888)	(1.6490)
ISO_EMS	0.0758	0.0811	0.0815	0.0779
	(0.4193)	(0.4527)	(0.4549)	(0.4337)
Lev	-2.2725	-2.2261	-2.2165	-2.2458
	(-0.6438)	(-0.6275)	(-0.6239)	(-0.6324)
Cons	-39.2807	-38.0457	-37.9838	-38.7427
	(-0.4714)	(-0.4560)	(-0.4550)	(-0.4662)
Firm-fixed effect	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
N	799	799	799	799
R_2	0.0393	0.0396	0.0397	0.0394
adj. R_2	0.0171	0.0162	0.0163	0.0159
F	2.4552	2.3653	2.3648	2.3538

5.4 Results of effects of environmental practices on financial performance

5.4.1 Results of effects of integrated environmental practices on financial performance

5.4.1.1 Results of effects of integrated environmental practices on ROA

Table 5-7 presents the results of the effects of the environmental pillar score on ROA after controlling for scopes 1, 2 and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$).

In Model 19, the result reveals that the environmental pillar score has significant and positive impacts on ROA (n_2=0.0605, p<0.01) after controlling for the effects of $\Delta CO_2 1$, which indicates that a 1% increase in the environmental pillar score is associated with an increase of 0.0605% in ROA, ceteris paribus.

The results of Model 21 show a positive relationship between the environmental pillar score and ROA (p_2=0.0625, p<0.01) after controlling for the effects of $\Delta CO_2 2$, thus suggesting that a 1% increase in the environmental pillar score will result in 0.0625% increase in ROA, ceteris paribus.

The results of Model 23 indicate that environmental pillar score has a positive impact on ROA (r_2=0.0671, p<0.01) after controlling for the effects of $\Delta CO_2 3$, which indicates that a 1% increase in the environmental pillar score will result in 0.0671% increase in ROA, ceteris paribus.

Based on Models 19, 21, and 23, the results shows that the environmental pillar score has significant and positive impacts on ROA regardless of whether the effects of $\Delta CO_2 1$, $\Delta CO_2 2$, or $\Delta CO_2 3$ is controlled. Thus, the results lend support to H_7 (a).

5.4.1.2 Results of effects of integrated environmental practices on Tobin's q

Table 5-7 presents the results of the effects of the environmental pillar score on Tobin's q after controlling for the effects of scopes 1, 2 and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$).

In Model 20, the results show that the environmental pillar score is not in relation to Tobin's q (o_2=-0.0002, p=0.893) after controlling for the effects of $\Delta CO_2 1$.

The results of Model 22 reveal that the relationship between the environmental pillar score and Tobin's q is not significant (q_2=-0.0002, p=0.916) after controlling for the effects of $\Delta CO_2 2$.

The results of Model 24 indicate that the environmental pillar score is not related to Tobin's q (s_2=-0.0001, p=0.948) after controlling for the effects of $\Delta CO_2 3$.

As shown in Models 20, 22, and 24, the results presented that the environmental pillar score is not associated with Tobin's q regardless of whether the effects of $\Delta CO_2 1$, $\Delta CO_2 2$, or $\Delta CO_2 3$ is controlled. Therefore, the results reject H_7 (b).

Table 5-7 Estimation results: the effects of environmental pillar score on financial performance.

	Dependent Variable: ROA			Dependent Variable: Tobin's q		
	Estimate Model 19	Estimate Model 21	Estimate Model 23	Estimate Model 20	Estimate Model 22	Estimate Model 24
$\Delta CO_2 1$	-1.7603***			0.0364		
	(-2.7726)			(0.5962)		
$\Delta CO_2 2$		-1.6789***			0.0409	
		(-2.6842)			(0.6658)	
$\Delta CO_2 3$			-1.4833***			0.0497
			(-2.6654)			(0.8008)
Pillars	0.0605***	0.0625***	0.0671***	-0.0002	-0.0002	-0.0001
	(3.0707)	(3.1914)	(3.6324)	(-0.1347)	(-0.1058)	(-0.0653)
LogFs	-0.1379	-0.1515	-0.1946	-0.3865***	-0.3874***	-0.3890***
	(-0.2117)	(-0.2326)	(-0.3022)	(-3.5544)	(-3.5487)	(-3.5674)
LogNsr	1.2176	1.2265	1.2432	0.7143*	0.7152*	0.7172*
	(1.5230)	(1.5390)	(1.5448)	(1.7992)	(1.8013)	(1.7989)
LogCI	-0.0979	-0.0951	-0.0933	-0.1688***	-0.1687***	-0.1684***
	(-0.3250)	(-0.3166)	(-0.3084)	(-2.8723)	(-2.8686)	(-2.8670)
LogEI	0.9785*	0.9726*	0.9696*	-0.1157	-0.1161	-0.1175
	(1.7043)	(1.6918)	(1.6823)	(-0.8753)	(-0.8794)	(-0.8893)
ISO_EMS	-0.4706	-0.4633	-0.4454	-0.1608*	-0.1612*	-0.1623*
	(-0.5241)	(-0.5161)	(-0.4989)	(-1.8595)	(-1.8642)	(-1.8645)
Lev	-0.0736***	-0.0742***	-0.0758***	0.0122	0.0122	0.0122
	(-2.6595)	(-2.6802)	(-2.7537)	(1.3264)	(1.3234)	(1.3208)
Cons	-17.7821	-17.9866	-18.0923	-6.2768	-6.2819	-6.3014
	(-1.2253)	(-1.2410)	(-1.2421)	(-0.9731)	(-0.9740)	(-0.9753)
Firm-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	799	799	799	799	799	799
R_2	0.0903	0.0890	0.0876	0.2176	0.2177	0.2181
adj. R_2	0.0670	0.0656	0.0641	0.1975	0.1976	0.1980
F	4.2595	4.3074	4.2856	5.1768	5.1688	5.1669

5.4.2 Results of effects of emission reduction practices on financial performance

5.4.2.1 Results of effects of emission reduction practices on ROA

Table 5-8 shows the results of the effects of emission reduction score on ROA after controlling for the effects of scope 1, 2 and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$).

The results of Model 25 show that emission reduction score is positively related to ROA (t_2=0.0659, p<0.01) after controlling for the effects of $\Delta CO_2 1$, which indicates that a 1% increase in emission reduction score is associated with an increase of 0.0659% in ROA, ceteris paribus.

In Model 27, the results show the emission reduction score is positively associated with ROA (w_2=0.0684, p<0.01) after controlling for the effects of $\Delta CO_2 2$ suggests that a 1% increase in the emission reduction score will result in a 0.0684% increase in ROA, ceteris paribus.

In Model 29, the results reveal that the emission reduction score has positive impact on ROA (y_2=0.0733, p<0.01) after controlling for the effects of $\Delta CO_2 3$, which indicates that a 1% increase in the emission reduction score is associated with a 0.0733% increase in ROA, ceteris paribus.

The results in Models 25, 27, and 29 show that the emission reduction score has significant and positive impact on ROA regardless of whether the effects of $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$ is controlled. Thus, the results support H_8 (a).

5.4.2.2 Results of effects of emission reduction practices on Tobin's q

Table 5-8 shows the results of the effects of the emission reduction score on Tobin's q after controlling for the effects of scope 1, 2 and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$,

$\Delta CO_2 2$, and $\Delta CO_2 3$).

In Model 26, the results show that emission reduction score is not in relation to Tobin's q (u_2=0.0012, p=0.457) after controlling for the effects of $\Delta CO_2 1$.

The results of Model 28 show that emission reduction score has associated with Tobin's q (q_2=0.0013, p=0.439) after controlling for the effects of $\Delta CO_2 2$.

The results of Model 30 reveal that the emission reduction score is not associated with Tobin's q (z_2=0.0013, p=0.428) after controlling for the effects of $\Delta CO_2 3$.

The results of Models 26, 28, and 30 show that the emission reduction score is not associated with Tobin's q regardless of which scope of the effects of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) is controlled. Therefore, H_8 (b) is rejected.

Table 5-8 Estimation results: the effects of emission reduction score on financial performance.

	Dependent Variable: ROA			Dependent Variable: Tobin's q		
	Estimate Model 25	Estimate Model 27	Estimate Model 29	Estimate Model 26	Estimate Model 28	Estimate Model 30
$\Delta CO_2 1$	-1.4945**			0.0602		
	(-2.1962)			(0.9941)		
$\Delta CO_2 2$		-1.3874**			0.0651	
		(-2.0728)			(1.0618)	
$\Delta CO_2 3$			-1.1938**			0.0702
			(-1.9852)			(1.1305)
Emissions	0.0659***	0.0684***	0.0733***	0.0012	0.0013	0.0013
	(2.9162)	(3.0305)	(3.3969)	(0.7457)	(0.7761)	(0.7956)
LogFs	-0.0864	-0.1012	-0.1346	-0.3878***	-0.3887***	-0.3893***
	(-0.1251)	(-0.1462)	(-0.1961)	(-3.5368)	(-3.5298)	(-3.5390)
LogNsr	0.9730	0.9753	0.9713	0.7089*	0.7095*	0.7110*
	(1.2100)	(1.2157)	(1.2040)	(1.7908)	(1.7921)	(1.7929)
LogCI	-0.1016	-0.0985	-0.0968	-0.1682***	-0.1681***	-0.1677***
	(-0.3400)	(-0.3308)	(-0.3229)	(-2.8584)	(-2.8550)	(-2.8541)

LogEI	0.9621	0.9540	0.9495	-0.1164	-0.1169	-0.1182
	(1.6279)	(1.6099)	(1.5971)	(-0.8791)	(-0.8836)	(-0.8925)
ISO_EMS	-0.4057	-0.3978	-0.3787	-0.1590*	-0.1594*	-0.1607*
	(-0.4488)	(-0.4402)	(-0.4210)	(-1.8255)	(-1.8307)	(-1.8368)
Lev	-0.0679**	-0.0684**	-0.0694**	0.0121	0.0121	0.0121
	(-2.3732)	(-2.3857)	(-2.4227)	(1.3238)	(1.3210)	(1.3200)
Cons	-15.3371	-15.4638	-15.4059	-6.2860	-6.2883	-6.3048
	(-1.0434)	(-1.0529)	(-1.0459)	(-0.9772)	(-0.9776)	(-0.9798)
Firm-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	799	972	799	799	799	799
R_2	0.0901	0.0888	0.0878	0.2180	0.2182	0.2187
adj. R_2	0.0667	0.0654	0.0644	0.1979	0.1981	0.1986
F	4.3994	4.4569	4.4842	5.1510	5.1485	5.1403

5.4.3 Results of effects of resource use practices on financial performance

5.4.3.1 Results of effects of resource use practices on ROA

Table 5-9 shows the results of the effects of the resource use score on ROA after controlling for the effects of scope 1, 2 and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$).

The results of Model 31 show that the resource use score is not associate with ROA (χ_2=-0.0086, p=0.708) after controlling for the effects of $\Delta CO_2 1$.

In Model 33, the relationship between the resource use score and ROA is not significant (μ_2=-0.0083, p= 0.720) after controlling for the effects of $\Delta CO_2 2$.

In Model 35, the results show that the impact of the resource use score on ROA is not significant (ϕ_1=-0.0085, p=0.711) after controlling for the effects of$\Delta CO_2 3$.

The results of Models 31, 33, and 35 show that the resource use score is not associated with ROA regardless of whether the effects of $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$ is controlled.

Therefore, the results reject H_9 (a).

5.4.3.2 Results of effects of resource use practices on Tobin's q

Table 5-9 shows the results of the effects of the resource use score on Tobin's q after controlling for the effects of scope 1, 2 and 3 CO_2 emission variations (i.e., ΔCO_21, ΔCO_22, and ΔCO_23).

The results of Model 32 show that resource use score is not related to Tobin's q (η_2=-0.0040, p=0.122) after controlling for the effects of ΔCO_21.

The results of Model 34 reveal that the non-significant relationship between resource use score and Tobin's q (φ_2=-0.0040, p= 0.122) after controlling for the effects of ΔCO_22.

The results of Model 36 indicate that resource use score is not associated with Tobin's q (γ_2=-0.0040, p= 0.123) after controlling for the effects of ΔCO_23.

The results of Models 32, 34, and 36 show that the resource use score is not associated with Tobin's q regardless of whether the effects of ΔCO_21, ΔCO_22, and ΔCO_23 is controlled. Therefore, the results reject H_9 (b).

Table 5-9 Estimation results: effects of resource use score on financial performance.

	Dependent Variable: ROA			Dependent Variable: Tobin's q		
	Estimate Model 31	Estimate Model 33	Estimate Model 35	Estimate Model 32	Estimate Model 34	Estimate Model 36
ΔCO_21	-2.6344***			0.0351		
	(-4.5337)			(0.6796)		
ΔCO_22		-2.5696***			0.0390	
		(-4.5173)			(0.7521)	
ΔCO_23			-2.3007***			0.0463
			(-4.4781)			(0.8668)
Resources	-0.0086	-0.0083	-0.0085	-0.0040	-0.0040	-0.0040
	(-0.3759)	(-0.3594)	(-0.3717)	(-1.5606)	(-1.5589)	(-1.5550)
LogFs	-0.0188	-0.0319	-0.1009	-0.3780***	-0.3789***	-0.3803***

	(-0.0275)	(-0.0464)	(-0.1480)	(-3.4502)	(-3.4460)	(-3.4646)
LogNsr	1.2883	1.2995	1.3462	0.7262*	0.7271*	0.7290*
	(1.5646)	(1.5824)	(1.6222)	(1.8209)	(1.8233)	(1.8193)
LogCI	-0.1228	-0.1208	-0.1201	-0.1648***	-0.1647***	-0.1645***
	(-0.4057)	(-0.4010)	(-0.3948)	(-2.8589)	(-2.8567)	(-2.8554)
LogEI	0.9972*	0.9912*	0.9814*	-0.1171	-0.1176	-0.1188
	(1.7625)	(1.7494)	(1.7223)	(-0.8953)	(-0.8995)	(-0.9093)
ISO_EMS	-0.4748	-0.4653	-0.4430	-0.1499*	-0.1503*	-0.1514*
	(-0.5127)	(-0.5024)	(-0.4817)	(-1.7812)	(-1.7874)	(-1.7889)
Lev	-0.0646**	-0.0649**	-0.0667**	0.0120	0.0120	0.0120
	(-2.4199)	(-2.4345)	(-2.5025)	(1.3263)	(1.3239)	(1.3208)
Cons	-15.3265	-15.4941	-15.4521	-6.2886	-6.2919	-6.3076
	(-1.0553)	(-1.0681)	(-1.0620)	(-0.9818)	(-0.9824)	(-0.9838)
Firm-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	799	945	799	799	799	799
R_2	0.0749	0.0723	0.0672	0.2219	0.2220	0.2224
adj. R_2	0.0511	0.0484	0.0433	0.2019	0.2020	0.2024
F	3.0485	3.0756	3.0258	5.2901	5.2809	5.2934

5.4.4 Results of effects of environmental innovation practices on financial performance

5.4.4.1 Results of effects of environmental innovation practices on ROA

The results reported in Table 5-10 present the effects of environmental innovation score on ROA after controlling for the effects of scope 1, 2 and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$).

The results of Model 37 show that the environmental innovation score has a positive impact on ROA (κ_2=0.0427, p<0.01) after controlling for the effects of $\Delta CO_2 1$, which indicates that a 1% increase in the environmental innovation score is associated with an increase of 0.0427% in ROA.

The results of Model 39 show a positive relationship between the environmental innovation score and ROA (ϖ_2=0.0426, p<0.01) after controlling for the effects of$\Delta CO_2 2$, thus suggesting that a 1% increase in the environmental innovation score will lead to an increase of 0.0426% in ROA.

The results of Model 41 show the environmental innovation score is positively associated with ROA (ψ_2=0.0432, p<0.01) after controlling for the effects of$\Delta CO_2 3$, which indicates that a 1% increase in the environmental innovation score is linked to a 0.0432% increase in ROA.

The results of Models 37, 39, and 41 show that the environmental innovation score has a significant and positive impact on ROA regardless of whether the effects of $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$ is controlled. Thus, the results lend support to H_{10} (a).

5.4.4.2 Results of effects of environmental innovation practices on Tobin's q

Table 5-10 shows the results of the effects of the environmental innovation score on Tobin's q after controlling for the effects of scope 1, 2 and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$).

The results of Model 38 show that the environmental innovation scores are negatively related to Tobin's q (ϖ_2=-0.0023, p=0.048) after controlling for the effects of $\Delta CO_2 1$, which indicates that a 1% increase in the environmental innovation score will lead to a decrease of 0.0233% in Tobin's q.

In Model 40, the environmental innovation score has negative impact on Tobin's q (σ_2=-0.0023, p=0.048) after controlling for the effects of $\Delta CO_2 2$, thus suggesting that a reduction of 0.0038% in Tobin's q is in response to the increase in environmental innovation score.

The results of Model 42 indicate that the increase in the environmental innovation score is negatively related to Tobin's q (υ_2=-0.0023, p=0.047) after controlling for the effects of $\Delta CO_2 3$.

The results of Models 38, 40, and 42 show that the environmental innovation score is negatively associated with Tobin's q regardless of whether the effects of $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$ is controlled. Therefore, the results reject H_{10} (b).

Table 5-10 Estimation results: effects of environmental innovation score on financial performance.

	Dependent Variable: ROA			Dependent Variable: Tobin's q		
	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
	Model 37	Model 39	Model 41	Model 38	Model 40	Model 42
$\Delta CO_2 1$	-2.5811***			0.0372		
	(-4.7003)			(0.6735)		
$\Delta CO_2 2$		-2.5134***			0.0408	
		(-4.6882)			(0.7361)	
$\Delta CO_2 3$			-2.2732***			0.0500
			(-4.6355)			(0.8803)
Innovations	0.0427***	0.0426***	0.0432***	-0.0023**	-0.0023**	-0.0023**
	(3.3141)	(3.3059)	(3.3268)	(-1.9976)	(-1.9970)	(-2.0068)
LogFs	-0.4751	-0.4878	-0.5568	-0.3638***	-0.3646***	-0.3662***
	(-0.7284)	(-0.7461)	(-0.8557)	(-3.5481)	(-3.5440)	(-3.5653)
LogNsr	1.2900	1.3031	1.3430*	0.7127*	0.7135*	0.7159*
	(1.6161)	(1.6361)	(1.6599)	(1.7995)	(1.8018)	(1.7984)
LogCI	-0.0123	-0.0100	-0.0085	-0.1750***	-0.1749***	-0.1746***
	(-0.0384)	(-0.0314)	(-0.0264)	(-3.0319)	(-3.0295)	(-3.0277)
LogEI	0.8224	0.8160	0.8070	-0.1064	-0.1068	-0.1083
	(1.4491)	(1.4354)	(1.4110)	(-0.8377)	(-0.8419)	(-0.8539)
ISO_EMS	-0.4031	-0.3931	-0.3690	-0.1657*	-0.1661*	-0.1673*
	(-0.4663)	(-0.4550)	(-0.4303)	(-1.8224)	(-1.8283)	(-1.8305)
Lev	-0.0677**	-0.0681**	-0.0697**	0.0124	0.0124	0.0123
	(-2.3972)	(-2.4148)	(-2.4754)	(1.3565)	(1.3543)	(1.3501)
Cons	-13.6966	-13.8676	-13.7730	-6.3714	-6.3742	-6.3930
	(-0.9841)	(-0.9977)	(-0.9827)	(-0.9887)	(-0.9892)	(-0.9912)
Firm-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	799	799	799	799	799	799

R_2	0.1056	0.1030	0.0988	0.2247	0.2248	0.2253
adj. R_2	0.0826	0.0799	0.0756	0.2048	0.2049	0.2053
F	3.2859	3.3019	3.2613	5.4686	5.4576	5.4543

5.5 Mediating effects of environmental practices on relationship between CO_2 emission variations and financial performance

Based on the results presented in S*ections 5.2-5.4*, whether environmental scores (i.e., environmental pillar score, emission reduction score, resource use score, and environmental innovation score) play mediating roles in the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and financial performance (i.e., ROA and Tobin's q) is discussed as follows.

5.5.1 Results of mediating effects of integrated environmental practices on relationship between CO_2 emission variations and financial performance

5.5.1.1 Results of mediating effects of integrated environmental practices on relationship between CO_2 emission variations and ROA

First, as discussed in *Section 5.2.1*, the results for the total effects show negative and significant relationships between "$\Delta CO_2 1$ and ROA", "$\Delta CO_2 2$ and ROA", and "$\Delta CO_2 3$ and ROA". Secondly, as discussed in *Section 5.3.1,* the results reveal negative and significant relationships between "$\Delta CO_2 1$ and environmental pillar score", "$\Delta CO_2 2$ and environmental pillar score", and "$\Delta CO_2 3$ and environmental pillar score". Thirdly, as discussed in *Section 5.4.1.1*, the results indicate positive and significant relationships between environmental pillar score and ROA after controlling for the effects of $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$ in the regressions.

For the direct effects, Table 5-7 shows i) a negative relationship between $\Delta CO_2 1$ and

ROA (n_1=-1.7603, p<0.01) when the environmental pillar score is considered in Model 19. Specifically, a 1% increase of scope 1 CO_2 emission is linked to a decrease of 1.7603% in ROA, ceteris paribus; conversely, a 1% decrease in scope 1 CO_2 emission is linked to an increase of 1.7603% in ROA, ceteris paribus; ii) a negative relationship between $\Delta CO_2 2$ and ROA (p_1=-1.6789, p<0.01) when adding the environmental pillar score in model 21. Specifically, a 1% increase in scope 2 CO_2 emission will lead to 1.6789% decrease in ROA, ceteris paribus; conversely, 1% decrease in scope 2 CO_2 emission is in response to an increase of 1.6789% in ROA, ceteris paribus; iii) a negative relationship between the scope 3 CO_2 emission variation and ROA (r_1=-1.4833, p<0.01). Specifically, a 1% increase in scope 3 CO_2 emission is associated with a decrease of 1.4833% in ROA, ceteris paribus; conversely, a 1% decrease in scope 3 CO_2 emission is in response to an increase of 1.4833% in ROA, ceteris paribus.

Based on the above discussion, the environmental pillar score has mediating role in the relationships between "$\Delta CO_2 1$ and ROA", "$\Delta CO_2 2$ and ROA", and "$\Delta CO_2 3$ and ROA". The coefficients of $\Delta CO_2 1$ decrease from -2.6248 to (Model 1) to -1.7603 (Model 19), $\Delta CO_2 2$ decrease from -2.5606 (Model 3) to -1.6789 (Model 21), and $\Delta CO_2 3$ decrease from -2.2907 (Model 5) to -1.4833 (Model 23) when adding the environmental pillar score to the regressions, implying partial mediation effects of environmental pillar scores in the relationships between "ΔCO_2 1 and ROA", "$\Delta CO_2 2$ and ROA", and "$\Delta CO_2 3$ and ROA". Thus, the results support H_{11} (a), H_{11} (b), and H_{11} (c).

5.5.1.2 Results of mediating effects of integrated environmental practices on relationship between CO_2 emission variations and Tobin's q

As discussed in *Section 5.2.2*, the results of the analysis of the total effects indicate non-relationships between "$\Delta CO_2 1$ and Tobin's q", "$\Delta CO_2 2$ and Tobin's q", and "$\Delta CO_2 3$

and Tobin's q". Then, as presented in *Section 5.3.1,* the results show negative and significant relationships between "$\Delta CO_2 1$ and the environmental pillar score", "$\Delta CO_2 2$ and the environmental pillar score", and "$\Delta CO_2 3$ and the environmental pillar score". Thirdly, as shown in *Section 5.4.1.2*, there are non-significant relationships between the environmental pillar score and Tobin's q after controlling for the effects of $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$ in the regressions.

The result for the direct effects (see Table 5-7), the effects of $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$ on Tobin's q is not significant (o_1=0.0364, p=0.552; q_1=0.0409, p=0.507; s_1=0.0497, p=0.425) in Models 20, 22, and 24.

Based on the above discussion, the environmental pillar score does not mediate the relationships between the "$\Delta CO_2 1$ and Tobin's q", "$\Delta CO_2 2$ and Tobin's q", and "$\Delta CO_2 3$ and Tobin's q". Therefore, the results reject H_{11} (d), H_{11} (e), and H_{11} (f).

5.5.2 Results of mediating effects of emission reduction practices on relationship between CO_2 emission variations and financial performance

5.5.2.1 Results of mediating effects of emission reduction practices on relationship between CO_2 emission variations and ROA

As presented in *Section 5.2.1*, there are negative and significant relationships between "$\Delta CO_2 1$ and ROA", "$\Delta CO_2 2$ and ROA", and "$\Delta CO_2 3$ and ROA" for the total effects. S*ection 5.3.2 show* negative and significant relationships between "$\Delta CO_2 1$ and the emission reduction score", "$\Delta CO_2 2$ and the emission reduction score", and "$\Delta CO_2 3$ and the emission reduction score". As reported in *Section 5.4.2.1,* the positive and significant relationships between the emission reduction score and ROA after controlling for the effects of $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$ in the regressions.

As for the direct effects (see Table 5-8), i) $\Delta CO_2 1$ is negatively associated with ROA

(t_1=-1.4945, p<0.05) when the emission reduction score is added to the regression (Model 25). Specifically, a 1% increase in scope 1 CO_2 emission will lead to 1.4945% decrease in ROA, while a 1% decrease in scope 1 CO_2 emission will lead to 1.4945% increase in ROA. ii) $\Delta CO_2 2$ is negatively associated with ROA (w_1=-1.3874, p<0.05) when the emission reduction score is added to the regression (Model 27). Specifically, a 1% increase in scope 2 CO_2 emission is linked to a 1.3874% decrease in ROA. Conversely, a 1.3874% increase in ROA is in response to a 1% decrease in scope 2 CO_2 emission. iii) $\Delta CO_2 3$ is negatively associated with ROA (y_1=-1.1938, p= 0.050) when the emission reduction score is added to the regression (Model 29). Specifically, a 1% increase in scope 3 CO_2 emission will result in a decrease of 1.1938% in ROA, while an increase of 1.1938% in ROA is in response to a 1% decrease in scope 3 CO_2 emission.

Thus, the emission reduction score has mediating role in the relationships between "$\Delta CO_2 1$ and ROA", "$\Delta CO_2 2$ and ROA", and "$\Delta CO_2 3$ and ROA". The coefficients of $\Delta CO_2 1$ decrease from -2.6248 to (Model 1) to -1.4945 (Model 25), $CO_2 2$ decrease from -2.5606 (Model 3) to -1.3874 (Model 27), and $\Delta CO_2 3$ decrease from -2.2907 (Model 5) to -1.1938 (Model 29) when the emission reduction score is added to the regressions. The results indicate that the emission reduction score has partial mediating effects in the relationships between "ΔCO_2 1 and ROA", "$\Delta CO_2 2$ and ROA", and "$\Delta CO_2 3$ and ROA". Thus, the results support H_{12} (a), H_{12} (b), and H_{12} (c).

5.5.2.2 Results of mediating effects of emission reduction practices on relationship between CO_2 emission variations and Tobin's q

In *Section 5.2.2*, the results show non-significant relationships between "$\Delta CO_2 1$ and Tobin's q", "$\Delta CO_2 2$ and Tobin's q", and "$\Delta CO_2 3$ and Tobin's q" for the total effects. In *Section 5.3.2,* the results reveal that negative and significant relationships between "$\Delta CO_2 1$

and the emission reduction score", "$\Delta CO_2 2$ and the emission reduction score", and "$\Delta CO_2 3$ and the emission reduction score". In *Section 5.4.2.2*, the results show non-significant relationships between the emission reduction score and Tobin's q after controlling for the effects of $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$ in the regressions.

For the direct effect (see Table 5-8), the effects of $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$ on Tobin's q is not significant (u_1=0.0602, p=0.322; q_1=0.0651, p=0.291; z_1=0.0702, p=0.261) in Models 26, 28, and 30.

Based on the above discussion, the emission reduction score does not mediate the relationships between the "ΔCO_2 1 and Tobin's q", "$\Delta CO_2 2$ and Tobin's q", and "$\Delta CO_2 3$ and Tobin's q. Therefore, the results reject H_{12} (d), H_{12} (e), and H_{12} (f).

5.5.3 Results of mediating effects of resource use practices on relationship between CO_2 emission variations and financial performance

5.5.3.1 Results of mediating effects of resource use practices on relationship between CO_2 emission variations and ROA

As shown in *Section 5.2.1*, the results show negative and significant relationships between "$\Delta CO_2 1$ and ROA", "$\Delta CO_2 2$ and ROA", and "$\Delta CO_2 3$ and ROA" for the total effects. In *Section 5.3.3*, the results show non-significant relationships between "$\Delta CO_2 1$ and the resource use score", "$\Delta CO_2 2$ and the resource use score", "$\Delta CO_2 3$ and the resource use score". As discussed in *Section 5.4.3.1*, the results show non-significant relationships between the resource use score and ROA after controlling for the effects of scope 1, 2 , and 3 CO_2 emission variations in the regressions.

For the direct effects (see Table 5-9), i) the results show that i) $\Delta CO_2 1$ is negatively related to ROA (χ_1=-2.6344, p<0.01) when the resource use score is added to the regression

(Model 31). Specifically, a 1% increase in scope 1 CO_2 emission will lead to 2.6344% decrease in ROA, and conversely, a 1% decrease in scope 1 CO_2 emission will lead to 2.6344% increase in ROA; ii) $\Delta CO_2 2$ is negatively related to ROA (μ_1=-2.5696, p<0.01) when the resource use score is added to the regression (Model 33). Specifically, a 1% increase in scope 2 CO_2 emission is linked to a 2.5696% decrease in ROA, while a 2.5696% increase in ROA is in response to a 1% decrease in scope 2 CO_2 emission; iii) $\Delta CO_2 3$ is negatively related to ROA (ϕ_1=-2.3007, p<0.01) when the resource use score is added to the regression (Model 35). Specifically, a 1% increase in scope 3 CO_2 emission is associated with a decrease of 2.3007% in ROA, while an increase of 2.3007% in ROA is in response to a 1% decrease in scope 3 CO_2 emission.

Thus, the resource use score does not play mediating role in the relationships between "$\Delta CO_2 1$ and ROA", "$\Delta CO_2 2$ and ROA", "$\Delta CO_2 3$ and ROA", Therefore, the results reject H_{13} (a), H_{13} (b), H_{13} (c).

5.5.3.2 Results of mediating effects of resource use practices on relationship between CO_2 emission variations and Tobin's q

The results in *Section 5.2.2* show insignificant relationships between "$\Delta CO_2 1$ and Tobin's q", "$\Delta CO_2 2$ and Tobin's q", and "$\Delta CO_2 3$ and Tobin's q" for the total effects. The results in *Section 5.3.3* present insignificant relationships between "$\Delta CO_2 1$ and the resource use score", "$\Delta CO_2 2$ and the resource use score", "$\Delta CO_2 3$ and the resource use score". The results in *Section 5.4.3.2* indicate insignificant relationships between the resource use score and Tobin's q after controlling for the effects of scope 1, 2 , and 3 CO_2 emission variations in the regressions.

For the direct effects (see Table 5-9), the effects of $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$ on Tobin's q is not significant (η_1=0.0351, p=0.498; φ_1=0.0390, p=0.454; γ_1=0.0463, p=

0.388) in Models 32, 34, and 36.

In light of the discussion above, the resource use score does not play mediating role in the relationships between "$\Delta CO_2 1$ and Tobin's q", "$\Delta CO_2 2$ and Tobin's q", and "$\Delta CO_2 3$ and Tobin's q". Therefore, the results reject H_{13} (d), H_{13} (e), and H_{13} (f).

5.5.4 Results of mediating effects of environmental innovation practices on CO_2 emission variations and financial performance

5.5.4.1 Results of mediating effects of environmental innovation practices on relationship between CO_2 emission variations and ROA

As discussed in S*ection 5.2.1*, the results show negative and significant relationships between "$\Delta CO_2 1$ and ROA", "$\Delta CO_2 2$ and ROA", and "$\Delta CO_2 3$ and ROA" for the total effects. In *Section 5.3.4,* the results show the relationships between "$\Delta CO_2 1$ and the environmental innovation score", "$\Delta CO_2 2$ and the environmental innovation score", and "$\Delta CO_2 3$ and the environmental innovation score" are not significant. The results in *Section 5.4.4.1* indicate that the environmental innovation score has significant and positive impact on ROA after controlling the effects of scope 1, 2 , and 3 CO_2 emission variations in the regressions.

With regard to the direct effects (see Table 5-10), i) $\Delta CO_2 1$ has a negative impact on ROA (κ_1=-2.5811, p<0.01) when the environmental innovation score is added to the regression (Model 37). Specifically, a 1% increase in scope 1 CO_2 emission will lead to 2.5811% decrease in ROA, while a 1% decrease in scope 1 CO_2 emission will result in 2.5811% increase in ROA; ii) $\Delta CO_2 2$ has a negative impact on ROA (ϖ_1=-2.5134, p<0.01) when the environmental innovation score is added to the regression (Model 39). Specifically, a 1% increase in scope 2 CO_2 emission will result in 2.5134% decrease in ROA, while 2.5134% increase in ROA is in response to a 1% decrease in scope 2 CO_2 emission. iii)

$\Delta CO_2 3$ has a negative impact on ROA (ψ_2=-2.2732, p<0.01) when the environmental innovation score is added to the regression (Model 41). Specifically, a 1% increase in scope 3 CO_2 emission will lead to 2.2732% decrease in ROA, while a 1% decrease in scope 3 CO_2 emission will result in a 2.2732% increase in ROA.

Considering the discussion above, the environmental innovation score does not mediate the relationships between "$\Delta CO_2 1$ and ROA", "$\Delta CO_2 2$ and ROA", "$\Delta CO_2 3$ and ROA", which reject H_{14} (a), H_{14} (b), H_{14} (c).

5.5.4.2 Results of mediating effects of environmental innovation practices on relationship between CO_2 emission variations and Tobin's q

As discussed in *Section 5.2.2,* the results show non-significant relationships between "$\Delta CO_2 1$ and Tobin's q", "$\Delta CO_2 2$ and Tobin's q", and "$\Delta CO_2 3$ and Tobin's q" for the total effects. In *Section 5.3.4,* the results show non-significant relationships between "$\Delta CO_2 1$ and the environmental innovation score", "$\Delta CO_2 2$ and the environmental innovation score", and "$\Delta CO_2 3$ and the environmental innovation score". The results in *Section 5.4.4.2* show that the environmental innovation score has negative impacts on Tobin's q after controlling for the effects of scope 1, 2 , and 3 CO_2 emission variations in the regressions.

As for the direct effects (see Table 5-10), the effects of $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$ on Tobin's q is not significant (ϖ_1=0.0372, p=0.502 ; σ_1=0.0408, p=0.463; υ_1=0.0500, p=0.381) in Models 38, 40, and 42.

Therefore, it can be concluded that the environmental innovation score does not mediate the relationships between"$\Delta CO_2 1$ and Tobin's q", "$\Delta CO_2 2$ and Tobin's q", and "$\Delta CO_2 3$ and Tobin's q", which reject H_{14} (d), H_{14} (e), and H_{14} (f).

5.6 Bootstrapping results

As bootstrapping is considered the supplementary method to the causal steps approach (Hayes, 2009), this method is to test the mediating effects and validate the analysis results of the causal steps approach. Specifically, the bias-corrected bootstrapping method with 1,000 replications (MacKinnon et al., 2004b; Preacher & Hayes, 2008) is used. If the bootstrap 95% confidence interval (CI) of the indirect effects excludes zero, the mediating effect is significant and the proposed mediation hypotheses are established; on the contrary, if the bootstrap 95% CI of the indirect effects includes zero, the mediating effect is not significant, and the proposed mediation hypotheses are rejected (Zhao et al., 2010).

5.6.1 Results of mediating effects of integrated environmental practices on relationship between CO_2 emission variations and financial performance

Table 5-11 shows the bootstrapping results of the effects of the environmental pillar score on the relationships between each scope of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) and financial performance in terms of ROA and Tobin's q.

With ROA as the dependent variable, the bootstrap 95% CI, the lower limit CI (LLCI) and upper limit CI (ULCI) of the bias-corrected percentile of the indirect effects (i.e., $\Delta CO_2 1$-environmental pillar score-ROA) is -1.3913, -0.3972, respectively. The LLCI and ULCI of the indirect effects (i.e., $\Delta CO_2 2$-environmental pillar score-ROA) is -1.4086 and -0.3846, respectively. The LLCI and ULCI of the indirect effects (i.e., $\Delta CO_2 3$-environmental pillar score-ROA) is -1.2660 and -0.3865, respectively. Thus, the results show that the bootstrap 95% CIs of these paths do not contain zero, which indicates that the environmental pillar score mediated the relationships between "$\Delta CO_2 1$ and ROA", "$\Delta CO_2 2$ and ROA", and "$\Delta CO_2 3$ and ROA". The results therefore support H_{11} (a), H_{11} (b), and H_{11}

(c).

Focusing on Tobin’s q as the dependent variable, bootstrap 95% CI for the indirect effects, including $\Delta CO_2 1$-environmental pillar score-Tobin’s q, $\Delta CO_2 2$-environmental pillar score-Tobin’s q, and $\Delta CO_2 3$-environmental pillar score-Tobin’s q, are (-0.0390, 0.0541), (-0.0408, 0.0506), and (-0.0419, 0.0404) , respectively. The bootstrap 95% CI of these paths include zero, indicating that the environmental pillar score does not mediate the relationships between “$\Delta CO_2 1$ and Tobin’s q”, “$\Delta CO_2 2$ and Tobin’s q”, and “$\Delta CO_2 3$ and Tobin’s q” and thus H_{11} (d), H_{11} (e), and H_{11} (f) are not supported.

Table 5-11 Estimation results: mediating effects of environmental pillar score on relationship between CO_2 emission variations and financial performance.

Relationship	Bootstrapping results		
	Coefficient	BootLLCI	BootULCI
$\Delta CO_2 1$-Environmental pillar score-ROA			
Total effect: $\Delta CO_2 1$-ROA	-2.6248	-3.7480	-1.9819
Indirect effect: $\Delta CO_2 1$-Environmental pillar score -ROA	-0.8645	-1.3913	-0.3972
Direct effect: $\Delta CO_2 1$-ROA	-1.7603	-2.9491	-0.9976
$\Delta CO_2 2$-Environmental pillar score-ROA			
Total effect: $\Delta CO_2 2$-ROA	-2.5606	-3.6482	-1.8185
Indirect effect: $\Delta CO_2 2$-Environmental pillar score-ROA	-0.8817	-1.4086	-0.3846
Direct effect: $\Delta CO_2 2$-ROA	-1.6789	-2.6878	-0.8018
$\Delta CO_2 3$-Environmental pillar score-ROA			
Total effect: $\Delta CO_2 3$-ROA	-2.2907	-3.1498	-1.5780
Indirect effect: $\Delta CO_2 3$-Environmental pillar score-ROA	-0.8075	-1.2660	-0.3865
Direct effect: $\Delta CO_2 3$-ROA	-1.4833	-2.5073	-0.7223
$\Delta CO_2 1$-Environmental pillar score-Tobin's q			
Total effect: $\Delta CO_2 1$-Tobin's q	0.0395	-0.0880	0.1459
Indirect effect: $\Delta CO_2 1$-Environmental pillar score-Tobin's q	0.0031	-0.0390	0.0541
Direct effect: $\Delta CO_2 1$-Tobin's q	0.0364	-0.0982	0.1582
$\Delta CO_2 2$-Environmental pillar score-Tobin's q			
Total effect: $\Delta CO_2 2$ -Tobin's q	0.0433	-0.0836	0.1605
Indirect effect: $\Delta CO_2 2$-Environmental pillar score-Tobin's q	0.0024	-0.0408	0.0506

Direct effect: $\Delta CO_2 2$-Tobin's q	0.0409	-0.0917	0.1676
$\Delta CO_2 3$-Environmental pillar score-Tobin's q			
Total effect: $\Delta CO_2 3$-Tobin's q	0.0509	-0.0784	0.1531
Indirect effect: $\Delta CO_2 3$-Environmental pillar score-Tobin's q	0.0013	-0.0419	0.0404
Direct effect: $\Delta CO_2 3$-Tobin's q	0.0497	-0.0848	0.1633

Note: BootLLCI=Lower limits confidence interval, BootULCI=Upper limits confidence interval

5.6.2 Results of mediating effects of emission reduction practices on relationship between CO_2 emission variations and financial performance

As shown in Table 5-12, the bootstrapping results show the effects of the emission reduction score on the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) and financial performance in terms of ROA and Tobin's q.

For the effects of the emission reduction score on the relationship between the CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) and ROA, the LLCI and ULCI of the indirect effects, including $\Delta CO_2 1$-emission reduction score-ROA, $\Delta CO_2 2$-emission reduction score-ROA, and $\Delta CO_2 3$-emission reduction score-ROA, are (-1.8327, -0.3617), (-1.8364, -0.4152), and (-1.7370, -0.5616), respectively. As the bootstrap 95% CI for these paths does not include zero, the indirect effects are statistically significant. Thus, the emission reduction score mediates the relationship between "ΔCO_2 1 and ROA", "$\Delta CO_2 2$ and ROA", and "$\Delta CO_2 3$ and ROA". Thus, the results therefore lend support to H_{12} (a), H_{12} (b), and H_{12} (c).

For the effects of the emission reduction score on the relationship between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) and Tobin's q, the LLCI and ULCI of the indirect effects, including $\Delta CO_2 1$-emission reduction score-Tobin's q, $\Delta CO_2 2$-emission reduction score-Tobin's q, and $\Delta CO_2 3$- emission reduction score-Tobin's q, are (-0.0740, 0.0437), (-0.0778, 0.0376), and (-0.0702, 0.0261), respectively. The bootstrap 95% CI contains zero, and thus these indirect effects are not statistically significant. The results suggest that there are no mediating effects of the emission reduction score in the relationship between $\Delta CO_2 1$ and Tobin's q", "$\Delta CO_2 2$ and Tobin's q", and "$\Delta CO_2 3$ and Tobin's q" and thus H_{12} (d), H_{12} (e), and H_{12} (f) are not supported.

Table 5-12 Estimation results: mediating effects of emission reduction score on relationship between CO_2 emission variations and financial performance.

Relationship	Bootstrapping results		
	Coefficient	BootLLCI	BootULCI
$\Delta CO_2 1$-Emission reduction score-ROA			
Total effect: $\Delta CO_2 1$-ROA	-2.6248	-3.6923	-1.9373
Indirect effect: $\Delta CO_2 1$-Emission reduction score-ROA	-1.1303	-1.8327	-0.3617
Direct effect: $\Delta CO_2 1$-ROA	-1.4945	-2.7881	-0.5211
$\Delta CO_2 2$-Emission reduction score-ROA			
Total effect: $\Delta CO_2 2$-ROA	-2.5606	-3.5595	-1.8519
Indirect effect: $\Delta CO_2 2$-Emission reduction score-ROA	-1.1732	-1.8364	-0.4152
Direct effect: $\Delta CO_2 2$-ROA	-1.3874	-2.5710	-0.4088
$\Delta CO_2 3$-Emission reduction score-ROA			
Total effect: $\Delta CO_2 3$-ROA	-2.2907	-3.1925	-1.6008
Indirect effect: $\Delta CO_2 3$-Emission reduction score-ROA	-1.0969	-1.7370	-0.5616
Direct effect: $\Delta CO_2 3$-ROA	-1.1938	-2.3700	-0.2819
$\Delta CO_2 1$-Emission reduction score-Tobin's q			
Total effect: $\Delta CO_2 1$-Tobin's q	0.0395	-0.0871	0.1622
Indirect effect: $\Delta CO_2 1$-Emission reduction score-Tobin's q	-0.0207	-0.0740	0.0437
Direct effect: $\Delta CO_2 1$-Tobin's q	0.0602	-0.0823	0.1789
$\Delta CO_2 2$-Emission reduction score-Tobin's q			
Total effect: $\Delta CO_2 2$-Tobin's q	0.0433	-0.0709	0.1703
Indirect effect: $\Delta CO_2 2$-Emission reduction score-Tobin's q	-0.0218	-0.0778	0.0376
Direct effect: $\Delta CO_2 2$-Tobin's q	0.0651	-0.0531	0.2071
$\Delta CO_2 3$-Emission reduction score-Tobin's q			
Total effect: $\Delta CO_2 3$-Tobin's q	0.0509	-0.0873	0.1519
Indirect effect: $\Delta CO_2 3$-Emission reduction score -Tobin's q	-0.0192	-0.0702	0.0261
Direct effect: $\Delta CO_2 3$-Tobin's q	0.0702	-0.0602	0.1869

5.6.3 Results of mediating effects of resource use practices on relationship between CO_2

emission variations and financial performance

Table 5-13 presents the bootstrap results of the effects of the resource use score in the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) and financial performance in terms of ROA and Tobin's q.

With the ROA as the dependent variable, the results of the LLCI and ULCI for the indirect effects, including $\Delta CO_2 1$-resource use score-ROA, $\Delta CO_2 2$-resource use score-ROA), and $\Delta CO_2 3$-resource use score-ROA, are (-0.0336, 0.1491),(-0.0262, 0.1665), and (-0.0240, 0.1407), respectively. The results show that the bootstrap 95% CI of these indirect effects include zero, which indicates that the resource use score does not mediate the relationship between $\Delta CO_2 1$ and ROA", "$\Delta CO_2 2$ and ROA", and "$\Delta CO_2 3$ and ROA", thus rejecting H_{13} (a), H_{13} (b), and H_{13} (c).

With Tobin's q as the dependent variable, the results show that the LLCI and ULCI for the indirect effects, including $\Delta CO_2 1$-resource use score-Tobin's q, $\Delta CO_2 2$-resource use score-Tobin's q), and $\Delta CO_2 3$-resource use score-Tobin's q, are (-0.0029, 0.0252), (-0.0046, 0.0235), and (-0.0039, 0.0230), respectively. The bootstrap 95% CI of these indirect effects contain zero, which suggests that the resource use score has no mediating effects in the relationship between "$\Delta CO_2 1$ and Tobin's q", "$\Delta CO_2 2$ and Tobin's q", and "$\Delta CO_2 3$ and Tobin's q". Therefore, the results reject hypotheses H_{13} (d), H_{13} (e), and H_{13} (f).

Table 5-13 Estimation results: mediating effects of resource use score on relationship between CO_2 emission variations and financial performance.

Relationship	Bootstrapping results		
	Coefficient	BootLLCI	BootULCI
$\Delta CO_2 1$-Resource use score-ROA			
Total effect: $\Delta CO_2 1$-ROA	-2.6248	-3.6671	-1.9062
Indirect effect: $\Delta CO_2 1$-Resource use score-ROA	0.0096	-0.0336	0.1491
Direct effect: $\Delta CO_2 1$-ROA	-2.6344	-3.6417	-1.9051

$\Delta CO_2 2$-Resource use score-ROA			
Total effect: $\Delta CO_2 2$-ROA	-2.5606	-3.5911	-1.8420
Indirect effect: $\Delta CO_2 2$-Resource use score-ROA	0.0089	-0.0262	0.1665
Direct effect: $\Delta CO_2 2$-ROA	-2.5696	-3.5841	-1.8282
$\Delta CO_2 3$-Resource use score-ROA			
Total effect: $\Delta CO_2 3$-ROA	-2.2907	-3.3086	-1.6554
Indirect effect: $\Delta CO_2 3$-Resource use score-ROA	0.0099	-0.0240	0.1407
Direct effect: $\Delta CO_2 3$-ROA	-2.3007	-3.3014	-1.6605
$\Delta CO_2 1$-Resource use score-Tobin's q			
Total effect: $\Delta CO_2 1$-Tobin's q	0.0395	-0.0786	0.1525
Indirect effect: $\Delta CO_2 1$-Resource use score-Tobin's q	0.0044	-0.0029	0.0252
Direct effect: $\Delta CO_2 1$-Tobin's q	0.0351	-0.0802	0.1453
$\Delta CO_2 2$-Resource use score-Tobin's q			
Total effect: $\Delta CO_2 2$-Tobin's q	0.0433	-0.0893	0.1606
Indirect effect: $\Delta CO_2 2$-Resource use score-Tobin's q	0.0043	-0.0046	0.0235
Direct effect: $\Delta CO_2 2$-Tobin's q	0.0390	-0.0911	0.1513
$\Delta CO_2 3$-Resource use score-Tobin's q			
Total effect: $\Delta CO_2 3$-Tobin's q	0.0509	-0.0661	0.1585
Indirect effect: $\Delta CO_2 3$-Resource use score-Tobin's q	0.0047	-0.0039	0.0230
Direct effect: $\Delta CO_2 3$-Tobin's q	0.0463	-0.0680	0.1545

5.6.4 Results of mediating effects of environmental innovation practices on relationship between CO_2 emission variations and financial performance

As shown in Table 5-14, the bootstrapping results show the effects of the environmental innovation score on the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) and financial performance in terms of ROA and Tobin's q.

With ROA as the dependent variable, the LLCI and ULCI for the indirect effects, including $\Delta CO_2 1$-environmental innovation score-ROA, $\Delta CO_2 2$-environmental innovation score-ROA, and $\Delta CO_2 3$-environmental innovation score-ROA ,are (-0.2950, 0.2385), (-0.3213, 0.1944), and (-0.2657, 0.2400), respectively. The bootstrap 95% CI for these indirect effects include zero, thus indicating that the mediating effect of the environmental innovation score cannot be found in the relationship between "$\Delta CO_2 1$ and ROA", "$\Delta CO_2 2$

and ROA", and "$\Delta CO_2 3$ and ROA" and thus H_{14} (a), H_{14} (b), and H_{14} (c) are not supported.

With Tobin's q as the dependent variable, the LLCI and ULCI for the indirect effects, including $\Delta CO_2 1$-environmental innovation score-Tobin's q, $\Delta CO_2 2$-environmental innovation score-Tobin's q, and $\Delta CO_2 3$-environmental innovation score-Tobin's q are (-0.0138, 0.0230), (-0.0104, 0.0244), and (-0.0144, 0.0192), respectively. The results of the bootstrap 95% CI include zero, which suggests that these indirect effects are not statistically significant, and thus the environmental innovation score does not mediate the relationships between "$\Delta CO_2 1$ and Tobin's q", "$\Delta CO_2 2$ and Tobin's q", and "$\Delta CO_2 3$ and Tobin's q". As such, H_{14} (d), H_{14} (e), and H_{14} (f) are not supported.

Table 5-14 Estimation results: mediating effects of environmental innovation score on relationship between CO_2 emission variations and financial performance.

Relationship	Bootstrapping results		
	Coefficient	BootLLCI	BootULCI
$\Delta CO_2 1$-Environmental innovation score-ROA			
Total effect: $\Delta CO_2 1$-ROA	-2.6248	-3.7175	-1.9210
Indirect effect: $\Delta CO_2 1$-Environmental innovation score-ROA	-0.0437	-0.2950	0.2385
Direct effect: $\Delta CO_2 1$-ROA	-2.5811	-3.5877	-1.8469
$\Delta CO_2 2$-Environmental innovation score-ROA			
Total effect: $\Delta CO_2 2$-ROA	-2.5606	-3.7327	-1.8462
Indirect effect: $\Delta CO_2 2$-Environmental innovation score-ROA	-0.0473	-0.3213	0.1944
Direct effect: $\Delta CO_2 2$-ROA	-2.5134	-3.6056	-1.7773
$\Delta CO_2 3$-Environmental innovation score-ROA			
Total effect: $\Delta CO_2 3$-ROA	-2.2907	-3.2076	-1.6674
Indirect effect: $\Delta CO_2 3$-Environmental innovation score-ROA	-0.0175	-0.2657	0.2400
Direct effect: $\Delta CO_2 3$-ROA	-2.2732	-3.2616	-1.6340
$\Delta CO_2 1$-Environmental innovation score-Tobin's q			
Total effect: $\Delta CO_2 1$-Tobin's q	0.0395	-0.0874	0.1507
Indirect effect: $\Delta CO_2 1$-Environmental innovation score-Tobin's q	0.0023	-0.0138	0.0230
Direct effect: $\Delta CO_2 1$-Tobin's q	0.0372	-0.0947	0.1572
$\Delta CO_2 2$-Environmental innovation score-Tobin's q			
Total effect: $\Delta CO_2 2$ -Tobin's q	0.0433	-0.0802	0.1746

Indirect effect: $\Delta CO_2 2$-Environmental innovation score-Tobin's q	0.0025	-0.0104	0.0244
Direct effect: $\Delta CO_2 2$-Tobin's q	0.0408	-0.0875	0.1649
$\Delta CO_2 3$-Environmental innovation score-Tobin's q			
Total effect: $\Delta CO_2 3$ -Tobin's q	0.0509	-0.0630	0.1622
Indirect effect: $\Delta CO_2 3$-Environmental innovation score-Tobin's q	0.0009	-0.0144	0.0192
Direct effect: $\Delta CO_2 3$-Tobin's q	0.0500	-0.0703	0.1633

5.7 Results of robustness check

This section reported the results of robustness check, including i) using ROE and Tobin's q_1 as alternative measures of financial performance; and ii) adding dividend yield, net profit margin, EPS, and sales revenue as additional control variables in the econometric models 1-42.

5.7.1 Alternative measures of financial performance

As this study use alternative indicators (i.e., ROE and Tobin's q_1) of financial performance, thus the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) and the environmental scores in terms of the environmental pillar score, emission reduction score, resource use score and environmental innovation score do not need to be tested in the robustness check.

5.7.1.1 Results of effects of CO_2 emission variations on financial performance

Tables 5-15 and Table 5-16 show the results of the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) and financial performance in terms of ROE and Tobin's q_1. The robustness tests results are consistent with the results of the main analysis.

Table 5-15 Estimation results: effects of CO_2 emission variations on ROE.

	Dependent Variable: ROE			
	Estimate	Estimate	Estimate	Estimate
$\Delta CO_2 1$		-15.5045^{***}		
		(-7.9495)		
$\Delta CO_2 2$			-15.5837^{***}	
			(-8.0678)	
$\Delta CO_2 3$				-13.4613^{***}
				(-7.6530)
LogFs	-1.7772	1.5471	1.5734	1.0490
	(-0.8867)	(0.7783)	(0.7883)	(0.5227)
LogNsr	17.5934^{***}	14.1023^{***}	14.0711^{***}	14.4643^{***}
	(4.8316)	(3.8235)	(3.8232)	(3.8658)
LogCI	-2.8933^{**}	-3.2748^{***}	-3.2725^{***}	-3.2559^{***}
	(-2.5315)	(-2.9004)	(-2.8929)	(-2.8304)
LogEI	-1.1023	0.6777	0.6946	0.5744
	(-0.5331)	(0.3547)	(0.3617)	(0.2946)
ISO_EMS	-2.5173	-1.8143	-1.7294	-1.6301
	(-0.8448)	(-0.6077)	(-0.5732)	(-0.5399)
Lev	0.0187	0.0985	0.0987	0.0858
	(0.1471)	(0.7663)	(0.7625)	(0.6753)
Cons	-244.3724^{***}	-225.6869^{***}	-226.1387^{***}	-226.533^{***}
	(-3.6176)	(-3.4099)	(-3.4291)	(-3.4006)
Firm-fixed effect	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
N	799	799	799	799
R_2	0.0794	0.1648	0.1640	0.1472
adj. R_2	0.0581	0.1444	0.1436	0.1264
F	4.3040	10.7391	10.8819	11.6181

Table 5-16 Estimation results: effects of CO_2 emission variations on Tobin's q_1.

	Dependent Variable: Tobin's q_1			
	Estimate	Estimate	Estimate	Estimate
$\Delta CO_2 1$		0.0243		
		(0.4733)		

ΔCO_22			0.0272	
			(0.5297)	
ΔCO_23				0.0310
				(0.5582)
LogFs	-0.4203***	-0.4254***	-0.4261***	-0.4267***
	(-3.3252)	(-3.3862)	(-3.3815)	(-3.4019)
LogNsr	0.8359*	0.8414*	0.8421*	0.8432*
	(1.7281)	(1.7334)	(1.7351)	(1.7272)
LogCI	-0.1968***	-0.1962***	-0.1962***	-0.1960***
	(-2.7533)	(-2.7638)	(-2.7622)	(-2.7687)
LogEI	-0.0673	-0.0701	-0.0705	-0.0712
	(-0.4606)	(-0.4800)	(-0.4829)	(-0.4889)
Lev	0.0143	0.0142	0.0142	0.0142
	(1.3191)	(1.3016)	(1.2998)	(1.2981)
ISO_EMS	-0.1286	-0.1297	-0.1299	-0.1306
	(-1.0579)	(-1.0656)	(-1.0685)	(-1.0690)
Cons	-8.1207	-8.1503	-8.1529	-8.1625
	(-1.0273)	(-1.0300)	(-1.0304)	(-1.0298)
Firm-fixed effect	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
N	797	797	797	797
R_2	0.2064	0.2066	0.2067	0.2068
adj. R_2	0.1880	0.1872	0.1873	0.1874
F	3.2423	3.1086	3.0968	3.0872

5.7.1.2 Results of effects of environmental practices on financial performance

Tables 5-17 to Table 5-20 present the results of the effects of the environmental scores (i.e., environmental pillar score, emission reduction score, resource use score and environmental innovation score) on financial performance (i.e., ROE and Tobin's q_1).

Focusing on ROE as the dependent variable, the results show that the environmental pillar score is positively related to ROE after controlling for the effects of CO_2 emission variations (i.e., ΔCO_21, ΔCO_22 and ΔCO_23). The emission reduction score has positive impact on ROE after controlling for the effects of CO_2 emission variations (i.e., ΔCO_21,

$\Delta CO_2 2$ and $\Delta CO_2 3$). The resource use score is not associated with ROE after controlling for the effects of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$). The environmental innovation score is positively related to ROE after controlling for the effects of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$). In general, the results are consistent with the main analysis results presented in *Sections 5.4.1.1, 5.4.2.1, 5.4.3.1,* and *5.4.4.1.*

With Tobin's q_1 as the dependent variable, the results indicate that the environmental pillar score is positively associated with Tobin's q_1 after controlling for the effects of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$). The emission reduction scores have positive impacts on Tobin's q_1 after controlling for the effects of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$). The resource use score is not related to Tobin's q_1 after controlling for the effects of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$). The environmental innovation score is negatively related to Tobin's q_1 after controlling for the effects of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$). The results are consistent with the main analysis results reported in *Sections 5.4.1.2, 5.4.2.2, 5.4.3.2,* and *5.4.4.2.*

Based on the results presented in *Sections 5.4 and 5.7.1,* we find that both the environmental pillar score and emission reduction scores plays mediating roles in the relationships between "ΔCO_2 1 and ROE", "$\Delta CO_2 2$ and ROE", and "$\Delta CO_2 3$ and ROE". However, both the environmental pillar score and emission reduction score do not mediate the relationships between "ΔCO_2 1 and Tobin's q_1", "$\Delta CO_2 2$ and Tobin's q_1", and "$\Delta CO_2 3$ and Tobin's q_1". The resource use score and environmental innovation score do not mediate the relationships between "$\Delta CO_2 1$ and ROE", "$\Delta CO_2 2$ and ROE", "$\Delta CO_2 3$ and ROE", "ΔCO_2 1 and Tobin's q_1", "$\Delta CO_2 2$ and Tobin's q_1", and "$\Delta CO_2 3$ and Tobin's q_1". Therefore, the mediation analysis results for the robustness check are in line with the main analysis results reported in *Section 5.5 and 5.6.*

Table 5-17 Estimation results: effects of environmental pillar score on financial performance.

	Dependent Variable: ROE			Dependent Variable: Tobin's q_1		
	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
$\Delta CO_2 1$	-11.9975^{***}			0.0061		
	(-6.8283)			(0.0983)		
$\Delta CO_2 2$		-12.0510^{***}			0.0100	
		(-6.8142)			(0.1621)	
$\Delta CO_2 3$			-9.9405^{***}			0.0173
			(-5.8483)			(0.2671)
Pillars	0.2455^{***}	0.2505^{***}	0.2925^{***}	-0.0013	-0.0012	-0.0011
	(3.2828)	(3.3041)	(3.8298)	(-0.6471)	(-0.6220)	(-0.5867)
LogFs	1.1412	1.1671	0.7223	-0.4234^{***}	-0.4241^{***}	-0.4255^{***}
	(0.5652)	(0.5755)	(0.3553)	(-3.3805)	(-3.3753)	(-3.4012)
LogNsr	13.9209^{***}	13.8785^{***}	14.1255^{***}	0.8423^{*}	0.8429^{*}	0.8444^{*}
	(3.8065)	(3.8008)	(3.8253)	(1.7349)	(1.7365)	(1.7300)
LogCI	-3.1401^{***}	-3.1371^{***}	-3.1034^{***}	-0.1969^{***}	-0.1968^{***}	-0.1966^{***}
	(-2.7907)	(-2.7865)	(-2.7301)	(-2.7839)	(-2.7810)	(-2.7889)
LogEI	0.5898	0.6085	0.5109	-0.0696	-0.0700	-0.0709
	(0.3096)	(0.3179)	(0.2652)	(-0.4785)	(-0.4816)	(-0.4882)
Lev	0.0608	0.0605	0.0448	0.0144	0.0144	0.0143
	(0.4577)	(0.4522)	(0.3400)	(1.3033)	(1.3008)	(1.2994)
ISO_EMS	-1.7027	-1.6318	-1.5397	-0.1302	-0.1304	-0.1309
	(-0.5661)	(-0.5379)	(-0.5064)	(-1.0763)	(-1.0778)	(-1.0770)
Cons	-235.6743^{***}	-236.1516^{***}	-238.0638^{***}	-8.0974	-8.1031	-8.1167
	(-3.4930)	(-3.5084)	(-3.5033)	(-1.0217)	(-1.0227)	(-1.0212)
Firm-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	799	799	799	797	797	797
R_2	0.1811	0.1811	0.1719	0.2070	0.2071	0.2071
adj. R_2	0.1601	0.1601	0.1506	0.1866	0.1866	0.1867
F	12.6662	12.8667	11.0169	3.1804	3.1813	3.1781

Table 5-18 Estimation results: effects of emission reduction score on financial performance.

	Dependent Variable: ROE	Dependent Variable: Tobin's q_1

	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
$\Delta CO_2 1$	-9.2181***			0.0293		
	(-5.2322)			(0.4775)		
$\Delta CO_2 2$		-9.2476***			0.0333	
		(-5.2286)			(0.5409)	
$\Delta CO_2 3$			-7.2699***			0.0367
			(-4.0646)			(0.5535)
Emissions	0.3666***	0.3695***	0.4136***	0.0003	0.0004	0.0004
	(4.2873)	(4.2773)	(4.7230)	(0.1508)	(0.1831)	(0.1947)
LogFs	1.2768	1.2972	0.9648	-0.4257***	-0.4263***	-0.4268***
	(0.6548)	(0.6627)	(0.4922)	(-3.3824)	(-3.3756)	(-3.3921)
LogNsr	12.4929***	12.4546***	12.4909***	0.8402*	0.8406*	0.8414*
	(3.6615)	(3.6555)	(3.6607)	(1.7343)	(1.7352)	(1.7321)
LogCI	-3.1106***	-3.1087***	-3.0784***	-0.1961***	-0.1960***	-0.1958***
	(-2.7316)	(-2.7281)	(-2.6739)	(-2.7615)	(-2.7590)	(-2.7678)
LogEI	0.4660	0.4781	0.3786	-0.0703	-0.0707	-0.0714
	(0.2498)	(0.2550)	(0.2004)	(-0.4820)	(-0.4851)	(-0.4907)
Lev	0.0782	0.0783	0.0685	0.0142	0.0141	0.0141
	(0.5887)	(0.5864)	(0.5173)	(1.2930)	(1.2909)	(1.2910)
ISO_EMS	-1.3005	-1.2446	-1.1369	-0.1293	-0.1295	-0.1302
	(-0.4214)	(-0.4008)	(-0.3651)	(-1.0617)	(-1.0635)	(-1.0658)
Cons	-225.7805***	-226.0108***	-226.2964***	-8.1509	-8.1534	-8.1630
	(-3.5020)	(-3.5137)	(-3.5143)	(-1.0293)	(-1.0298)	(-1.0292)
Firm-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	799	799	799	797	797	797
R_2	0.1950	0.1949	0.1891	0.2066	0.2067	0.2068
adj. R_2	0.1743	0.1742	0.1682	0.1862	0.1862	0.1864
F	12.6264	12.8566	11.7532	2.9919	2.9938	2.9909

Table 5-19 Estimation results: effects of resource use score on financial performance.

	Dependent Variable: ROE			Dependent Variable: Tobin's q_1		
	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate

$\Delta CO_2 1$	-15.4950***			0.0207		
	(-8.1388)			(0.4041)		
$\Delta CO_2 2$		-15.5730***			0.0237	
		(-8.2602)			(0.4625)	
$\Delta CO_2 3$			-13.4500***			0.0273
			(-7.8886)			(0.4917)
Resources	0.0086	0.0099	0.0097	-0.0032	-0.0032	-0.0032
	(0.0797)	(0.0916)	(0.0886)	(-1.2037)	(-1.2021)	(-1.1983)
LogFs	1.5281	1.5517	1.0275	-0.4184***	-0.4191***	-0.4197***
	(0.7688)	(0.7774)	(0.5103)	(-3.3095)	(-3.3047)	(-3.3263)
LogNsr	14.0764***	14.0414***	14.4354***	0.8510*	0.8517*	0.8527*
	(3.7430)	(3.7422)	(3.7902)	(1.7470)	(1.7487)	(1.7408)
LogCI	-3.2831***	-3.2821***	-3.2653***	-0.1931***	-0.1931***	-0.1929***
	(-2.8685)	(-2.8615)	(-2.7948)	(-2.7584)	(-2.7569)	(-2.7632)
LogEI	0.6806	0.6980	0.5775	-0.0712	-0.0715	-0.0722
	(0.3571)	(0.3644)	(0.2972)	(-0.4911)	(-0.4940)	(-0.4996)
Lev	0.0989	0.0991	0.0862	0.0141	0.0140	0.0140
	(0.7666)	(0.7633)	(0.6762)	(1.2938)	(1.2920)	(1.2905)
ISO_EMS	-1.8376	-1.7561	-1.6566	-0.1210	-0.1213	-0.1219
	(-0.5975)	(-0.5652)	(-0.5333)	(-1.0153)	(-1.0183)	(-1.0186)
Cons	-225.6807***	-226.1308 ***	-226.5281***	-8.1523	-8.1552	-8.1637
	(-3.4074)	(-3.4266)	(-3.3983)	(-1.0325)	(-1.0330)	(-1.0322)
Firm-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	799	799	799	797	797	797
R_2	0.1648	0.1640	0.1472	0.2087	0.2087	0.2088
adj. R_2	0.1434	0.1425	0.1253	0.1883	0.1884	0.1884
F	10.2071	10.3432	11.1224	2.9062	2.8947	2.8831

Table 5-20 Estimation results: effects of environmental innovation score on financial performance.

	Dependent Variable: ROE			Dependent Variable: Tobin's q_1		
	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
$\Delta CO_2 1$	-15.3812***			0.0221		
	(-7.9839)			(0.4097)		

$\Delta CO_2 2$		-15.4507***			0.0248	
		(-8.0788)			(0.4599)	
$\Delta CO_2 3$			-13.4111***			0.0302
			(-7.4922)			(0.5235)
Innovations	0.1203*	0.1200*	0.1237*	-0.0022*	-0.0022*	-0.0022*
	(1.7375)	(1.7346)	(1.7803)	(-1.7631)	(-1.7624)	(-1.7676)
LogFs	0.3140	0.3416	-0.2014	-0.4026***	-0.4032***	-0.4042***
	(0.1443)	(0.1559)	(-0.0912)	(-3.3513)	(-3.3465)	(-3.3737)
LogNsr	14.1802***	14.1512***	14.5275***	0.8400*	0.8407*	0.8421*
	(3.7431)	(3.7422)	(3.7689)	(1.7346)	(1.7363)	(1.7285)
LogCI	-2.9397**	-2.9381**	-2.9134**	-0.2024***	-0.2023***	-0.2021***
	(-2.5863)	(-2.5799)	(-2.5159)	(-2.8692)	(-2.8675)	(-2.8743)
LogEI	0.1766	0.1937	0.0678	-0.0609	-0.0612	-0.0621
	(0.0904)	(0.0986)	(0.0340)	(-0.4310)	(-0.4338)	(-0.4412)
ISO_EMS	-1.5465	-1.4634	-1.3524	-0.1347	-0.1349	-0.1357
	(-0.5338)	(-0.5001)	(-0.4624)	(-1.0591)	(-1.0619)	(-1.0629)
Lev	0.0888	0.0889	0.0761	0.0144	0.0143	0.0143
	(0.6682)	(0.6653)	(0.5798)	(1.3174)	(1.3157)	(1.3134)
ISO_EMS	-221.1085***	-221.5805***	-221.7422***	-8.2367	-8.2391	-8.2506
	(-3.3137)	(-3.3332)	(-3.2875)	(-1.0372)	(-1.0376)	(-1.0371)
Firm-fixed effect	Yes	Yes	Yes		Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	799	799	799	797	797	797
R_2	0.1804	0.1794	0.1636	0.2119	0.2119	0.2121
adj. R_2	0.1593	0.1583	0.1421	0.1916	0.1916	0.1918
F	10.6938	10.6615	10.1570	3.2975	3.2806	3.2575

5.7.1.3 Bootstrapping results of effects of environmental practices on relationship between CO_2 emission variations and financial performance

The results shown in Tables 5-21 to Table 5-24 show that the environmental pillar score and emission reduction score play mediating roles in the relationships between "ΔCO_2 1 and ROE", "$\Delta CO_2$2 and ROE", and "$\Delta CO_2$3 and ROE", but neither the environmental pillar scores nor emission reduction score mediate the relationships between "ΔCO_2 1 and Tobin's q_1", "$\Delta CO_2$2 and Tobin's q_1", and "$\Delta CO_2$3 and Tobin's q_1". Both the resource use score and environmental innovation score do not mediate the relationships between "ΔCO_2 1 and ROE", "$\Delta CO_2$2 and ROE", "$\Delta CO_2$3 and ROE", "ΔCO_2 1 and Tobin's q_1", "$\Delta CO_2$2 and Tobin's q_1", and "$\Delta CO_2$3 and Tobin's q_1". Thus, the results are consistent with the findings in the main analysis presented in S*ections 5.5 and 5.6*.

Table 5-21 Estimation results: mediating effects of environmental pillar score on relationship between CO_2 emission variations and financial performance.

Relationship	Bootstrapping results		
	Coefficient	BootLLCI	BootULCI
$\Delta CO_2$1-Environmental pillar score-ROE			
Total effect: $\Delta CO_2$1-ROE	-15.5045	-20.7152	-10.7295
Indirect effect: $\Delta CO_2$1- Environmental pillar score-ROE	-3.5070	-5.8288	-1.8072
Direct effect: $\Delta CO_2$1-ROE	-11.9975	-17.0602	-7.0233
$\Delta CO_2$2-Environmental pillar score-ROE			
Total effect: $\Delta CO_2$2-ROE	-15.5837	-20.8440	-10.8829
Indirect effect: $\Delta CO_2$2-Environmental pillar score-ROE	-3.5327	-5.8813	-1.6576
Direct effect: $\Delta CO_2$2-ROE	-12.0510	-17.0435	-6.8988
$\Delta CO_2$3-Environmental pillar score-ROE			
Total effect: $\Delta CO_2$3-ROE	-13.4613	-18.6071	-8.4710
Indirect effect: $\Delta CO_2$3-Environmental pillar score-ROE	-3.5208	-5.9529	-1.8768
Direct effect: $\Delta CO_2$3-ROE	-9.9405	-14.9167	-4.5193
$\Delta CO_2$1-Environmental pillar score-Tobin's q_1			
Total effect: $\Delta CO_2$1-Tobin's q_1	0.0243	-0.1354	0.1458
Indirect effect: $\Delta CO_2$1-Environmental pillar score-Tobin's q_1	0.0182	-0.0305	0.0852
Direct effect: $\Delta CO_2$1-Tobin's q_1	0.0061	-0.1664	0.1396
$\Delta CO_2$2-Environmental pillar score-Tobin's q_1			
Total effect: $\Delta CO_2$2 -Tobin's q_1	0.0272	-0.1154	0.1407
Indirect effect: $\Delta CO_2$2-Environmental pillar score -Tobin's q_1	0.0172	-0.0343	0.0780
Direct effect: $\Delta CO_2$2-Tobin's q_1	0.0100	-0.1455	0.1429
$\Delta CO_2$3-Environmental pillar score-Tobin's q_1			
Total effect: $\Delta CO_2$3-Tobin's q_1	0.0310	-0.0997	0.1608
Indirect effect: $\Delta CO_2$3-Environmental pillar score -Tobin's q_1	0.0137	-0.0247	0.0655
Direct effect: $\Delta CO_2$3-Tobin's q_1	0.0173	-0.1213	0.1480

Table 5-22 Estimation results: mediating effects of emission reduction score on relationship between CO_2 emission variations and financial performance.

Relationship	Bootstrapping results		
	Coefficient	BootLLCI	BootULCI
$\Delta CO_2$1-Emission reduction score-ROE			
Total effect: $\Delta CO_2$1-ROE	-15.5045	-20.4958	-11.1299
Indirect effect: $\Delta CO_2$1-Emission reduction score-ROE	-6.2864	-9.1927	-3.7041
Direct effect: $\Delta CO_2$1-ROE	-9.2181	-14.6258	-4.1124
$\Delta CO_2$2-Emission reduction score-ROE			
Total effect: $\Delta CO_2$2-ROE	-15.5837	-21.0571	-11.2200
Indirect effect: $\Delta CO_2$2-Emission reduction score-ROE	-6.3361	-9.3221	-3.9328
Direct effect: $\Delta CO_2$2-ROE	-9.2476	-14.8346	-3.8776
$\Delta CO_2$3-Emission reduction score-ROE			
Total effect: $\Delta CO_2$3-ROE	-13.4613	-18.5043	-8.6511
Indirect effect: $\Delta CO_2$3-Emission reduction score-ROE	-6.1914	-8.7387	-3.9483
Direct effect: $\Delta CO_2$3-ROE	-7.2699	-12.4473	-2.0058
$\Delta CO_2$1-Emission reduction score-Tobin's q_1			
Total effect: $\Delta CO_2$1-Tobin's q_1	0.0243	-0.1090	0.1532
Indirect effect: $\Delta CO_2$1-Emission reduction score-Tobin's q_1	-0.0050	-0.0641	0.0834
Direct effect: $\Delta CO_2$1-Tobin's q_1	0.0293	-0.1181	0.1650
$\Delta CO_2$2-Emission reduction score-Tobin's q_1			
Total effect: $\Delta CO_2$2-Tobin's q_1	0.0272	-0.1285	0.1384
Indirect effect: $\Delta CO_2$2-Emission reduction score-Tobin's q_1	-0.0061	-0.0702	0.0768
Direct effect: $\Delta CO_2$2-Tobin's q_1	0.0333	-0.1279	0.1541
$\Delta CO_2$3-Emission reduction score-Tobin's q_1			
Total effect: $\Delta CO_2$3-Tobin's q_1	0.0310	-0.1027	0.1412
Indirect effect: $\Delta CO_2$3-Emission reduction score-Tobin's q_1	-0.0058	-0.0598	0.0714
Direct effect: $\Delta CO_2$3-Tobin's q_1	0.0367	-0.1186	0.1493

Table 5-23 Estimation results: mediating effects of resource use score on relationship between CO_2 emission variations and financial performance.

Relationship	Bootstrapping results		
	Coefficient	BootLLCI	BootULCI
$\Delta CO_2$1-Resource use score-ROE			
Total effect: $\Delta CO_2$1-ROE	-15.5045	-20.6085	-11.1908

Indirect effect: $\Delta CO_2$1-Resource use score -ROE	-0.0096	-0.6253	0.3454
Direct effect: $\Delta CO_2$1-ROE	-15.4950	-20.6890	-11.2080
$\Delta CO_2$2-Resource use score-ROE			
Total effect: $\Delta CO_2$2-ROE	-15.5837	-20.8548	-11.0636
Indirect effect: $\Delta CO_2$2-Resource use score-ROE	-0.0107	-0.6280	0.3187
Direct effect: $\Delta CO_2$2-ROE	-15.5730	-21.3014	-11.1587
$\Delta CO_2$3-Resource use score-ROE			
Total effect: $\Delta CO_2$3-ROE	-13.4613	-18.2516	-8.6963
Indirect effect: $\Delta CO_2$3-Resource use score-ROE	-0.0114	-0.8936	0.3605
Direct effect: $\Delta CO_2$3-ROE	-13.4500	-18.4355	-8.7152
$\Delta CO_2$1-Resource use score-Tobin's q_1			
Total effect: $\Delta CO_2$1-Tobin's q_1	0.0243	-0.1241	0.1398
Indirect effect: $\Delta CO_2$1-Resource use score-Tobin's q_1	0.0035	-0.0031	0.0250
Direct effect: $\Delta CO_2$1-Tobin's q_1	0.0207	-0.1276	0.1370
$\Delta CO_2$2-Resource use score-Tobin's q_1			
Total effect: $\Delta CO_2$2-Tobin's q_1	0.0272	-0.1135	0.1532
Indirect effect: $\Delta CO_2$2-Resource use score-Tobin's q_1	0.0034	-0.0035	0.0211
Direct effect: $\Delta CO_2$2-Tobin's q_1	0.0237	-0.1162	0.1514
$\Delta CO_2$3-Resource use score-Tobin's q_1			
Total effect: $\Delta CO_2$3-Tobin's q_1	0.0310	-0.0994	0.1423
Indirect effect: $\Delta CO_2$3-Resource use score-Tobin's q_1	0.0037	-0.0027	0.0274
Direct effect: $\Delta CO_2$3-Tobin's q_1	0.0273	-0.1038	0.1389

Table 5-24 Estimation results: mediating effects of environmental innovation score on relationships between CO_2 emission variations and financial performance.

Relationship	Bootstrapping results		
	Coefficient	BootLLCI	BootULCI
$\Delta CO_2$1-Environmental innovation score-ROE			
Total effect: $\Delta CO_2$1-ROE	-15.5045	-20.5737	-10.7136
Indirect effect: $\Delta CO_2$1-Environmental innovation score-ROE	-0.1233	-1.1311	0.5968
Direct effect: $\Delta CO_2$1-ROE	-15.3812	-20.6322	-10.5466
$\Delta CO_2$2-Environmental innovation score-ROE			
Total effect: $\Delta CO_2$2-ROE	-15.5837	-21.0978	-11.3331
Indirect effect: $\Delta CO_2$2-Environmental innovation score-ROE	-0.1330	-1.2465	0.4893
Direct effect: $\Delta CO_2$2-ROE	-15.4507	-20.9753	-10.9905
$\Delta CO_2$3-Environmental innovation score-ROE			
Total effect: $\Delta CO_2$3-ROE	-13.4613	-18.5513	-8.2356

Indirect effect: $\Delta CO_2 3$-Environmental innovation score-ROE	-0.0502	-1.0047	0.6595
Direct effect: $\Delta CO_2 3$-ROE	-13.4111	-18.4860	-8.1047
$\Delta CO_2 1$-Environmental innovation score-Tobin's q_1			
Total effect: $\Delta CO_2 1$-Tobin's q_1	0.0243	-0.1097	0.1457
Indirect effect: $\Delta CO_2 1$-Environmental innovation score-Tobin's q_1	0.0022	-0.0111	0.0290
Direct effect: $\Delta CO_2 1$-Tobin's q_1	0.0221	-0.1116	0.1458
$\Delta CO_2 2$-Environmental innovation score-Tobin's q_1			
Total effect: $\Delta CO_2 2$-Tobin's q_1	0.0272	-0.1223	0.1497
Indirect effect: $\Delta CO_2 2$-Environmental innovation score-Tobin's q_1	0.0024	-0.0105	0.0274
Direct effect: $\Delta CO_2 2$-Tobin's q_1	0.0248	-0.1263	0.1459
$\Delta CO_2 3$-Environmental innovation score-Tobin's q_1			
Total effect: $\Delta CO_2 3$-Tobin's q_1	0.0310	-0.1184	0.1339
Indirect effect: $\Delta CO_2 3$-Environmental innovation score-Tobin's q_1	0.0007	-0.0127	0.0219
Direct effect: $\Delta CO_2 3$-Tobin's q_1	0.0302	-0.1138	0.1343

5.7.2 Omitted variables

This study adds four control variables to the Models (1)-(42) for the robustness test, including dividend yield, net profit margin, EPS, and sales revenue.

5.7.2.1 Results of effects of CO_2 emission variations on financial performance

Tables 5-25 and Table 5-26 list the results of the effects of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) on financial performance (i.e., ROA and Tobin's q) after adding four additional control variables to Models 1-6. The robustness test results are consistent with the main analysis results reported in S*ection 5.2*.

Table 5-25 Estimation results: effects of CO_2 emission variations on ROA.

	Dependent Variable: ROA			
	Controls only	Estimate	Estimate	Estimate
$\Delta CO_2 1$		-2.5525^{***}		
		(-4.4669)		
$\Delta CO_2 2$			-2.4807^{***}	

			(-4.4243)	
$\Delta CO_2 3$				-2.1600***
				(-4.3376)
LogFs	-0.3337	0.1759	0.1608	0.0714
	(-0.4973)	(0.2506)	(0.2293)	(0.1034)
LogNsr	1.6349**	1.0542	1.0707	1.1146
	(2.0868)	(1.1727)	(1.1993)	(1.2385)
LogCI	-0.1463	-0.2040	-0.2041	-0.2173
	(-0.5031)	(-0.6673)	(-0.6683)	(-0.7109)
LogEI	0.6077	0.8313	0.8240	0.7936
	(0.9370)	(1.3013)	(1.2895)	(1.2428)
Lev	-0.0724**	-0.0655*	-0.0659*	-0.0657*
	(-2.0132)	(-1.8804)	(-1.8934)	(-1.8567)
ISO_EMS	-0.7937	-0.7230	-0.7045	-0.6999
	(-0.8067)	(-0.7253)	(-0.7072)	(-0.7078)
DY	-0.1783	-0.2211	-0.2222	-0.2196
	(-1.2318)	(-1.4645)	(-1.4717)	(-1.4572)
EPS	-0.0128*	-0.0116*	-0.0116*	-0.0123*
	(-1.9258)	(-1.6761)	(-1.6938)	(-1.8458)
NPM	0.0013	-0.0008	-0.0008	-0.0008
	(0.0862)	(-0.0495)	(-0.0528)	(-0.0492)
LogSales	1.5750	1.5600	1.5487	1.6290
	(0.9408)	(0.9367)	(0.9317)	(0.9778)
Cons	-18.6114	-14.9609	-15.1044	-14.7315
	(-1.2091)	(-0.9164)	(-0.9292)	(-0.8998)
Firm-fixed effect	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
N	657	657	657	657
R_2	0.0420	0.0738	0.0714	0.0659
adj. R_2	0.0103	0.0416	0.0392	0.0335
F	2.2188	2.7967	2.8326	2.7654

Note: DY=Dividend yield, EPS=Earnings per share, NPM= Net profit margin

Table 5-26 Estimation results: effects of CO_2 emission variations on Tobin's q.

	Dependent Variable: Tobin's q

	Controls only	Estimate	Estimate	Estimate
$\Delta CO_2 1$		0.0467		
		(0.9709)		
$\Delta CO_2 2$			0.0510	
			(1.0653)	
$\Delta CO_2 3$				0.0590
				(1.1019)
LogFs	-0.3869***	-0.3962***	-0.3970***	-0.3979***
	(-3.2056)	(-3.2955)	(-3.2905)	(-3.3218)
LogNsr	0.6777	0.6884	0.6893	0.6920
	(1.4867)	(1.5069)	(1.5091)	(1.5048)
LogCI	-0.1049	-0.1038	-0.1037	-0.1029
	(-1.4930)	(-1.4800)	(-1.4775)	(-1.4684)
LogEI	-0.1162	-0.1203	-0.1206	-0.1212
	(-0.7278)	(-0.7497)	(-0.7520)	(-0.7563)
Lev	0.0145	0.0144	0.0143	0.0143
	(1.5185)	(1.5088)	(1.5086)	(1.5016)
ISO_EMS	-0.1149	-0.1162	-0.1167	-0.1174
	(-1.3099)	(-1.3249)	(-1.3332)	(-1.3348)
DY	-0.0478**	-0.0470**	-0.0469**	-0.0467**
	(-2.4087)	(-2.3748)	(-2.3690)	(-2.3797)
EPS	-0.0003	-0.0003	-0.0003	-0.0003
	(-0.2762)	(-0.2942)	(-0.2960)	(-0.2860)
NPM	0.0042	0.0042	0.0042	0.0043
	(1.3185)	(1.3221)	(1.3239)	(1.3239)
LogSales	0.3938**	0.3941**	0.3944**	0.3923**
	(2.1664)	(2.1677)	(2.1691)	(2.1618)
Cons	-5.8356	-5.9025	-5.9077	-5.9416
	(-0.7630)	(-0.7718)	(-0.7726)	(-0.7753)
Firm-fixed effect	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
N	657	657	657	657
R_2	0.2380	0.2388	0.2390	0.2394
adj. R_2	0.2128	0.2124	0.2126	0.2130

F	5.2956	5.3087	5.2891	5.2646

5.7.2.2 Results of effects of CO_2 emission variations on environmental practices

Tables 5-27 to Table 5-30 show the results of the effects of CO_2 emission variations (i.e., ΔCO_21, ΔCO_22 and ΔCO_23) on the environmental scores (i.e., environmental pillar score, emission reduction score, resource use score, and environmental innovation score) after adding four additional control variables in Models 7-18. The robustness test results align with the main analysis results presented in *Section 5.3.*

Table 5-27 Estimation results: effects of CO_2 emission variations on environmental pillar score.

	Dependent Variable: Environmental pillar score			
	Controls only	Estimate	Estimate	Estimate
ΔCO_21		-14.6639^{***}		
		(-4.3992)		
ΔCO_22			-14.3752^{***}	
			(-4.3696)	
ΔCO_23				-11.9616^{***}
				(-4.2362)
LogFs	-0.5052	2.4219	2.3599	1.7379
	(-0.3021)	(1.4159)	(1.3784)	(1.0362)
LogNsr	3.1372	-0.1990	-0.1322	0.2559
	(1.2225)	(-0.0980)	(-0.0648)	(0.1286)
LogCI	-1.1077	-1.4390^{*}	-1.4425^{*}	-1.5005^{*}
	(-1.1759)	(-1.8524)	(-1.8277)	(-1.8457)
LogEI	-0.6607	0.6239	0.5925	0.3687
	(-0.4882)	(0.5296)	(0.5008)	(0.2992)
Lev	0.0411	0.0806	0.0788	0.0781
	(0.4055)	(0.8487)	(0.8253)	(0.7873)
ISO_EMS	-1.4984	-1.0924	-0.9819	-0.9794
	(-0.5583)	(-0.4003)	(-0.3585)	(-0.3541)
DY	0.2716	0.0255	0.0171	0.0426
	(0.5492)	(0.0623)	(0.0414)	(0.0996)

EPS	-0.0508***	-0.0436**	-0.0438**	-0.0481**
	(-2.7162)	(-2.4698)	(-2.4695)	(-2.5538)
NPM	-0.0489	-0.0610**	-0.0614**	-0.0605**
	(-1.4467)	(-2.5528)	(-2.5862)	(-2.4162)
LogSales	5.7277	5.6415	5.5753	6.0267
	(1.3965)	(1.4572)	(1.4400)	(1.5197)
Cons	31.4308	52.4024*	51.7533*	52.9168*
	(0.8051)	(1.9618)	(1.8993)	(1.9423)
Firm-fixed effect	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
N	657	657	657	657
R_2	0.0594	0.2432	0.2324	0.1881
adj. R_2	0.0283	0.2169	0.2057	0.1600
F	2.7679	4.2070	4.0693	3.7903

Table 5-28 Estimation results: effects of CO_2 emission variations on emission reduction score.

	Dependent Variable: Emission reduction score			
	Controls only	Estimate	Estimate	Estimate
$\Delta CO_2 1$		-17.6485***		
		(-10.6913)		
$\Delta CO_2 2$			-17.5749***	
			(-10.8848)	
$\Delta CO_2 3$				-15.0328***
				(-11.7523)
LogFs	-1.8279	1.6950	1.6750	0.9912
	(-1.0632)	(1.0985)	(1.0740)	(0.6107)
LogNsr	7.5459**	3.5307*	3.5489*	3.9248*
	(2.3831)	(1.6950)	(1.7031)	(1.8682)
LogCI	-0.4638	-0.8625	-0.8731	-0.9574
	(-0.5693)	(-1.2304)	(-1.2310)	(-1.3544)
LogEI	-0.9335	0.6126	0.5987	0.3602
	(-0.6518)	(0.5124)	(0.4987)	(0.2819)
Lev	-0.0679	-0.0203	-0.0218	-0.0214
	(-0.5718)	(-0.2113)	(-0.2255)	(-0.2082)

ISO_EMS	-2.7985*	-2.3097	-2.1670	-2.1461
	(-1.6783)	(-1.4652)	(-1.3690)	(-1.3035)
DY	0.4146	0.1184	0.1035	0.1267
	(1.0994)	(0.3358)	(0.2922)	(0.3559)
EPS	-0.0438***	-0.0352***	-0.0353**	-0.0404***
	(-2.8258)	(-2.6836)	(-2.5874)	(-2.7342)
NPM	-0.0415	-0.0560	-0.0568	-0.0561
	(-0.9101)	(-1.3865)	(-1.4317)	(-1.4110)
LogSales	3.5752	3.4713	3.3888	3.9508
	(0.8393)	(1.0623)	(1.0344)	(1.1606)
Cons	-16.8648	8.3752	7.9812	10.1378
	(-0.3376)	(0.2387)	(0.2275)	(0.2861)
Firm-fixed effect	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
N	657	657	657	657
R_2	0.0889	0.3639	0.3560	0.2989
adj. R_2	0.0587	0.3418	0.3337	0.2746
F	3.2366	20.7186	20.2554	19.9708

Table 5-29 Estimation results: effects of CO_2 emission variations on resource use score.

	Dependent Variable: Resource use score			
	Controls only	Estimate	Estimate	Estimate
$\Delta CO_2 1$		0.1428		
		(0.1196)		
$\Delta CO_2 2$			0.1273	
			(0.1059)	
$\Delta CO_2 3$				0.1423
				(0.1320)
LogFs	2.2756	2.2471	2.2502	2.2489
	(0.9723)	(0.9818)	(0.9832)	(0.9790)
LogNsr	2.5510	2.5835	2.5800	2.5853
	(1.0166)	(1.0113)	(1.0104)	(1.0155)
LogCI	1.1078	1.1110	1.1107	1.1124
	(0.9293)	(0.9299)	(0.9294)	(0.9303)

LogEI	-0.7712	-0.7837	-0.7823	-0.7835
	(-0.3743)	(-0.3884)	(-0.3878)	(-0.3877)
Lev	-0.0807	-0.0811	-0.0811	-0.0812
	(-0.7118)	(-0.7124)	(-0.7120)	(-0.7136)
ISO_EMS	1.7896	1.7857	1.7850	1.7834
	(0.9226)	(0.9209)	(0.9207)	(0.9200)
DY	0.5383	0.5407	0.5405	0.5410
	(1.0546)	(1.0529)	(1.0518)	(1.0516)
EPS	0.0038	0.0037	0.0037	0.0037
	(0.2719)	(0.2675)	(0.2683)	(0.2698)
NPM	-0.0749	-0.0748	-0.0748	-0.0748
	(-1.6126)	(-1.6005)	(-1.6009)	(-1.5994)
LogSales	4.7188	4.7197	4.7202	4.7153
	(1.4083)	(1.4076)	(1.4075)	(1.4063)
Cons	13.3730	13.1688	13.1930	13.1174
	(0.3275)	(0.3173)	(0.3179)	(0.3156)
Firm-fixed effect	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
N	657	657	657	657
R_2	0.1663	0.1663	0.1663	0.1663
adj. R_2	0.1387	0.1374	0.1374	0.1374
F	2.0461	1.9653	1.9622	1.9542

Table 5-30 Estimation results: effects of CO_2 emission variations on environmental innovation score.

	Dependent Variable: Environmental innovation score			
	Controls only	Estimate	Estimate	Estimate
$\Delta CO_2 1$		1.6082		
		(0.5085)		
$\Delta CO_2 2$			1.6106	
			(0.5070)	
$\Delta CO_2 3$				2.4970
				(0.9089)
LogFs	8.4424***	8.1214***	8.1214***	7.9741***
	(2.6410)	(2.7351)	(2.7295)	(2.6717)

LogNsr	0.4703	0.8362	0.8367	1.0718
	(0.0933)	(0.1784)	(0.1783)	(0.2327)
LogCI	-2.4127	-2.3764	-2.3752	-2.3307
	(-1.2795)	(-1.2699)	(-1.2691)	(-1.2461)
LogEI	3.4153	3.2744	3.2749	3.2004
	(1.0524)	(1.0340)	(1.0338)	(1.0100)
Lev	0.3708*	0.3664*	0.3666*	0.3631*
	(1.8710)	(1.8394)	(1.8394)	(1.8172)
ISO_EMS	-0.1759	-0.2204	-0.2337	-0.2842
	(-0.0497)	(-0.0623)	(-0.0661)	(-0.0806)
DY	-0.5825	-0.5556	-0.5540	-0.5347
	(-0.7011)	(-0.6543)	(-0.6515)	(-0.6277)
EPS	0.0295	0.0287	0.0287	0.0289
	(0.3692)	(0.3596)	(0.3596)	(0.3631)
NPM	0.2198*	0.2212*	0.2212*	0.2223*
	(1.8867)	(1.8773)	(1.8788)	(1.8720)
LogSales	-6.2941	-6.2846	-6.2770	-6.3565
	(-0.8890)	(-0.8849)	(-0.8833)	(-0.8959)
Cons	-47.4505	-49.7504	-49.7275	-51.9357
	(-0.5526)	(-0.5920)	(-0.5916)	(-0.6248)
Firm-fixed effect	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
N	657	657	657	657
R_2	0.0476	0.0483	0.0483	0.0494
adj. R_2	0.0161	0.0153	0.0153	0.0164
F	1.8074	1.7507	1.7466	1.7412

5.7.2.3 Results of effects of environmental practices on financial performance

Tables 5-31 to Table 5-34 present the results of the effects of the environmental scores (i.e., environmental pillar score, emission reduction score, resource use score, and environmental innovation score) on financial performance (i.e., ROA and Tobin's q) after controlling for CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$), and adding four additional control variables in Models 19-42. Generally, the robustness test results are in line with the findings in the main analysis as shown in *Section 5.4*.

Table 5-31 Estimation results: effects of environmental pillar score on financial performance.

	Dependent Variable: ROA			Dependent Variable: Tobin's q		
	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
$\Delta CO_2 1$	-1.6545***			0.0515		
	(-2.6450)			(0.9358)		
$\Delta CO_2 2$		-1.5726**			0.0561	
		(-2.5332)			(1.0178)	
$\Delta CO_2 3$			-1.3483**			0.0634
			(-2.4739)			(1.0236)
Pillars	0.0612***	0.0632***	0.0679***	0.0003	0.0004	0.0004
	(2.8834)	(2.9860)	(3.4019)	(0.2061)	(0.2251)	(0.2239)
LogFs	0.0275	0.0117	-0.0465	-0.3970***	-0.3979***	-0.3986***
	(0.0395)	(0.0168)	(-0.0678)	(-3.3020)	(-3.2941)	(-3.3255)
LogNsr	1.0664	1.0791	1.0972	0.6884	0.6894	0.6919
	(1.2202)	(1.2418)	(1.2463)	(1.5054)	(1.5077)	(1.5042)
LogCI	-0.1159	-0.1130	-0.1154	-0.1033	-0.1032	-0.1024
	(-0.3775)	(-0.3685)	(-0.3756)	(-1.4724)	(-1.4684)	(-1.4597)
LogEI	0.7931	0.7865	0.7686	-0.1205	-0.1208	-0.1214
	(1.2062)	(1.1953)	(1.1681)	(-0.7517)	(-0.7540)	(-0.7572)
Lev	-0.0704**	-0.0708**	-0.0710**	0.0143	0.0143	0.0143
	(-1.9877)	(-2.0009)	(-1.9917)	(1.4985)	(1.4983)	(1.4913)
ISO_EMS	-0.6561	-0.6425	-0.6335	-0.1158	-0.1164	-0.1171
	(-0.6846)	(-0.6711)	(-0.6660)	(-1.3232)	(-1.3307)	(-1.3336)
DY	-0.2227	-0.2233	-0.2225	-0.0470**	-0.0469**	-0.0467**
	(-1.4299)	(-1.4321)	(-1.4232)	(-2.3744)	(-2.3689)	(-2.3794)
EPS	-0.0089	-0.0089	-0.0091	-0.0003	-0.0003	-0.0003
	(-1.2207)	(-1.2158)	(-1.2584)	(-0.2831)	(-0.2833)	(-0.2723)
NPM	0.0030	0.0031	0.0033	0.0043	0.0043	0.0043
	(0.1910)	(0.1963)	(0.2138)	(1.3178)	(1.3206)	(1.3181)
LogSales	1.2145	1.1965	1.2200	0.3923**	0.3924**	0.3902**

	(0.7369)	(0.7270)	(0.7425)	(2.1981)	(2.1985)	(2.1893)
Cons	-18.1701	-18.3736	-18.3225	-5.9195	-5.9261	-5.9608
	(-1.1353)	(-1.1521)	(-1.1384)	(-0.7697)	(-0.7707)	(-0.7726)
Firm-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	657	657	657	657	657	657
R_2	0.0900	0.0889	0.0873	0.2389	0.2390	0.2395
adj. R_2	0.0569	0.0558	0.0541	0.2112	0.2114	0.2118
F	3.4540	3.4832	3.3941	5.0700	5.0510	5.0389

Table 5-32 Estimation results: effects of emission reduction score on financial performance.

	Dependent Variable: ROA			Dependent Variable: Tobin's q		
	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
$\Delta CO_2 1$	-1.3129*			0.0709		
	(-1.8905)			(1.2493)		
$\Delta CO_2 2$		-1.2048*			0.0760	
		(-1.7531)			(1.3212)	
$\Delta CO_2 3$			-0.9961			0.0798
			(-1.6233)			(1.2689)
Emissions	0.0702***	0.0726***	0.0774***	0.0014	0.0014	0.0014
	(2.7982)	(2.9013)	(3.2502)	(0.7738)	(0.7931)	(0.7813)
LogFs	0.0568	0.0392	-0.0053	-0.3985***	-0.3994***	-0.3993***
	(0.0760)	(0.0524)	(-0.0072)	(-3.3033)	(-3.2946)	(-3.3185)
LogNsr	0.8062	0.8131	0.8107	0.6835	0.6843	0.6865
	(0.9123)	(0.9252)	(0.9160)	(1.4969)	(1.4983)	(1.4981)
LogCI	-0.1434	-0.1407	-0.1431	-0.1026	-0.1024	-0.1016
	(-0.4844)	(-0.4765)	(-0.4839)	(-1.4595)	(-1.4555)	(-1.4458)
LogEI	0.7883	0.7805	0.7657	-0.1211	-0.1215	-0.1217
	(1.1651)	(1.1520)	(1.1323)	(-0.7549)	(-0.7573)	(-0.7587)
Lev	-0.0641*	-0.0643*	-0.0640*	0.0144	0.0144	0.0143
	(-1.7962)	(-1.8014)	(-1.7805)	(1.5092)	(1.5094)	(1.5009)
ISO_EMS	-0.5607	-0.5472	-0.5338	-0.1130	-0.1136	-0.1145
	(-0.5763)	(-0.5630)	(-0.5517)	(-1.2823)	(-1.2908)	(-1.2992)
DY	-0.2294	-0.2297	-0.2295	-0.0472**	-0.0470**	-0.0468**

	(-1.5321)	(-1.5334)	(-1.5300)	(-2.3882)	(-2.3815)	(-2.3917)
EPS	-0.0091	-0.0091	-0.0092	-0.0003	-0.0003	-0.0003
	(-1.2275)	(-1.2242)	(-1.2497)	(-0.2519)	(-0.2517)	(-0.2376)
NPM	0.0032	0.0033	0.0036	0.0043	0.0043	0.0043
	(0.1875)	(0.1945)	(0.2093)	(1.3375)	(1.3409)	(1.3363)
LogSales	1.3162	1.3027	1.3231	0.3893**	0.3895**	0.3869**
	(0.8253)	(0.8181)	(0.8339)	(2.1675)	(2.1685)	(2.1590)
Cons	-15.5492	-15.6838	-15.5164	-5.9139	-5.9191	-5.9556
	(-0.9260)	(-0.9359)	(-0.9180)	(-0.7719)	(-0.7725)	(-0.7756)
Firm-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	657	657	657	657	657	657
R_2	0.0911	0.0902	0.0892	0.2394	0.2396	0.2400
adj. R_2	0.0581	0.0571	0.0561	0.2117	0.2119	0.2124
F	3.3100	3.3399	3.3138	5.1436	5.1254	5.1307

Table 5-33 Estimation results: effects of resource use score on financial performance.

	Dependent Variable: ROA			Dependent Variable: Tobin's q		
	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
$\Delta CO_2 1$	-2.5505***			0.0473		
	(-4.4609)			(0.9801)		
$\Delta CO_2 2$		-2.4788***			0.0514	
		(-4.4185)			(1.0734)	
$\Delta CO_2 3$			-2.1579***			0.0595
			(-4.3278)			(1.1082)
Resources	-0.0144	-0.0145	-0.0145	-0.0037	-0.0037	-0.0037
	(-0.5939)	(-0.5983)	(-0.5983)	(-1.3519)	(-1.3516)	(-1.3525)
LogFs	0.2082	0.1934	0.1039	-0.3879***	-0.3887***	-0.3896***
	(0.2945)	(0.2737)	(0.1493)	(-3.2278)	(-3.2220)	(-3.2539)
LogNsr	1.0914	1.1081	1.1520	0.6979	0.6988	0.7015
	(1.1964)	(1.2228)	(1.2618)	(1.5228)	(1.5251)	(1.5210)
LogCI	-0.1880	-0.1880	-0.2012	-0.0997	-0.0996	-0.0988
	(-0.6089)	(-0.6094)	(-0.6517)	(-1.4347)	(-1.4322)	(-1.4228)
LogEI	0.8200	0.8126	0.7823	-0.1231	-0.1235	-0.1241

	(1.2806)	(1.2686)	(1.2218)	(-0.7731)	(-0.7754)	(-0.7799)
Lev	-0.0667*	-0.0670*	-0.0669*	0.0141	0.0141	0.0140
	(-1.9090)	(-1.9221)	(-1.8837)	(1.4935)	(1.4933)	(1.4862)
ISO_EMS	-0.6973	-0.6787	-0.6742	-0.1096	-0.1101	-0.1109
	(-0.6903)	(-0.6723)	(-0.6731)	(-1.2630)	(-1.2714)	(-1.2733)
DY	-0.2133	-0.2144	-0.2118	-0.0450**	-0.0449**	-0.0447**
	(-1.4053)	(-1.4121)	(-1.3980)	(-2.3471)	(-2.3413)	(-2.3516)
EPS	-0.0115*	-0.0116*	-0.0123*	-0.0003	-0.0003	-0.0003
	(-1.6878)	(-1.7054)	(-1.8597)	(-0.2780)	(-0.2797)	(-0.2697)
NPM	-0.0018	-0.0019	-0.0018	0.0040	0.0040	0.0040
	(-0.1203)	(-0.1239)	(-0.1198)	(1.2426)	(1.2443)	(1.2444)
LogSales	1.6279	1.6170	1.6972	0.4115**	0.4117**	0.4097**
	(0.9769)	(0.9724)	(1.0192)	(2.2780)	(2.2795)	(2.2727)
Cons	-14.7714	-14.9134	-14.5419	-5.8539	-5.8591	-5.8933
	(-0.9036)	(-0.9163)	(-0.8877)	(-0.7683)	(-0.7690)	(-0.7719)
Firm-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	657	657	657	657	657	657
R_2	0.0744	0.0720	0.0666	0.2421	0.2423	0.2427
adj. R_2	0.0408	0.0383	0.0327	0.2146	0.2147	0.2152
F	2.6844	2.7149	2.6525	4.9129	4.9095	4.8821

Table 5-34 Estimation results: effects of environmental innovation score on financial performance.

	Dependent Variable: ROA			Dependent Variable: Tobin's q		
	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
$\Delta CO_2$1	-2.6274***			0.0516		
	(-4.6907)			(1.0333)		
$\Delta CO_2$2		-2.5556***			0.0558	
		(-4.6501)			(1.1259)	
$\Delta CO_2$3			-2.2775***			0.0666
			(-4.5650)			(1.2165)
Innovations	0.0465***	0.0465***	0.0471***	-0.0030**	-0.0030**	-0.0030**
	(3.6712)	(3.6580)	(3.6773)	(-2.0263)	(-2.0281)	(-2.0509)
LogFs	-0.2022	-0.2168	-0.3038	-0.3717***	-0.3725***	-0.3737***

	(-0.3044)	(-0.3267)	(-0.4640)	(-3.3564)	(-3.3513)	(-3.3884)
LogNsr	1.0153	1.0318	1.0642	0.6909	0.6919	0.6952
	(1.2074)	(1.2354)	(1.2576)	(1.5082)	(1.5106)	(1.5078)
LogCI	-0.0934	-0.0937	-0.1076	-0.1110	-0.1108	-0.1100
	(-0.2804)	(-0.2814)	(-0.3226)	(-1.6035)	(-1.6008)	(-1.5891)
LogEI	0.6789	0.6717	0.6430	-0.1104	-0.1107	-0.1115
	(1.0486)	(1.0367)	(0.9920)	(-0.7329)	(-0.7354)	(-0.7409)
Lev	-0.0826**	-0.0829**	-0.0828**	0.0155	0.0155	0.0154
	(-2.2669)	(-2.2804)	(-2.2503)	(1.5835)	(1.5834)	(1.5769)
ISO_EMS	-0.7127	-0.6937	-0.6866	-0.1168	-0.1174	-0.1183
	(-0.7496)	(-0.7307)	(-0.7296)	(-1.2718)	(-1.2805)	(-1.2834)
DY	-0.1953	-0.1964	-0.1945	-0.0487**	-0.0486**	-0.0483**
	(-1.3529)	(-1.3609)	(-1.3503)	(-2.5057)	(-2.4996)	(-2.5103)
EPS	-0.0129	-0.0130	-0.0137*	-0.0002	-0.0002	-0.0002
	(-1.5743)	(-1.5870)	(-1.7145)	(-0.2415)	(-0.2434)	(-0.2314)
NPM	-0.0111	-0.0111	-0.0112	0.0049	0.0049	0.0049
	(-0.6810)	(-0.6837)	(-0.6947)	(1.4543)	(1.4562)	(1.4564)
LogSales	1.8525	1.8405	1.9281	0.3751**	0.3754**	0.3730**
	(1.1161)	(1.1111)	(1.1610)	(2.1011)	(2.1024)	(2.0937)
Cons	-12.6452	-12.7926	-12.2876	-6.0524	-6.0577	-6.0996
	(-0.8414)	(-0.8551)	(-0.8119)	(-0.7860)	(-0.7868)	(-0.7906)
Firm-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	657	657	657	657	657	657
R_2	0.1103	0.1078	0.1032	0.2510	0.2512	0.2518
adj. R_2	0.0780	0.0754	0.0706	0.2238	0.2240	0.2246
F	3.0003	3.0092	2.9375	5.2740	5.2467	5.1750

5.7.2.4 Bootstrapping results of mediating effects of environmental practices on relationship between CO_2 emission variations and financial performance

Tables 5-35 to Table 5-38 show the bootstrapping results of the mediating effects of the environmental scores (i.e., environmental pillar score, emission reduction score, resource use score, and environmental innovation score) on the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$ and $\Delta CO_2 3$) and financial performance (i.e., ROA and Tobin's q) after incorporating four additional control variables in the regressions. In general, the robustness test results are consistent with the main analysis results reported in *Sections 5.5 and 5.6.*

Table 5-35 Estimation results: mediating effects of environmental pillar score on relationship between CO_2 emission variations and financial performance.

Relationship	Bootstrapping results		
	Coefficient	BootLLCI	BootULCI
$\Delta CO_2 1$-Environmental pillar score-ROA			
Total effect: $\Delta CO_2 1$-ROA	-2.5525	-3.7190	-1.6970
Indirect effect: $\Delta CO_2 1$-Environmental pillar score-ROA	-0.8980	-1.6981	-0.3022
Direct effect: $\Delta CO_2 1$-ROA	-1.6545	-2.8650	-0.5463
$\Delta CO_2 2$-Environmental pillar score-ROA			
Total effect: $\Delta CO_2 2$-ROA	-2.4807	-3.6088	-1.6314
Indirect effect: $\Delta CO_2 2$-Environmental pillar score-ROA	-0.9081	-1.5747	-0.3382
Direct effect: $\Delta CO_2 2$-ROA	-1.5726	-2.7812	-0.5668
$\Delta CO_2 3$-Environmental pillar score-ROA			
Total effect: $\Delta CO_2 3$-ROA	-2.1600	-3.2387	-1.4447
Indirect effect: $\Delta CO_2 3$-Environmental pillar score -ROA	-0.8117	-1.4629	-0.3413
Direct effect: $\Delta CO_2 3$-ROA	-1.3483	-2.5107	-0.4360
$\Delta CO_2 1$-Environmental pillar score-Tobin's q			
Total effect: $\Delta CO_2 1$-Tobin's q	0.0467	-0.0948	0.1936
Indirect effect: $\Delta CO_2 1$-Environmental pillar score-Tobin's q	-0.0048	-0.0582	0.0512
Direct effect: $\Delta CO_2 1$-Tobin's q	0.0515	-0.0974	0.2104
$\Delta CO_2 2$-Environmental pillar score-Tobin's q			
Total effect: $\Delta CO_2 2$-Tobin's q	0.0510	-0.0863	0.1918
Indirect effect: $\Delta CO_2 2$-Environmental pillar score-Tobin's q	-0.0051	-0.0609	0.0520
Direct effect: $\Delta CO_2 2$-Tobin's q	0.0561	-0.1061	0.2013
$\Delta CO_2 3$-Environmental pillar score-Tobin's q			
Total effect: $\Delta CO_2 3$-Tobin's q	0.0590	-0.0736	0.1897
Indirect effect: $\Delta CO_2 3$-Environmental pillar score-Tobin's q	-0.0043	-0.0524	0.0382
Direct effect: $\Delta CO_2 3$-Tobin's q	0.0634	-0.0691	0.2051

Table 5-36 Estimation results: mediating effects of emission reduction score on relationship between CO_2 emission variations and financial performance.

Relationship	Bootstrapping results		
	Coefficient	BootLLCI	BootULCI
$\Delta CO_2$1-Emission reduction score-ROA			
Total effect: $\Delta CO_2$1-ROA	-2.5525	-3.8533	-1.7563
Indirect effect: $\Delta CO_2$1-Emission reduction score-ROA	-1.2396	-2.0969	-0.3985
Direct effect: $\Delta CO_2$1-ROA	-1.3129	-2.6210	-0.1705
$\Delta CO_2$2-Emission reduction score-ROA			
Total effect: $\Delta CO_2$2-ROA	-2.4807	-3.5725	-1.5973
Indirect effect: $\Delta CO_2$2-Emission reduction score-ROA	-1.2759	-2.1503	-0.4823
Direct effect: $\Delta CO_2$2-ROA	-1.2048	-2.4755	0.0724
$\Delta CO_2$3-Emission reduction score-ROA			
Total effect: $\Delta CO_2$3-ROA	-2.1600	-3.2620	-1.4069
Indirect effect: $\Delta CO_2$3-Emission reduction score-ROA	-1.1639	-1.9050	-0.4940
Direct effect: $\Delta CO_2$3-ROA	-0.9961	-2.4042	0.0050
$\Delta CO_2$1-Emission reduction score-Tobin's q			
Total effect: $\Delta CO_2$1-Tobin's q	0.0467	-0.0940	0.1836
Indirect effect: $\Delta CO_2$1-Emission reduction score-Tobin's q	-0.0242	-0.0885	0.0435
Direct effect: $\Delta CO_2$1-Tobin's q	0.0709	-0.0779	0.2151
$\Delta CO_2$2-Emission reduction score-Tobin's q			
Total effect: $\Delta CO_2$2-Tobin's q	0.0510	-0.0745	0.2162
Indirect effect: $\Delta CO_2$2-Emission reduction score-Tobin's q	-0.0251	-0.0951	0.0380
Direct effect: $\Delta CO_2$2-Tobin's q	0.0760	-0.0660	0.2310
$\Delta CO_2$3-Emission reduction score-Tobin's q			
Total effect: $\Delta CO_2$3-Tobin's q	0.0590	-0.0651	0.2019
Indirect effect: $\Delta CO_2$3-Emission reduction score-Tobin's q	-0.0208	-0.0785	0.0396
Direct effect: $\Delta CO_2$3-Tobin's q	0.0798	-0.0579	0.2271

Table 5-37 Estimation results: mediating effects of resource use score on relationship between CO_2 emission variations and financial performance.

Relationship	Bootstrapping results		
	Coefficient	BootLLCI	BootULCI
$\Delta CO_2$1-Resource use score-ROA			

Total effect: $\Delta CO_2$1-ROA	-2.5525	-3.8820	-1.7891
Indirect effect: $\Delta CO_2$1-Resource use score-ROA	-0.0021	-0.1079	0.0639
Direct effect: $\Delta CO_2$1-ROA	-2.5505	-3.8893	-1.7455
$\Delta CO_2$2-Resource use score-ROA			
Total effect: $\Delta CO_2$2-ROA	-2.4807	-3.6983	-1.6500
Indirect effect: $\Delta CO_2$2-Resource use score -ROA	-0.0018	-0.1284	0.0604
Direct effect: $\Delta CO_2$2-ROA	-2.4788	-3.6782	-1.6368
$\Delta CO_2$3-Resource use score-ROA			
Total effect: $\Delta CO_2$3-ROA	-2.1600	-3.0964	-1.3647
Indirect effect: $\Delta CO_2$3-Resource use score-ROA	-0.0021	-0.0975	0.0690
Direct effect: $\Delta CO_2$3-ROA	-2.1579	-3.1401	-1.3622
$\Delta CO_2$1-Resource use score-Tobin's q			
Total effect: $\Delta CO_2$1-Tobin's q	0.0467	-0.1000	0.1826
Indirect effect: $\Delta CO_2$1-Resource use score-Tobin's q	-0.0005	-0.0153	0.0154
Direct effect: $\Delta CO_2$1-Tobin's q	0.0473	-0.0978	0.1827
$\Delta CO_2$2-Resource use score-Tobin's q			
Total effect: $\Delta CO_2$2-Tobin's q	0.0510	-0.0970	0.2054
Indirect effect: $\Delta CO_2$2-Resource use score-Tobin's q	-0.0005	-0.0182	0.0131
Direct effect: $\Delta CO_2$2-Tobin's q	0.0514	-0.0961	0.2005
$\Delta CO_2$3-Resource use score-Tobin's q			
Total effect: $\Delta CO_2$3-Tobin's q	0.0590	-0.0763	0.2103
Indirect effect: $\Delta CO_2$3-Resource use score-Tobin's q	-0.0005	-0.0183	0.0115
Direct effect: $\Delta CO_2$3-Tobin's q	0.0595	-0.0758	0.2076

Table 5-38 Estimation results: mediating effects of environmental innovation score on relationship between CO_2 emission variations and financial performance.

Relationship	Bootstrapping results		
	Coefficient	BootLLCI	BootULCI
$\Delta CO_2$1-Environmental innovation score-ROA			
Total effect: $\Delta CO_2$1-ROA	-2.5525	-3.7468	-1.7714
Indirect effect: $\Delta CO_2$1-Environmental innovation score-ROA	0.0749	-0.2529	0.4781
Direct effect: $\Delta CO_2$1-ROA	-2.6274	-3.7739	-1.8674
$\Delta CO_2$2-Environmental innovation score-ROA			
Total effect: $\Delta CO_2$2-ROA	-2.4807	-3.5032	-1.5998
Indirect effect: $\Delta CO_2$2-Environmental innovation score-ROA	0.0749	-0.3440	0.4529
Direct effect: $\Delta CO_2$2-ROA	-2.5556	-3.5868	-1.6814
$\Delta CO_2$3-Environmental innovation score-ROA			

Total effect: $\Delta CO_2 3$-ROA	-2.1600	-3.2087	-1.3537
Indirect effect: $\Delta CO_2 3$-Environmental innovation score-ROA	0.1175	-0.2278	0.5011
Direct effect: $\Delta CO_2 3$-ROA	-2.2775	-3.3642	-1.4117
$\Delta CO_2 1$-Environmental innovation score-Tobin's q			
Total effect: $\Delta CO_2 1$-Tobin's q	0.0467	-0.0844	0.2020
Indirect effect: $\Delta CO_2 1$-Environmental innovation score-Tobin's q	-0.0048	-0.0351	0.0194
Direct effect: $\Delta CO_2 1$-Tobin's q	0.0516	-0.0875	0.2000
$\Delta CO_2 2$-Environmental innovation score-Tobin's q			
Total effect: $\Delta CO_2 2$-Tobin's q	0.0510	-0.0880	0.2063
Indirect effect: $\Delta CO_2 2$- Environmental innovation score-Tobin's q	-0.0049	-0.0402	0.0169
Direct effect: $\Delta CO_2 2$-Tobin's q	0.0558	-0.0916	0.2072
$\Delta CO_2 3$-Environmental innovation score-Tobin's q			
Total effect: $\Delta CO_2 3$ -Tobin's q	0.0590	-0.0821	0.2052
Indirect effect: $\Delta CO_2 3$-Environmental innovation score-Tobin's q	-0.0076	-0.0425	0.0119
Direct effect: $\Delta CO_2 3$-Tobin's q	0.0666	-0.0751	0.2224

Chapter Summary

This chapter elaborates the analysis results, which are summarized in Table 5-39. The results of using the causal steps approach and bootstrapping method are consistent. The robustness test also validates the reliability of the results derived from the main analysis. The results are summarized as follows:

For the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and financial performance (i.e., ROA and Tobin's q). The results show that a decrease in scope 1, 2 and 3 CO_2 emissions enhance ROA. Conversely, an increase in scope 1, 2 and 3 CO_2 emissions decrease ROA. However, an increase or a decrease in scope 1, 2 and 3 CO_2 emissions is not associated with Tobin's q. The robustness test results validate these findings.

For the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and environmental scores (i.e., environmental pillar score, emission reduction score, and resource use score, and environmental innovation score). The results show that a decrease in scope 1, 2, and 3 CO_2 emissions increases environmental pillar score and emission reduction score. Conversely, an increase in scopes 1, 2, and 3 CO_2 emissions decreases environmental pillar score and emission reduction score. But the results show the nonsignificant relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and environmental scores (i.e., resource use score and environmental innovation score). These results are validated by robustness test.

For the effects of the environmental scores on financial performance after controlling for the effects of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$). The results show the positive relationships between "the environmental pillar score and ROA", "the emission reduction score and ROA" , and "the environmental innovation score and ROA" after controlling for the effects of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) in the regressions. The results also show a negative relationship between "the environmental innovation score and Tobin's q", and nonsignificant relationships between "the environmental pillar score and Tobin's q", "the emission reduction score and Tobin's q", "the resource use score and ROA", and "the resource use score and Tobin's q" after controlling for the effects of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) in the regressions. The results of the robustness test are consistent with these findings of the main analysis.

For the mediating effects of the environmental scores in the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and financial performance, both the environmental pillar score and emission reduction score mediate the relationships between "$\Delta CO_2 1$ and ROA", "$\Delta CO_2 2$ and ROA", and "$\Delta CO_2 3$ and ROA". However, neither the environmental pillar score nor the emission reduction score plays mediating roles in the relationships between "Δ$CO_2$1 and Tobin's q", "Δ$CO_2$2 and Tobin's q", and "Δ$CO_2$3 and Tobin's q". In addition, the resource use score and environmental innovation score do not mediate the relationships between Δ$CO_2$1 and ROA", "Δ$CO_2$2 and ROA", "Δ$CO_2$3 and ROA" and "Δ$CO_2$1 and Tobin's q", "Δ$CO_2$2 and Tobin's q", and "Δ$CO_2$3 and Tobin's q". The bootstrapping results consistent with the results by using causal steps approach, and the robustness test results validate these findings. In Chapter 6, the results obtained from Chapter 5 are further discussed.

Table 5-39 Summary of the results.

	Main analysis results		**Robustness test results**				
			Four additional control variables are added in Models 1-42		Alternative indicators of financial performance		
Hypothesis	Causal step approach	Bootstrapping method	Casual step approach	Bootstrapping method	Hypothesis	Causal step approach	Bootstrapping method
H_1:$\Delta CO_2$1-Financial performance					**H_1:$\Delta CO_2$1-Financial performance**		
H_1(a): $\Delta CO_2$1-ROA	Supported	Supported	Supported	Supported	H_1(a): $\Delta CO_2$1-ROE	Supported	Supported
H_1(b): $\Delta CO_2$1-Tobin's q	Rejected	Rejected	Rejected	Rejected	H_1(b): $\Delta CO_2$1-Tobin's q_1	Rejected	Rejected
H_2:$\Delta CO_2$2-Financial performance					**H_2:$\Delta CO_2$2-Financial performance**		
H_2(a): $\Delta CO_2$2-ROA	Supported	Supported	Supported	Supported	H_2(a): $\Delta CO_2$2-ROE	Supported	Supported
H_2(b): $\Delta CO_2$2-Tobin's q	Rejected	Rejected	Rejected	Rejected	H_2(b): $\Delta CO_2$2-Tobin's q_1	Rejected	Rejected
H_3:$\Delta CO_2$3-Financial performance					**H_3:$\Delta CO_2$3-Financial performance**		
H_3(a): $\Delta CO_2$3-ROA	Supported	Supported	Supported	Supported	H_3(a): $\Delta CO_2$3-ROE	Supported	Supported
H_3(b): $\Delta CO_2$3-Tobin's q	Rejected	Rejected	Rejected	Rejected	H_3(b): $\Delta CO_2$3-Tobin's q_1	Rejected	Rejected
H_4:$\Delta CO_2$1-Performance in implementing environmental practices					**H_4:$\Delta CO_2$1-performance in implementing environmental practices**		
H_4(a): $\Delta CO_2$1-Performance in implementing integrated environmental practices (environmental pillar score)	Supported	-	Supported	-	H_4(a): $\Delta CO_2$1-Performance in implementing integrated environmental practices (environmental pillar score)	-	-

H_4(b): $\Delta CO_2$1-Performance in implementing emission reduction practices (emission reduction score)	Supported	-	Supported	-	H_4(b): $\Delta CO_2$1-Performance in implementing emission reduction practices (emission reduction score)	-	-
H_4(c): $\Delta CO_2$1-Performance in implementing resource use practices (resource use score)	Rejected	-	Rejected	-	H_4(c): $\Delta CO_2$1-Performance in implementing resource use practices (resource use score)	-	-
H_4(d): $\Delta CO_2$1-Performance in implementing environmental innovation practices (environmental innovation score)	Rejected	-	Rejected	-	H_4(d): $\Delta CO_2$1-Performance in implementing environmental innovation practices (environmental innovation score)	-	-
H_5:$\Delta CO_2$2-Performance in implementing environmental practices					**H_5:$\Delta CO_2$2-Performance in implementing environmental practices**		
H_5(a): $\Delta CO_2$2-Performance in implementing integrated environmental practices (environmental pillar score)	Supported	-	Supported	-	H_5(a): $\Delta CO_2$2-Performance in implementing integrated environmental practices (environmental pillar score)	-	-
H_5(b): $\Delta CO_2$2-Performance in implementing emission reduction practices (emission reduction score)	Supported	-	Supported	-	H_5(b): $\Delta CO_2$2-Performance in implementing emission reduction practices (emission reduction score)	-	-
H_5(c): $\Delta CO_2$2-Performance in implementing resource use practices (resource use score)	Rejected	-	Rejected	-	H_5(c): $\Delta CO_2$2-Performance in implementing resource use practices (resource use score)	-	-
H_5(d): $\Delta CO_2$2-Performance in implementing environmental innovation practices (environmental innovation score)	Rejected	-	Rejected	-	H_5(d): $\Delta CO_2$2-Performance in implementing environmental innovation practices (environmental innovation score)	-	-
H_6:$\Delta CO_2$3-Performance in implementing environmental practices					**H_6:$\Delta CO_2$3-Performance in implementing environmental practices**		

H_6(a): $\Delta CO_2$3-Performance in implementing integrated environmental practices (environmental pillar score)	Supported	-	Supported	-	H_6(a): $\Delta CO_2$3-Performance in implementing integrated environmental practices (environmental pillar score)	-	-
H_6(b): $\Delta CO_2$3-Performance in implementing emission reduction practices (emission reduction score)	Supported	-	Supported	-	H_6(b): $\Delta CO_2$3-Performance in implementing emission reduction practices (emission reduction score)	-	-
H_6(c): $\Delta CO_2$3-Performance in implementing resource use practices (resource use score)	Rejected	-	Rejected	-	H_6(c): $\Delta CO_2$3-Performance in implementing resource use practices (resource use score)	-	-
H_6(d): $\Delta CO_2$3-Performance in implementing environmental innovation practices (environmental innovation score)	Rejected	-	Rejected	-	H_6(d): $\Delta CO_2$3-Performance in implementing environmental innovation practices (environmental innovation score)	-	-
H_{7}: Integrated environmental practices-Financial performance					**H_{7}: Integrated environmental practices-Financial performance**		
H_7(a): Integrated environmental practices-ROA	Supported	-	Supported	-	H_7(a): Integrated environmental practices-ROE	Supported	-
H_7(b): Integrated environmental practices-Tobin's q	Rejected	-	Rejected	-	H_7(b): Integrated environmental practices-Tobin's q_1	Rejected	-
H_{8}: Emission reduction practices -Financial performance					**H_{8}: Emission reduction practices -Financial performance**		
H_8(a): Emission reduction practices-ROA	Supported	-	Supported	-	H_8(a): Emission reduction practices- ROE	Supported	-
H_8(b): Emission reduction practices-Tobin's q	Rejected	-	Rejected	-	H_8(b): Emission reduction practices- Tobin's q_1	Rejected	-
H_{9}:Resource use practices-Financial performance					**H_{9}:Resource use practices-Financial performance**		
H_9(a):Resource use practices-ROA	Rejected	-	Rejected	-	H_9(a):Resource use practices- ROE	Rejected	-

H_9(b): Resource use practices-Tobin's q	Rejected	-	Rejected	-	H_9(b): Resource use practices-Tobin's q_1	Rejected	-
H_{10}:Environmental innovation practices-Financial performance					**H_{10}:Environmental innovation practices-Financial performance**		
H_{10}(a):Environmental innovation practices-ROA	Supported	-	Supported	-	H_{10}(a):Environmental innovation practices-ROE	Supported	-
H_{10}(b):Environmental innovation practices-Tobin's q	Rejected	-	Rejected	-	H_{10}(b):Environmental innovation practices-Tobin's q_1	Rejected	-
H_{11}:ΔCO_2-Integrated environmental practices-Financial performance					**H_{11}:ΔCO_2-Integrated environmental practices-Financial performance**		
H_{11}(a): $\Delta CO_2$1-Integrated environmental practices-ROA	Supported	Supported	Supported	Supported	H_{11}(a): $\Delta CO_2$1-Integrated environmental practices-ROE	Supported	Supported
H_{11}(b): $\Delta CO_2$2-Integrated environmental practices-ROA	Supported	Supported	Supported	Supported	H_{11}(b): $\Delta CO_2$2-Integrated environmental practices-ROE	Supported	Supported
H_{11}(c): $\Delta CO_2$3-Integrated environmental practices-ROA	Supported	Supported	Supported	Supported	H_{11}(c): $\Delta CO_2$3-Integrated environmental practices-ROE	Supported	Supported
H_{11}(d): $\Delta CO_2$1-Integrated environmental practices-Tobin's q	Rejected	Rejected	Rejected	Rejected	H_{11}(d): $\Delta CO_2$1-Integrated environmental practices-Tobin's q_1	Rejected	Rejected
H_{11}(e): $\Delta CO_2$2-Integrated environmental practices-Tobin's q	Rejected	Rejected	Rejected	Rejected	H_{11}(e): $\Delta CO_2$2-Integrated environmental practices-Tobin's q_1	Rejected	Rejected
H_{11}(f): $\Delta CO_2$3-Integrated environmental practices-Tobin's q	Rejected	Rejected	Rejected	Rejected	H_{11}(f): $\Delta CO_2$3-Integrated environmental practices-Tobin's q_1	Rejected	Rejected
H_{12}:$\Delta CO_2$2-Emission reduction practices-Financial performance					**H_{12}:$\Delta CO_2$2-Emission reduction practices-Financial performance**		

H_{12}(a): $\Delta CO_2$1-Emission reduction practices-ROA	Supported	Supported	Supported	Supported	H_{12}(a): $\Delta CO_2$1-Emission reduction practices-ROE	Supported	Supported
H_{12}(b): $\Delta CO_2$2-Emission reduction practices-ROA	Supported	Supported	Supported	Supported	H_{12}(b): $\Delta CO_2$2-Emission reduction practices-ROE	Supported	Supported
H_{12}(c): $\Delta CO_2$3-Emission reduction practices-ROA	Supported	Supported	Supported	Supported	H_{12}(c): $\Delta CO_2$3-Emission reduction practices-ROE	Supported	Supported
H_{12}(d): $\Delta CO_2$1-Emission reduction practices-Tobin's q	Rejected	Rejected	Rejected	Rejected	H_{12}(d): $\Delta CO_2$1-Emission reduction practices-Tobin's q_1	Rejected	Rejected
H_{12}(e): $\Delta CO_2$2-Emission reduction practices-Tobin's q	Rejected	Rejected	Rejected	Rejected	H_{12}(e): $\Delta CO_2$2-Emission reduction practices-Tobin's q_1	Rejected	Rejected
H_{12}(f): $\Delta CO_2$3-Emission reduction practices-Tobin's q	Rejected	Rejected	Rejected	Rejected	H_{12}(f): $\Delta CO_2$3-Emission reduction practices-Tobin's q_1	Rejected	Rejected
H_{13}:ΔCO_2-Resource use practices-Financial performance					**H_{13}:ΔCO_2-Resource use practices-Financial performance**		
H_{13}(a): $\Delta CO_2$1-Resource use practices-ROA	Rejected	Rejected	Rejected	Rejected	H_{13}(a): $\Delta CO_2$1-Resource use score-ROE	Rejected	Rejected
H_{13}(b): $\Delta CO_2$2-Resource use practices-ROA	Rejected	Rejected	Rejected	Rejected	H_{13}(b): $\Delta CO_2$2-Resource use score-ROE	Rejected	Rejected
H_{13}(c): $\Delta CO_2$3-Resource use practices-ROA	Rejected	Rejected	Rejected	Rejected	H_{13}(c): $\Delta CO_2$3-Resource use score-ROE	Rejected	Rejected
H_{13}(d): $\Delta CO_2$1-Resource use practices-Tobin's q	Rejected	Rejected	Rejected	Rejected	H_{13}(d): $\Delta CO_2$1-Resource use score-Tobin's q_1	Rejected	Rejected
H_{13} (e): $\Delta CO_2$2-Resource use practices-Tobin's q	Rejected	Rejected	Rejected	Rejected	H_{13}(e): $\Delta CO_2$2-Resource use score-Tobin's q_1	Rejected	Rejected
H_{13} (f): $\Delta CO_2$3-Resource use practices-Tobin's q	Rejected	Rejected	Rejected	Rejected	H_{13}(f): $\Delta CO_2$3-Resource use score-Tobin's q_1	Rejected	Rejected
H_{14}:ΔCO_2-Environmental Innovation practices-Financial performance					**H_{14}:ΔCO_2-Environmental Innovation practices-Financial performance**		

H_{14}(a): $\Delta CO_2$1-Environmental innovation practices-ROA	Rejected	Rejected	Rejected	Rejected	H_{14}(a): $\Delta CO_2$1-Environmental innovation practices-ROE	Rejected	Rejected
H_{14}(b): $\Delta CO_2$2-Environmental innovation practices-ROA	Rejected	Rejected	Rejected	Rejected	H_{14}(b): $\Delta CO_2$2-Environmental innovation practices-ROE	Rejected	Rejected
H_{14}(c): $\Delta CO_2$3-Environmental innovation practices-ROA	Rejected	Rejected	Rejected	Rejected	H_{14}(c): $\Delta CO_2$3-Environmental innovation practices-ROE	Rejected	Rejected
H_{14}(d): $\Delta CO_2$1-Environmental innovation practices-Tobin's q	Rejected	Rejected	Rejected	Rejected	H_{14}(d): $\Delta CO_2$1-Environmental innovation practices-Tobin's q_1	Rejected	Rejected
H_{14}(e): $\Delta CO_2$2-Environmental innovation practices -Tobin's q	Rejected	Rejected	Rejected	Rejected	H_{14}(e): $\Delta CO_2$2-Environmental innovation practices -Tobin's q_1	Rejected	Rejected
H_{14}(f): $\Delta CO_2$3-Environmental innovation practices-Tobin's q	Rejected	Rejected	Rejected	Rejected	H_{14}(f): $\Delta CO_2$3-Environmental innovation practices-Tobin's q_1	Rejected	Rejected

Chapter 6 Discussion

6.1 Introduction

The purpose of this chapter is to integrate the research findings in chapter 4 to provide the foundations for the academic contribution of this study. The research findings are linked to the Research Questions 1-4 and Research Objectives 1-4 proposed in Chapter 1 to discern the learning about the relationships among CO_2 emissions, environmental practices, and financial performance, including the relationships between i) "scopes 1, 2 and 3 CO_2 emission variations (i.e., increase or decrease) and financial performance in terms of ROA and Tobin's q", ii) "scopes 1, 2 and 3 CO_2 emission variations and environmental practices (the integrated environmental practices and their individual practices, including emission reduction, resource use, and environmental innovation)", and iii) "environmental practices (i.e., the integrated environmental practices and their individual practices) and financial performance in terms of ROA and Tobin's q". The specific details are provided in the following sections.

6.2 Effects of CO_2 emissions on financial performance

6.2.1 Effects of CO_2 emission variations on ROA

Finding 1: The negative relationships between each scope of CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and ROA. Specifically, a decrease in scopes 1, 2 and 3 CO_2 emissions enhance ROA. Conversely, an increase in scopes 1, 2 and 3 CO_2 emissions decrease ROA.

The results suggest that companies have lower i) scope 1 CO_2 emission (i.e., direct CO_2 emissions) that are generated from the sources owned or controlled by companies;

ii) scope 2 CO_2 emission (i.e., indirect CO_2 emission) that emitted by consumption of purchased electricity, heat or steam in the facility where electricity, heat or steam are produced, and iii) scope 3 CO_2 emission (i.e., the indirect CO_2 emission) generated from other sources that are not owned or managed by the company, such as transportation of purchased fuels or utilization of sold products and services, thus enabling companies to use their assets effectively to generate profit. In contrast, companies with higher scopes 1, 2, and 3 CO_2 emissions are unable to effectively leverage their assets to produce profits.

The result of the effect of scope 1 CO_2 emission on ROA is consistent with that of previous studies, which indicate that a reduction in scope 1 CO_2 emission can increase ROA (Desai et al., 2022). As for the relationship between "scope 2 CO_2 emission and ROA" and "scope 3 CO_2 emission and ROA", previous studies have provided limited empirical evidence on these relationships. In general, previous studies have examined the relationship between total CO_2 emissions and ROA (Hart & Ahuja, 1996; Iwata & Okada, 2011; Lee et al., 2015), which shows that companies with reduced total CO_2 emission exhibit higher ROA (i.e., profitability). Since previous studies provide little empirical evidence on these two relationships, this study contributes to the existing literature by providing empirical evidence on them.

Based on the legitimacy theory, companies that have reduced their scopes 1, 2 and 3 CO_2 emissions indicate that they effectively respond to legitimacy threats. The legitimacy from the reduction of scopes 1, 2 and 3 CO_2 emissions are operational resources (Suchman, 1995) that helps companies increase their profit. Companies can profit by reducing compliance costs, lowering risks associated with fines, penalties, liabilities and reputational damage, and improving operational efficiency and saving on operational costs. Besides, CO_2 emission reduction can be achieved by adopting pollution prevention strategies, which is similar to total quality environmental management, thus contributing to improving operational efficiency and productivity, and reducing compliance and liability costs. All of these ultimately result in higher profit (Hart, 1995). In addition, the sample firms in this study are companies that participate in carbon credit/offset practices. It is possible that some of the companies with superior carbon performance (i.e., with a significant reduction in CO_2 emissions) sell their remaining carbon credits and reap the profits (Desai et al., 2022).

6.2.2 Effects of CO_2 emission variation on Tobin's q

Finding 2: The non-significant relationships between scopes 1, 2, and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and Tobin's q. Specifically, an increase or decrease in scopes 1, 2, and 3 CO_2 emissions are not related to Tobin's q.

As previously stated, companies can implement pollution prevention initiatives to reduce their CO_2 emissions, which increase their ROA. Because there is a large amount of low-hanging fruit in the initial phase of pollution prevention initiatives (Hart & Ahuja, 1996). In other words, simple and cost-effective behaviors and material changes lead to a significant reduction in CO_2 emissions (Hart & Ahuja, 1996) relative to the associated costs, which help companies obtain legitimacy. However, further reduction in CO_2 emissions becomes increasingly challenging, which demands substantial changes in processes, and use of completely new production technological innovations (Hart & Ahuja, 1996), both of which require substantial investment and expenses, thus discouraging companies from further pursuing ways to reduce their CO_2 emission. Companies tend to establish symbolic links with the social values (i.e., mitigating global warming and climate change) that are highly respected to create reputational endorsement effects (Ashforth & Gibbs, 1990; Palazzo & Scherer, 2006). If companies can obtain legitimacy by adopting simple and cost-effective behaviors, they will not adopt significant environmental actions to reduce their CO_2 emissions. Tobin's q is a measure of how investors perceive long-term potential of firms to create value (i.e., generating future profits and sustaining growth), and valuation of the markets of the ability of firms to generate future cash flows (Tobin, 1969). In addition, Tobin's q measures how a robust market perceives a firm in the face of future climate legislation (Delmas et al., 2015). Without significant environmental practices that further reduce CO_2 emissions in the long-term, the market and investors cannot assess the capability of a company in managing environmental risks or challenges in the long-term. Therefore, an increase or decrease in scopes 1, 2, and 3 CO_2 emissions does not have any impact on Tobin's q.

Therefore, Findings 1 and 2 meet Research Objective 2 and answer Research Question 2.

6.3 Effects of CO_2 emission on environmental practices

6.3.1 Effects of CO_2 emission variations on integrated environmental practices

Finding 3: The negative relationships between scopes 1, 2, and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and performance in implementing integrated environmental practices. Specifically, a decrease in scopes 1, 2, and 3 CO_2 emission enhance performance in implementing integrated environmental practices. Conversely, an increase in scope 1, 2, and 3 CO_2 emission decrease performance in implementing integrated environmental practices.

Implementing integrated environmental practices means to implement the combined environmental practices of emission reduction, resource use and environmental innovation. The results indicate that companies with reduced scopes 1, 2, and 3 CO_2 emissions can improve their performance of implementing integrated environmental practices, which shows that the companies are effectively implementing integrated environmental practices to reduce their scopes 1, 2, and 3 CO_2 emissions. Reducing scopes 1, 2, and 3 CO_2 emissions through implementing integrated environmental practices aligns with social norms and values. Thus, companies that implement integrated environmental practices for reducing CO_2 emission can be viewed as participating in a legitimacy process, which helps them to gain legitimacy. In contrast, companies with higher scopes 1, 2, and 3 CO_2 emissions show a deteriorated performance in implementing integrated environmental practices, which shows that companies are ineffectively implementing integrated environmental practices to reduce their scopes 1, 2, and 3 CO_2 emissions, and will lead to legitimacy threats to the credibility of the company and potentially affect their continued existence.

6.3.2 Effects of CO_2 emission variation on emission reduction practices

Finding 4: The negative relationships between scope 1, 2, and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and performance in implementing emission reduction practices. Specifically, a decrease in scope 1, 2, and 3 CO_2 emission improves the performance in implementing emission reduction practices. Conversely, an increase in scope 1, 2, and 3 CO_2 emissions lowers the performance in implementing emission reduction practices.

Emission reduction practices refer to reducing emissions throughout the production and operational processes. The results suggest companies with reduced scope 1, 2, and 3 CO_2 emissions improve their performance in implementing emission reduction practices, which demonstrate they are effectively implementing emission reduction practices to reduce their scope 1, 2, and 3 CO_2 emissions. The reduction in scope 1, 2, and 3 CO_2 emissions by implementing the emission reduction practices is in line with societal norms and values. Thus, companies implementing emission reduction practices for reducing CO_2 emission can be considered as engaging in a legitimacy process that helps them to obtain legitimacy. In contrast, companies with increased scope 1, 2, and 3 CO_2 emissions can decrease their performance in implementing the emission reduction practices, which demonstrates companies are ineffectively implementing emission reduction practices to reduce their scope 1, 2, and 3 CO_2 emissions, which will face legitimacy threats that potentially affect their ongoing existence.

6.3.3 Effects of CO_2 emission variation on resource use practices

Finding 5: The insignificant relationships between scope 1, 2, and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and performance in implementing resource use practices. Specifically, an increase or decrease in scope 1, 2 and 3 CO_2 emissions are not associated with performance in implementing resource use practices.

Resource use practices are defined as a reduction in the use of materials, energy or water, and enhancement of eco-friendly solutions by improving supply chain management. The results indicate that companies with increased or decreased scope 1, 2 and 3 CO_2 emissions cannot do not show improvements or worsening in their performance of implementing resource use practices. This is probably because resources use practices do not directly lead to reduction in scope 1, 2 and 3 CO_2

emissions, although these practices can help companies reduce such emissions. For example, reducing material use initially leads to lower energy use in the manufacturing process which subsequently results in lower scope 2 CO_2 emissions related to energy consumption. Similarly, reducing water usage initially lowers the energy consumption related to wastewater treatment, which in turn decreases scope 2 CO_2 emissions from energy consumption. In addition, improving eco-friendly solutions in products or materials design to promote recycling, reusing, or remanufacturing initially decreases materials consumption and purchasing, which in turn leads to a reduction in CO_2 emission associated with production (scope 1 CO_2 emission) and logistics (scope 3 CO_2 emission). Based on the above discussion, increased or decreased scope 1, 2 and 3 CO_2 emissions do not impact the performance in implementing resource use practices.

6.3.4 Effects of CO_2 emission variation on environmental innovation practices

Finding 6: The non-significant relationships between scope 1, 2, and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and performance in implementing environmental innovation practices. Specifically, an increase or decrease in scope 1, 2 and 3 CO_2 emissions are not linked to performance in implementing environmental innovation practices.

Environmental innovation practices involve reducing environmental expenses and burden for customers and using innovative environmental technologies and processes or eco-designed products to create new market opportunities. The results suggest that companies with increased or decreased scope 1, 2 and 3 CO_2 emissions cannot improve or worsen their performance in implementing environmental innovation practices. This is probably because reduction in scope 1, 2 and 3 CO_2 emissions cannot be directly achieved by implementing environmental innovation practices, even though they contribute to reducing scope 1, 2 and 3 CO_2 emissions. For example, reducing environmental expenses and burden for customers can be achieved by providing eco-friendly products to them. In this case, consumers will consume fewer materials and produce less waste, thus ultimately reducing scope 1, 2, and 3 CO_2 emissions. Using eco-designed products initially help companies to save on material use and reduce wastes, which in turn contribute to reducing energy consumption, and ultimately leading to CO_2 emissions reduction in the production of new materials (scope 1 CO_2 emissions), in energy use for reducing solid wastes or wastewater (scope 2 CO_2 emissions), and in the transport of purchased materials (scope 3 CO_2 emissions). Therefore, increased or reduced scope 1, 2 and 3 CO_2 emissions do not impact the performance in the implementation of environmental innovation practices.

Therefore, Research Objective 3 and Research Question 3 are addressed in Findings 3 to 6.

6.4 Effects of environmental practices on financial performance

6.4.1 Effects of integrated environmental practices on financial performance

Finding 7: The positive relationships between integrated environmental practices for scope 1, 2 and 3 CO_2 emissions reduction and ROA .

Implementing integrated environmental practices for reducing scope 1, 2 and 3 CO_2 emissions can improve ROA, which indicates that companies perform well in implementing integrated environmental practices of emission reduction, resource use, and environmental innovation practices for scope 1, 2 and 3 CO_2 emission reduction can obtain greater profitability. The findings are consistent with those in previous studies (Brogi & Lagasio, 2019; Ortas et al., 2015; Velte, 2019), which have found that companies with a higher environmental pillar score that reflects their integrated environmental practices are rewarded with higher profitability. Specifically, implementing integrated environmental practices for scope 1, 2 and 3 CO_2 emission reduction is the legitimacy process that reflects companies' capabilities to address environmental issues and respond to the legitimacy threats (i.e., CO_2 emission). The legitimacy obtained from implementing integrated environmental practices can be considered as an operational resource, which helps companies achieve their financial goals (i.e., higher profits). The financial benefits could be attributed to enhanced corporate reputation, improved investor interests, customer loyalty and satisfaction, improved operational efficiency (e.g., resource or energy use efficiency) due to CO_2 emission reduction, reduced costs (e.g., compliance and operational costs), less risk of receiving associated fines, penalties, and liabilities, and reputation damage.

Finding 8: The non-significant relationship between integrated environmental practices for scope 1, 2 and 3 CO_2 emission reduction and Tobin's q.

Although the results show that implementing integrated environmental practices for scope 1, 2 and 3 CO_2 emissions reduction can increase profitability, the results also show that integrated environmental practices (in terms of the environmental pillar score) are not related to Tobin's q, which are in line with previous studies (Abdi et al., 2022; Ahmad et al., 2023; Aydogmus et al., 2022; Gutiérrez-Ponce & Wibowo, 2023). This is because companies may adopt easy-to-implement and cost-effective measures in initial stage, which contribute to large reductions in scope 1, 2 and 3 CO_2 emissions (Hart &

Ahuja, 1996; Rooney, 1993), and save on costs (e.g., compliance costs), thereby improving profitability of firms. However, further reductions in scope 1, 2 and 3 CO_2 emissions require significant environmentally friendly actions-substantial changes in processes or even completely new production technologies (Frosch & Gallopoulos, 1989), which entail substantial environmental investment and expenses, and discourage companies from adopting them. For example, scope 1 CO_2 emission is derived from direct sources, such as the combustion of fossil fuels. For significantly reduce scope 1 CO_2 emission, companies need to invest in cleaner production technologies and related infrastructures and equipment. These environmental practices are reflected in their emission reduction practices (e.g., reducing emission during production process); scope 2 CO_2 emission stems from energy consumption. To significantly reduce scope 2 CO_2 emission, companies need to invest in renewable energy sources to reduce their energy use and CO_2 emissions. These environmental practices are reflected in their resource use practices (e.g., decreasing energy consumption); scope 3 CO_2 emission involves CO_2 emissions across supply or value chain of a company, such as packaging and transport of goods and products. To significantly scope 3 CO_2 emission, companies need to invest in optimizing packaging through eco-design, which will help them lower CO_2 emissions related to material use and waste generation, and reduce packaging size and weight, thus decreasing the fuel used for transport and reducing emitted CO_2 from transporting packaged goods. These environmental practices are reflected in the environmental innovation practices (e.g., using eco-design products). The environmental practices discussed above require substantial environmental investment and expenses, which discourage companies from adopting them. As stated earlier, Tobin's q is a measure of how investors perceive long-term potential of firms to create value (Tobin, 1969) (i.e., generating future profits and sustaining growth), and valuation of the markets of the ability of firms to generate future cash flow (Tobin, 1969). In addition, Tobin's q measures how a robust market perceives a firm in the face of future climate legislation (Delmas et al., 2015). Without more extensive environmental practices that further reduce CO_2 emissions in the long-term within the integrated environmental practices, the market and investors cannot assess capabilities of a company in manage environmental risks or challenges in the long-term. Thus, there is no relationship between integrated environmental practices and Tobin's q in this study.

Integrated environmental practices can improve ROA as opposed to Tobin's q which indicates that companies tend to establish symbolic links with social values for reputational endorsement effects (Ashforth & Gibbs, 1990; Palazzo & Scherer, 2006). Specifically, if companies can lower CO_2 emissions, obtain environmental legitimacy and establish a positive corporate reputation through simple and cost-effective measures within integrated environmental practices, they will not choose to use more demanding environmental practices within integrated environmental practices that require substantial environmental investment and expenses in addressing scope 1, 2 and 3 CO_2 emissions.

6.4.2 Effects of emission reduction practices on financial performance

Finding 9: The positive relationships between the emission reduction practices for scope 1, 2 and 3 CO_2 emission reduction and ROA.

The results indicate that companies that perform well in implementing emission reduction practices for scope 1, 2 and 3 CO_2 emission reduction during the production and operational processes can increase their profits. Similar to integrated environmental practices, companies implement emission reduction practices are engaging in a legitimacy process, which reflect their capabilities in addressing environmental issues and respond to legitimacy threats (e.g., CO_2 emission). The legitimacy gained from implementing emission reduction practices is considered to be an operational resource, to increase profitability.

Finding 10: The non-significant relationship between emission reduction practices for scope 1, 2 and 3 CO_2 emissions reduction and Tobin's q.

The result show that implementing emission reduction practices for scope 1, 2 and 3 CO_2 emissions reduction is not related to Tobin's q. Similar to the explanation for integrated environmental practices, companies may adopt simple and inexpensive measures within emission reduction practices for reducing scope 1, 2 and 3 CO_2 emissions at the initial stage, and thus obtain low hanging fruits-higher profits. But further reductions in scope 1, 2 and 3 CO_2 emissions need significant environmental practices within emission reduction practices that require substantial environmental investments and costs, thus discouraging companies from adopting them. In this case, the market cannot evaluate the abilities and performance of companies that are implementing emission reduction practices to address environmental issues in the long term. Thus, there is no relationship between emission reduction practices and Tobin's q in this study. The results also suggest that companies tend to establish symbolic links with social values for reputational endorsement effects (Ashforth & Gibbs, 1990; Palazzo & Scherer, 2006).

6.4.3 Effects of resource use practices on financial performance

Finding 11: : The non-significant relationship between resource use practices for scope 1, 2 and 3 CO_2 emission reduction and ROA.

Finding 12: The non-significant relationship between resource use practices for scope 1, 2 and 3 CO_2 emission reduction and Tobin's q.

The results show that resource use practices are not related to financial performance in terms of ROA and Tobin's q. This is probably because resource use practices will incur substantial environmental investment and expenses, and is time costly to reduce scope 1, 2 and 3 CO_2 emission. Specifically, reducing materials, energy or water consumption involves substantial environmental investments or expenses, such as establishing a recycling system to facilitate material circulation and reduce materials use, purchasing renewable energy sources to reduce energy consumption, and installing water-saving fixtures to decrease the usage of water. Improving supply chain management to enhance eco-friendly solutions is time costly because it involves five critical phases, including planning, sourcing, manufacturing, distribution and returns (Stavrulaki & Davis, 2010). The complexity of supply chain management increases the challenges of developing eco-friendly solutions and requires a substantial amount of time to see improvements. Thus, companies will not prioritize the implementation of resource use practices individually. In this case, the market cannot separately evaluate the performance of companies in implementing resource use practices. As such, the relationship between resource use practices and Tobin's q is not significant.

6.4.4 Effects of environmental innovation practices on financial performance

Finding 13: The positive relationship between environmental innovation practices for scope 1, 2 and 3 CO_2 emission reduction and ROA.

The results indicate that companies with a good performance in implementing environmental innovation practices are rewarded with more profitability, which aligns with the legitimacy theory. Specifically, implementing environmental innovation practices is a legitimacy process and the legitimacy from implementing environmental innovation practices is regarded as an operational resource of companies, which help companies establish competitive advantages and achieve increased profitability. For example, reducing the environmental expenses and burden for customers can enhance the legitimacy of companies by showing its commitment to sustainability, which contributes to improved corporate reputation, enhanced customer loyalty and satisfaction, and increased sales of products or services, which in turn increase profit. Using innovative environmental technologies and processes or eco-designed products to create new market opportunities can enhance legitimacy by showing its environmental innovation and efforts towards sustainability, which help companies distinguish themselves from their competitors and establish competitive advantages, thus leading to higher profits.

Finding 14: The negative relationship between the environmental innovation practices for scope 1, 2 and 3 CO_2 emission reduction and Tobin's q.

The result suggests that companies that perform well in implementing environmental innovation practices can lower their Tobin's q (i.e., firm value), although the result shows that implementing environmental innovation practices improves ROA. This is probably because companies adopt simple and cost-effective measures within environmental innovation practices to reduce scope 1, 2 and 3 CO_2 emissions for low-hanging fruits benefits. However, further reductions in scope 1, 2 and 3 CO_2 emissions require more significant environmental practices within environmental innovation practices that entail substantial investment and expenditures. Investors may not be optimistic about the future financial returns from implementing environmental innovation practices since they might be concerned about the investment and costs cannot be offset by the long-term gains or a long-term payback time, thus leading to a lower Tobin's q.

Therefore, Findings 7 to 14 achieve Research Objective 4 and address Research Question 4.

6.5 Effects of environmental practices on relationships between CO_2 emission and financial performance

6.5.1 Effects of integrated environmental practices on relationship between CO_2 emission variations and financial performance

Finding 15: Integrated environmental practices have negative mediating effects on the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and ROA.

Finding 16: Integrated environmental practices do not mediate the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and Tobin's q.

The negative mediating effects of integrated environmental practices on the relationships between "$\Delta CO_2 1$ and ROA", "$\Delta CO_2 2$ and ROA", and "$\Delta CO_2 3$ and ROA" indicate that integrated environmental practices are the mechanism that connect scope 1, 2 and 3 CO_2 emissions to ROA. Based on Suchman (1995), this finding implies that integrated environmental practices are a legitimate process/activity that reflects the abilities of a company to address environmental issues. The legitimacy obtained from implementing integrated environmental practices is an operational resource that helps companies increase profitability. However, integrated environmental practices do not mediate the relationships between "$\Delta CO_2 1$ and Tobin's q", "$\Delta CO_2 2$ and Tobin's q", and "$\Delta CO_2 3$ and Tobin's q", thus indicating CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) do not affect Tobin's q through integrated environmental practices.

The findings indicate that in the initial acts of pollution prevention are lots of "low-hanging fruits" (Hart & Ahuja, 1994; Rooney, 1993) within integrated environmental practices (e.g., lowering energy use), which contribute to large reductions in scope 1, 2 and 3 CO_2 emissions relative to the costs involved (Hart & Ahuja, 1994; Rooney, 1993), and help to save costs, thereby increasing profitability (Hart, 1995). However, further reductions in CO_2 emissions necessitates more significant environmental actions (Frosch and Gallopoulos,1989), which entail substantial environmental investments and expenses, thus companies are discouraged in implementing integrated environmental practices further reduce their emitted CO_2. For example, environmental supply chain management within integrated environmental practices require substantial changes in processes since it involves design, acquisition, manufacturing, distribution, use, reuse and disposal of products and services (Zsidisin & Siferd, 2001). As stated earlier, Tobin's q is a measure of how investors perceive the long-term potential of firms to create value, and valuation of the markets of the ability of firms to generate future cash flow (Tobin, 1969). In addition, Tobin's q measures how a robust market perceives a firm in the face of future climate legislation (Delmas et al., 2015). The absence of more significant environmental actions within integrated environmental practices for further CO_2 emission reduction means that the market cannot assess companies' capabilities of a company implementing the integrated environmental practices to manage environmental risks or challenges in the long-term. Thus, integrated environmental practices do not impact the relationship between each scope of CO_2 emission variation and Tobin's' q. Again, the finding also indicates that companies tend to establish symbolic links with social values for reputational endorsement effects (Ashforth & Gibbs, 1990; Palazzo & Scherer, 2006).

6.5.2 Effects of emission reduction practices on relationship between CO_2 emission variations and financial performance

Finding 17: Emission reduction practices have negative mediation effects on the relationships between CO_2 emission variations (i.e., ΔCO_21, ΔCO_22, and ΔCO_23) and ROA.

Finding 18: Emission reduction practices do not mediate the relationships between CO_2 emission variations (i.e., ΔCO_21, ΔCO_22, and ΔCO_23) and Tobin's q.

Emission reduction practices mediate the relationship between "ΔCO_21 and ROA", "ΔCO_22 and ROA", and "ΔCO_23 and ROA", which indicates that emission reduction practices are the mechanism that connect scope 1, 2 and 3 CO_2 emissions to ROA. Similar to integrated environmental practices, emission reduction practices are also a legitimate process/activity that reflects the ability to address environmental issues, and the legitimacy from implementing emission reduction practices is an operational resource that helps companies to establish competitive advantages and increase profitability. However, e emission reduction practices do not mediate the relationships between "ΔCO_21 and Tobin's q", "ΔCO_22 and Tobin's q", and "ΔCO_23 and Tobin's q", which indicates that ΔCO_21, ΔCO_22, and ΔCO_23 do not impact Tobin's q through emission reduction practices.

The findings again suggest that companies implement simple and cost-effective measures in the initial stages of pollution prevention (e.g., reducing CO2 emission) (Hart & Ahuja, 1994; Rooney, 1993) within emission reduction practices (e.g., staff transportation reductions), which largely reduces scope 1, 2 and 3 CO_2 emissions relative to the costs involved (Hart & Ahuja, 1994; Rooney, 1993), and contribute to cost savings, which increase profits (Hart, 1995). However, again, companies that wish to further reduce scope 1, 2 and 3 CO_2 emissions need to take significant environmental actions, such as making substantial changes in processes or even adopting completely new production technologies (Frosch and Gallopoulos,1989), thus requiring substantial environmental investments and expenses, so that companies are discouraged to take significant environmental actions within emission reduction practices to further reduce their emitted CO_2 emission. For example, the reduction of emitted CO_2 from cement production (i.e., emission reduction practices) requires entirely new production technologies, such as carbon capture and storage technologies. As mentioned, Tobin's q reflects firms' long-term potential for creating value and their intangible performance, and market perception on future climate legislation (Delmas et al., 2015). The absence of significant environmental practices within emission reduction practices for further reducing CO_2 emission, the market cannot evaluate firms' abilities and performance in implementing the emission reduction practices on managing environmental risks or challenges in the long-term. Thus, the mediating effect of emission reduction practices cannot be found for the relationships between each scope of CO_2 emission variation and Tobin's' q. Moreover, the findings also suggest that companies tend to establish symbolic links with the social values (i.e., reducing CO_2 emissions) by implementing simple and cost-effective measure within the emission reduction practices for scope 1, 2 and 3 CO_2 emissions reduction to create reputational endorsement effects (Ashforth & Gibbs, 1990; Palazzo & Scherer, 2006).

6.5.3 Effects of resource use practices on relationship between CO_2 emission variations and financial performance

Finding 19: Resource use practices do not mediate the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and ROA. Specifically, resource use practices do not mediate the relationships between "$\Delta CO_2 1$ and ROA", "$\Delta CO_2 2$ and ROA", and "$\Delta CO_2 3$ and ROA".

Finding 20: Resource use practices do not mediate the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and Tobin's q. Specifically, resource use practices do not mediate the relationships between "$\Delta CO_2 1$ and Tobin's q", "$\Delta CO_2 2$ and Tobin's q", and "$\Delta CO_2 3$ and Tobin's q".

The lack of the mediating effects of resource use practices in the relationship between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and ROA probably because implementing resource use practices cannot directly lead to reduction in CO_2 emissions (see *Section 5.3.3*). It is also possible that implementing resource use practices cannot increase profitability or firm value. Thus, companies do not prioritize adopting resource use practices individually for reducing scope 1, 2 and 3 CO_2 emissions.

6.5.4 Effects of environmental innovation practices on relationship between CO_2 emission variations and financial performance

Finding 21: Environmental innovation practices do not mediate the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and ROA. Specifically, environmental innovation practices do not mediate the relationships between “$\Delta CO_2 1$ and ROA”, “$\Delta CO_2 2$ and ROA”, and “$\Delta CO_2 3$ and ROA”.

Finding 22: Environmental innovation practices do not mediate the relationships between CO_2 emission variation (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and Tobin’s q. Specifically, environmental innovation practices do not mediate the relationships between “$\Delta CO_2 1$ and Tobin’s q”, “$\Delta CO_2 2$ and Tobin’s q”, and “$\Delta CO_2 3$ and Tobin’s q”.

Environmental innovation practices do not play mediating roles in the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and ROA. Specifically, the non-significant relationships between each scope of CO_2 emission variation and the environmental innovation practices and implementing environmental innovation practices have positive impact on ROA. The lack of mediation effects of environmental innovation practices probably because of an increase or a decrease in each scope of CO_2 emission cannot affect the performance in implementing environmental innovation practices. This is probably because scope 1, 2 and 3 CO_2 emissions cannot be directly reduced through environmental innovation practices (see details in *Section 5.3.4*).

Moreover, the environmental innovation practices do not mediate the relationships between CO_2 emission variation (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and Tobin’s q. Specifically, an increase or a decrease in each scope of CO_2 emission does not affect performance in implementing environmental innovation practices, and implementing environmental innovation practices lower Tobin’s q. The findings indicate that environmental innovation practices do not have a mediating effect probably because further reducing CO_2 emissions, by implementing more substantial environmental actions (e.g., renewing energy supply) within environmental innovation practices is more costly and requires more capital and technology investment (Hart & Ahuja, 1996), which is the additional financial burden that reduces the financial performance of a firm (Kim et al., 2023) in terms of Tobin's q. Besides, investors may not be optimistic about future financial returns from implementing more significant environmental practices within environmental innovation practices due to the significant investment and expenditures cannot be offset by the long-term gains or payback time, thus leading to a lower Tobin's q. Based on the above discussion, companies do not prioritize adopting significant environmental practices within the environmental innovation practices individually for reducing scope 1, 2 and 3 CO_2 emissions.

Therefore, Findings 15 to 22 achieve Research Objectives 1 and addresses Research Question 1.

Based on *Findings 1to 22*, following explanations are provided on why companies are not motivated to implement more substantial environmental practices to mitigate CO_2 emissions which shows their current efforts in reducing CO_2 emissions are insufficient to reach predefined emission reduction targets.

In terms of integrated environmental practices and emission reduction practices, the sample companies in this study tend to establish symbolic connections with social values (i.e., reducing CO_2 emissions) by implementing simple and cost-effective measures within integrated environmental practices and emission reduction practices for scope 1, 2 and 3 CO_2 emissions reduction to create reputational endorsement effects (Ashforth & Gibbs, 1990; Palazzo & Scherer, 2006), comply with regulations and gain legitimacy. This is because further reductions in CO_2 emissions require them to adopt significant environmental actions, such as using entirely new environmental technologies (low-carbon technologies), which entails significant investment and expenses. The legitimacy from implementing the simple and cost-effective measure within integrated environmental practices and emission reduction practices show their commitments to sustainability, and the legitimacy from implementing integrated environmental practices and emission reduction practices considered to be an operational resource that helps companies establish competitive advantages and reap more profits. If companies implement simple and cost-effective environmental practices can help them reduce CO_2 emissions, meet regulatory requirements, obtain environmental legitimacy, and increase their profitability, they may not be motivated to take significant environmental practices that will incur substantial environmental investments and expenditures in further reducing CO_2 emissions. For resource use practices, the sample companies in this study will not prioritize implementing resource use practices individually to reduce scope 1, 2 and 3 CO_2 emissions probably due to implementing resource use practices can improve neither profitability nor firm value, which do not align with companies' primary business goals of profit maximization. For environmental innovation practices, the sample companies in this study will not prioritize implementing environmental innovation practices individually to reduce scope 1, 2 and 3 CO_2 emissions probably due to scope 1, 2 and 3 CO_2 emissions cannot be directly reduced through environmental innovation practices. Besides, the further costly environmental actions within environmental innovation practices may not guarantee future financial returns of the companies. Based on the above discussion, the financial challenges and the business strategies that prioritize profit maximization are obstacles so that companies are reluctant to from take further action in reducing CO_2 emissions.

Moreover, few financial incentives are available to encourage companies to reduce their CO_2 emissions (Busch et al., 2022) through environmental practices. The absence of such financial incentives creates a situation where companies lack motivation to invest in environmental practices (e.g., resource use practices) that are substantial investment or expenses. They may focus solely on implementing inexpensive and easy-to-implement environmental practices to meet regulatory requirements. This will lead companies to prioritize regulatory compliance and legitimacy over efforts to reduce scope 1, 2 and 3 CO_2 emissions.

Chapter Summary

In Chapter 6, the empirical findings obtained in this study are discussed and summarized. How these research findings meet the research objectives and respond to the research questions are evaluated based on the empirical findings in this study. Table 6-1 summarizes the relationship among the research questions, objectives, and findings. Specifically, *Findings1 and 2* meet *Research Objective 2* and answer *Research Question 2*; *Findings 3 to 6* meet *Research Objective 3* and answer *Research Question 3*; *Findings 7 to 14* meet *Research Objective 4* and answer *Research Question 4*; *Findings 15 to 22* meet *Research Objective 1* and answer *Research Question 1.* In the following chapter, a conclusion is provided which links the research findings to theoretical and managerial implications. In addition, future research directions that pertain to this topic are provided and the research limitations are also outlined.

Table 6-1 Connection among research questions, research objectives and research findings.

Research Question	Research Objective	Research Finding	
Research question 2: What are the performance implications for each scope of CO_2 emission (i.e., scopes 1, 2, and 3)?	Research objective 2: to empirically examine the effects of each scope of CO_2 emission on financial performance.	Finding 1: Negative relationships between scope 1, 2, and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and ROA.	• A negative relationship between $\Delta CO_2 1$ and ROA. In other words, a decrease in scope 1 CO_2 emission enhances ROA. Conversely, an increase in scope 1 CO_2 emission decreases ROA. • A negative relationship between $\Delta CO_2 2$ and ROA. In other words, a decrease in scope 2 CO_2 emission enhances ROA. Conversely, an increase in scope 2 CO_2 emission decreases ROA. • A negative relationship between $\Delta CO_2 3$ and ROA. In other words, a decrease in scope 3 CO_2 emission enhances ROA. Conversely, an increase in scope 3 CO_2 emission decreases ROA.
		Finding 2: Non-significant relationships between scope 1, 2, and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and Tobin's q.	• A non-significant relationship between $\Delta CO_2 1$ and Tobin's q. In other words, an increase or a decrease in scope 1 CO_2 emission are not related to Tobin's q. • A non-significant relationship between $\Delta CO_2 2$ and Tobin's q. In other words, an increase or a decrease in scope 2 CO_2 emission are not related to Tobin's q.

			• A non-significant relationship between $\Delta CO_2 3$ and Tobin's q. In other words, an increase or a decrease in scope 3 CO_2 emission are not related to Tobin's q.
Research question 3: What are the effects of each scope of CO_2 emission (i.e., scopes 1, 2, and 3) on integrated environmental practices and their individual environmental practices (i.e., emission reduction, resource use, and environmental innovation)?	Research objective 3: to empirically examine the effects of each scope of CO_2 emissions on integrated environmental practices and their individual environmental practices (i.e., emission reduction, resource use, and environmental innovation).	Finding 3: Negative relationships between scope 1, 2, and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and performance in implementing integrated environmental practices.	• A negative relationship between $\Delta CO_2 1$ and performance in implementing integrated environmental practices. Specifically, a decrease in scope 1 CO_2 emission enhances performance in implementing integrated environmental practices. Conversely, an increase in scope 1 CO_2 emission decreases performance in implementing integrated environmental practices • A negative relationship between $\Delta CO_2 2$ and performance in implementing the integrated environmental practices. Specifically, a decrease in scope 2 CO_2 emission enhances performance in implementing integrated environmental practices. Conversely, an increase in scope 2 CO_2 emission decreases performance in implementing integrated environmental practices • A negative relationship between $\Delta CO_2 3$ and performance in implementing integrated environmental practices. Specifically, a

			decrease in scope 3 CO_2 emission enhances performance in implementing integrated environmental practices. Conversely, an increase in scope 3 CO_2 emission decreases performance in implementing integrated environmental practices.
		Finding 4: Negative relationships between scope 1, 2, and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and performance in implementing emission reduction practices.	• A negative relationship between $\Delta CO_2 1$ and performance in implementing emission reduction practices. Specifically, a decrease in scope 1 CO_2 emission improves the performance in implementing emission reduction practices. Conversely, an increase in scope 1 CO_2 emission lowers performance in implementing emission reduction practices. • A negative relationship between $\Delta CO_2 2$ and performance in implementing emission reduction practices. Specifically, a decrease in scope 2 CO_2 emission improves the performance in implementing emission reduction practices. Conversely, an increase in scope 2 CO_2 emission lowers performance in implementing emission reduction practices. • A negative relationship between $\Delta CO_2 3$ and performance in implementing emission reduction practices. Specifically, a decrease in scope 3 CO_2 emission improves the

			performance in implementing emission reduction practices. Conversely, an increase in scope 3 CO_2 emission lowers performance in implementing emission reduction practices.
		Finding 5: Insignificant relationships between scope 1, 2, and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and performance in implementing resource use practices.	• A non-significant relationship between $\Delta CO_2 1$ and performance in implementing resource use practices. Specifically, an increase or a decrease in scope 1 CO_2 emissions are not associated with performance in implementing resource use practices. • A non-significant relationship between $\Delta CO_2 2$ and performance in implementing resource use practices. Specifically, an increase or a decrease in scope 2 CO_2 emissions are not associated with performance in implementing resource use practices. • A non-significant relationship between $\Delta CO_2 3$ and performance in implementing resource use practices. Specifically, an increase or a decrease in scope 3 CO_2 emissions are not associated with performance in implementing resource use practices.
		Finding 6: Non-significant relationships between scope 1, 2, and 3 CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and performance in implementing environmental innovation practices.	• A non-significant relationship between $\Delta CO_2 1$ and performance in implementing environmental innovation practices. Specifically, an increase or a decrease in scope 1 CO_2 emissions are not linked to

			performance in implementing environmental innovation practices. • A non-significant relationship between $\Delta CO_2 2$ and performance in implementing environmental innovation practices. Specifically, an increase or a decrease in scope 2 CO_2 emissions are not linked to the performance in implementing environmental innovation practices. • A non-significant relationship between $\Delta CO_2 3$ and performance in implementing environmental innovation practices. Specifically, an increase or a decrease in scope 3 CO_2 emissions are not linked to performance in implementing environmental innovation practices.
Research question 4: What are the performance implications for integrated environmental practices and their individual practices (i.e., emission reduction, resource use, and environmental innovation)?	Research objective 4: to empirically examine the impacts of integrated environmental practices and their individual environmental practices (i.e., emission reduction, resource use, and environmental innovation) on financial performance in terms of ROA and Tobin's q.	• Finding 7: A positive relationship between integrated environmental practices for scope 1, 2 and 3 CO_2 emission reduction and ROA . • Finding 8: A non-significant relationship between the integrated environmental practices for scope 1, 2 and 3 CO_2 emission reduction and Tobin's q. • Finding 9: A positive relationship between the emission reduction practices for scope 1, 2 and 3 CO_2 emission reduction and ROA. • Finding 10: A non-significant relationship between the emission reduction practices for scope 1, 2 and 3 CO_2 emission reduction and Tobin's q • Finding 11: A non-significant relationship between the resource use practices for scope 1, 2 and 3 CO_2 emission reduction and ROA. • Finding 12: A non-significant relationship between the resource use practices for scope 1, 2 and 3 CO_2 emission reduction and Tobin's q. • Finding 13: A positive relationship between environmental innovation practices for scope 1, 2 and 3 CO_2 emission reduction and ROA.	

		• Finding 14: A negative relationship between the environmental innovation practices for scope 1, 2 and 3 CO_2 emission reduction and Tobin's q.	
Research question 1: Do integrated environmental practices in terms of emission reduction, resource use, and environmental innovation, and their individual environmental practices (i.e., emission reduction, resource use, and environmental innovation practices) act as mediators in the relationships between each scope of CO_2 emission (i.e., Scopes 1, 2, and 3) and financial performance?	Research objective 1: to empirically explore whether environmental practices (i.e., integrated environmental practices and their individual environmental practices) play mediating roles in the relationships between each scope of CO_2 emissions (i.e., scope 1, 2, and 3) and financial performance.	Finding 15: Integrated environmental practices have negative mediating effects on the relationships between CO_2 emission variations (i.e., ΔCO_21, ΔCO_22, and ΔCO_23) and ROA.	• Integrated environmental practices have negative mediating effects on the relationship between ΔCO_21 and ROA • Integrated environmental practices have negative mediating effects on the relationship between ΔCO_22 and ROA • Integrated environmental practices have negative mediating effects on the relationship between ΔCO_23 and ROA
		Finding 16: Integrated environmental practices do not mediate the relationships between CO_2 emission variations (i.e., ΔCO_21, ΔCO_22, and ΔCO_23) and Tobin's q.	• Integrated environmental practices do not mediate the relationship between ΔCO_21 and Tobin's q • Integrated environmental practices do not mediate the relationship between ΔCO_22 and Tobin's q • Integrated environmental practices do not mediate the relationship between ΔCO_23 and Tobin's q
		Finding 17: Emission reduction practices have negative mediating effects on the relationships between CO_2 emission variations (i.e., ΔCO_21, ΔCO_22, and ΔCO_23) and ROA.	• Emission reduction practices have negative mediating effect on the relationship between ΔCO_21 and ROA • Emission reduction practices have negative mediating effect on the relationship between ΔCO_22 and ROA • Emission reduction practices have negative mediating effect on the relationships between ΔCO_23 and ROA

		Finding 18: Emission reduction practices do not mediate the relationships between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and Tobin's q.	• Emission reduction practices do not mediate the relationship between $\Delta CO_2 1$ and Tobin's q • Emission reduction practices do not mediate the relationship between $\Delta CO_2 2$ and Tobin's q • Emission reduction practices do not mediate the relationship between $\Delta CO_2 3$ and Tobin's q
		Finding 19: Resource use practices do not mediate the relationships between CO_2 emission variation (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and ROA.	• Resource use practices do not mediate the relationship between $\Delta CO_2 1$ and ROA • Resource use practices do not mediate the relationship between $\Delta CO_2 2$ and ROA • Resource use practices do not mediate the relationship between $\Delta CO_2 3$ and ROA
		Finding 20: Resource use practices do not mediate the relationships between CO_2 emission variation (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and Tobin's q.	• Resource use practices do not mediate the relationship between $\Delta CO_2 1$ and Tobin's q • Resource use practices do not mediate the relationship between $\Delta CO_2 2$ and Tobin's • Resource use practices do not mediate the relationship between $\Delta CO_2 3$ and Tobin's q
		Finding 21: Environmental innovation practices do not mediate the relationships	• Environmental innovation practices do not mediate the relationship between $\Delta CO_2 1$ and ROA

		between CO_2 emission variations (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and ROA.	• Environmental innovation practices do not mediate the relationship between $\Delta CO_2 2$ and ROA • Environmental innovation practices do not mediate the relationship between $\Delta CO_2 3$ and ROA
		Finding 22: Environmental innovation practices do not mediate the relationships between CO_2 emission variation (i.e., $\Delta CO_2 1$, $\Delta CO_2 2$, and $\Delta CO_2 3$) and Tobin's q.	• Environmental innovation practices do not mediate the relationship between $\Delta CO_2 1$ and Tobin's q • Environmental innovation practices do not mediate the relationship between $\Delta CO_2 2$ and Tobin's q • Environmental innovation practices do not mediate the relationship between $\Delta CO_2 3$ and Tobin's q

Chapter 7 Conclusions

7.1 Introduction

In this chapter, the findings from Chapter 6 are outlined to provide the grounds for the academic and managerial implications, propose future research directions, discuss the research limitations, and conclude this study.

7.2 Academic implications

Firstly, as stated in Chapter 1, the primary objective of this study is to provide empirical evidence to explain the inconsistent findings on the relationship between CO_2 emissions and financial performance in the existing literature. To elucidate the mixed findings, this study has identified environmental practices, including integrated environmental practices and their individual practices-emission reduction, resource use, and environmental innovation practices as potential mediators. Whether these environmental practices affect the relationships between scopes 1, 2 and 3 CO_2 emission variations (i.e., increase or decrease) and financial performance in terms of ROA and Tobin's q are examined. Consistent with the legitimacy theory, the results show that both integrated environmental practices and emission reduction practices negatively mediated the relationship between each scope of CO_2 emission variation and ROA. The results indicate companies with reduced CO_2 emissions can improve their performance of implementing integrated environmental practices and emission reduction practices, which in turn improve ROA (i.e., profit). The findings align with the legitimacy theory and indicate companies implementing both integrated environmental practices and emission reduction practices take part in legitimacy process/activity (Suchman, 1995), which reflect their capabilities in addressing environmental issues related to the reduction of CO_2 emissions. The legitimacy from implementing integrated environmental practices and emission reduction practices serves as operational resources that help companies achieve higher profits (Suchman, 1995). The findings also indicate that financial benefits could be also gained from improving environmental practices (Buallay, 2019) (i.e., integrated environmental practices and emission reduction practices) for scope 1, 2 and 3 CO_2 emission reduction.

The results advance to the legitimacy theory by positioning legitimacy (implementing integrated environmental practices and emission reduction practices) as profit-generating resources rather than the passive survival strategy.

Secondly, although both integrated environmental practices and emission reduction practices negatively mediated the relationship between each scope of CO_2 emission variation and ROA, they do not mediate the relationship between each scope of CO_2 emission variation and Tobin's q. The results indicate that initial acts of reducing CO_2 emission are lots of "low-hanging fruits, which can help companies obtain legitimacy and increase profits. But further CO_2 emissions reductions require significant environmental actions and substantial environmental investments and expenses, discouraging firms implementing integrated environmental practices and emission reduction practices and limiting further CO_2 reductions (See details in *Section 6.2*). Without more significant environmental actions, the market cannot assess companies' long-term capabilities of implementing both practices to manage environmental risks or challenges. If companies implement simple and cost-effective environmental practices that can help them reduce CO_2 emissions, obtain legitimacy, and increase profitability, they may not be motivated to take significant environmental practices that will incur substantial environmental investments and expenditures in further reducing their CO_2 emissions. The results also indicate that the sample companies in this study tend to establish symbolic connections with social values (i.e., reducing CO2 emissions) by implementing simple and cost-effective measures within integrated environmental practices and emission reduction practices for scope 1, 2 and 3 CO_2 emissions reduction to create reputational endorsement effects (Ashforth & Gibbs, 1990; Palazzo & Scherer, 2006). The results advance to the legitimacy theory by suggesting that companies establish symbolic links with social values (i.e., symbolic legitimacy) can coexist with profits but not firm value.

Thirdly, the results show that each scope of CO_2 emission variation does not affect financial performance in terms of ROA and Tobin's q through resource use practices and environmental innovation practices. This can be explain by the following reasons: i) resource use practices and environmental innovation practices do not directly reduce scopes 1, 2 and 3 CO_2 emissions (see details in *Section 6.3.3-6.3.4*), although these practices may contribute to sustainability; ii) companies do not prioritize implementing resource use practices individually due to high environmental investment or expenses, time costly or the uncertain long-term returns (see *Section 6.4.3-6.4.4*), which will have adverse impact on financial performance; and iii) companies implement resource use practices and environmental innovation practices and consider them as legitimate seeking tools without reducing actual CO_2 emissions across scopes. This can be explained by the legitimacy theory that companies tend to establish symbolic links with social values for reputational endorsement effects (Ashforth & Gibbs, 1990; Palazzo & Scherer, 2006), rather than making substantive environmental changes.

Fourthly, among the three types of individual environmental practices, including emission reduction practices, resource use practices, and environmental innovation practices, emission reduction practices are demonstrated to be the most effective environmental practices through which each scope of CO_2 emission variation affects ROA. This is probably because the emission reduction practices can lead to a visible and direct reduction in scopes 1, 2, and 3 CO_2 emissions, which makes it easier for stakeholders to observe and assess their effectiveness compared to resource use practices and environmental innovation practices. Thus, companies implementing emission reduction practices are considered by stakeholders to have capabilities of effectively managing their scopes 1, 2, and 3 CO_2 emissions and complying with environmental regulations, which align closely with the environmental concerns of stakeholders and regulatory expectations. This can enhance the firm's legitimacy, reduce compliance costs and potential risks (e.g., penalties or legal liabilities), thus leading to better financial performance in terms of ROA.

Fifthly, from the methodology perspective, this study examines firms that implement carbon credit/offset practices as the sample firms that participate in reducing scope 1, 2, and 3 CO_2 emissions. By doing so, the specific barriers or challenges that these companies faced during CO_2 emission reduction are determined, which provides researchers with more nuanced perspectives and offer guidance to companies that are not engaged in CO_2 emissions reduction but would consider doing so in the future. The use of casual step approach and the bootstrapping method facilitate an examination into the research inquiries on whether integrated environmental practices and their individual practices are found as mediating factors in the relationship between scope 1, 2, and 3 CO_2 emissions variation and financial performance (i.e., ROA and Tobin's q). In addition, this study investigates the environmental scores reflecting different environmental practices, which measure companies' performance in implementing different environmental practices. Using these scores provide greater credibility and utility compared to those that focus solely on the extent of disclosure of environmental information. The former reflect companies' genuine efforts in reducing scope 1, 2, and 3 CO_2 emissions, which increases companies' legitimacy by demonstrating their tangible actions rather than simply providing environmental information.

7.3 Managerial implications

Based on the findings in this study, the following suggestions are proposed for companies.

Firstly, companies not only contribute to CO_2 emissions, but also play a pivotal role in mitigating them. Thus, companies could consider integrated environmental practices and emission reduction practices as the legitimacy processes/activities that reflect their capabilities to address CO_2 emissions. Moreover, companies could view the legitimacy gained from implementing integrated environmental practices and emission reduction practices as operational resources of the company, which contribute to establishing competitive advantages to increase their profits. Furthermore, companies could incorporate integrated environmental practices and emission reduction practices into their strategic plans and prioritize the implementation of integrated environmental practices and emission reduction practices to reduce their scope 1, 2, and 3 CO_2 emissions. As discussed in Chapter 6, integrated environmental practices and emission reduction practices for each scope of CO_2 emission reduction can improve ROA rather than Tobin's q, since firms' strategy prioritize profitability and they face financial challenges (i.e., substantial investments and expenses in implementing the significant environmental practices within the integrated environmental practices and emission reduction practices). Thus, policymakers could develop target environmental regulations for reducing scopes 1, 2, and 3 CO_2 emission by considering integrated environmental practices and emission reduction practices and distinguishing the extent of implementing both integrated environmental practices and emission reduction practices (i.e., simple and inexpensive environmental actions or significant environmental actions).

Secondly, among the three types of individual environmental practices (i.e., emission reduction, resource use and environmental innovation practices) for each scope of CO_2 emission reduction, companies should prioritize the emission reduction practices. Since emission reduction practices directly measure companies' effectiveness in reducing CO_2 emission during production and operational processes, which is the direct way of evaluating whether business activities are legitimate, comply with environmental standards, and align with environmental concerns and expectations of stakeholders compared to resource use and environmental innovation practices.

Thirdly, although the results show that integrated environment practices, emission reduction practices, and environmental innovation practices for CO_2 emission reduction can increase profitability, none of the environment practices examined in this study improve Tobin's q. Tobin's q is a measure of how investors perceive the long-term potential of firms to create value, and valuation of the markets of the ability of firms to generate future cash flow (Tobin, 1969). Climate change and CO_2 emissions are the two of the greatest challenges in the 21st century (Busch et al., 2022) that require ongoing attention as long as products are being produced, and energy is being consumed. Thus, it is advisable for managers to adopt a long-term perspective to tackle the environmental issues related to CO_2 emissions. In other words, companies should not solely tend to establish symbolic links with social values for reputational endorsement effects but make substantive environmental changes. By doing so, companies can cultivate competitive advantages that distinguish them from other competitors in their sector. Besides, government and non-government organizations are encouraged to provide financial incentives (e.g., subsidies, tax breaks) to support companies to adopt the environmental practices examined in this study to tackle environmental challenges, which could contribute to achieving the emission reduction target of limiting the global average temperature within 1.5°C. Aside from the above discussions, companies should strengthen their environmental risk management process to minimize potential environmental risks in advance, which contributes to reducing compliance costs, penalties, and fines, and ultimately translates into a better financial performance.

7.4 Research limitations

Every study has limitations, and this study is no exception. Firstly, the theoretical framework of this study includes three independent variables, four mediating variables, and two dependent variables. However, the moderating factors that may affect the relationships among CO_2 emission, environmental practices, and financial performance are not examined.

Secondly, this study uses panel data with observations over time for a number of companies. Although this study examines the lagged effects of the relationship among CO_2 emission (at year t-1), environmental practices (at year t), and financial performance (at year t), the effects of CO_2 emission (at year t-1) and environmental practices (at year t) on financial performance in subsequent years (e.g., at year t+1, t+2) are not investigated. The investigation is important since it helps companies better understand their financial implications of their environmental strategies, optimize their environmental practices and manage risks over time, and make more informed decisions to support their environmental goal and financial stability.

Thirdly, although this study adds four control variables to the econometric models for robustness check, it is possible that there are other factors affecting the relationships among CO_2 emission, environmental practices, and financial performance, causing the results to remain affected by the omitted variables.

Fourthly, the sample of this study includes companies that operate in different industries and sectors worldwide, but managers are not provided with empirical evidence and there are no customized managerial insights for the specific industries and sectors on the relationship among CO_2 emission, environmental practices，and financial performance.

7.5 Future research directions

This study proposes future research directions as follows:

Firstly, CO_2 emission is not only associated with companies' environmental practices, but it is also associated with companies' governance practices and social practices. Specifically, governance practices, such as executive compensation is important to investigate, since firms' costly investments are unlikely to be realized without the proactive engagement of influential executive management (Haque & Ntim, 2020); social practices, such as investing in employee commute alternatives is critical to investigate, as a significant portion of CO_2 emissions comes from commuting by car (Noussan & Jarre, 2021). Besides, environmental, social, and governance are commonly adopted indicators to assess companies' sustainability performance and risk profiles in the existing literature (Miralles-Quiros et al., 2019). This study lays grounds for future research to explore governance and social practices, and thus future studies could explore the role of governance practices and social practices in the relationship between CO_2 emissions and financial performance to explain the mixed findings in this relationship.

Secondly, this study provides insights into the performance implications of implementing integrated environmental practices and individual environmental practices (e.g., emission reduction, resource use and environmental innovation practices) for scope 1, 2, and 3 CO_2 emissions reduction. This lays grounds for future studies to explore other practices. For example, previous studies indicate that adopting circular economy (CE) practices can lead to significant economic benefits at the global, national, and household levels while supporting the achievement of net-zero emissions (Ferreira Gregorio et al., 2018; Mawutor et al., 2023). Thus, future studies could investigate CE practices (e.g., "10R"- refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle and recover) (Kirchherr et al., 2017), and investigate the performance implications of these practices for each scope of CO_2 emission reduction in different industries or sectors. The investigation is important since it connects the global emission reduction targets with the circular economy that relies on the circular business model that facilitates sustainability, resource efficiency, and economic development. Understanding the relationships between CO_2 emission, CE practices, and financial performance can help companies identify effective and target strategies to address their scope 1, 2 and 3 CO_2 emissions, aiding to achieve global emission reduction target within 1.5°C.

Thirdly, future research could examine the moderating factors that affect the relationships among CO_2 emission, environmental practices, and financial performance, such as environmentally sensitive industries (Yoon & Jeong, 2016) and CEO power (Li et al., 2018), which could provide us with more nuanced perspectives to understand the relationships among CO_2 emission, environmental practices, and financial performance.

Fourthly, future studies could examine the effects of CO_2 emission (at year t-1) and environmental practices (at year t) on financial performance in subsequent years (e.g., at year t+1, t+2).

Fifthly, it is necessary for future studies to investigate the relationship among CO_2 emission, environmental practices, and financial performance within specific industries or geographies, which contribute to improving the understanding of these relationships within specific sectors or environmental policy in specific geographic locations, as well as providing managers with managerial insights tailored to their industry and region.

7.6 Concluding remarks

The primary objective of this study is to examine whether integrated environmental practices and their individual practices (i.e., emission reduction, resource use, and environmental innovation) act as mediators on the relationships between each scope of CO_2 emission variation (i.e., scope 1, 2 and 3) and financial performance in terms of ROA and Tobin's q. The finding shows that integrated environmental practices and emission reduction practices play mediating roles in the relationships between scope 1, 2, and 3 CO_2 emission variation and ROA, which is consistent with the legitimacy theory. Companies should consider integrated environmental practices and emission reduction practices as legitimacy processes/activity that reflect the abilities of firms to address CO_2 emissions and operational resources of the companies that help them to increase profitability. Moreover, companies should not solely focus on simple and inexpensive measures within integrated environmental practices and emission reduction practices to reduce CO_2 emissions, obtain environmental legitimacy and increase profitability. They should also pay attention to significant environmental practices within integrated environmental practices and emission reduction practices for substantial reduction in scope 1, 2, and 3 CO_2 emissions. Investors may view the significant environmental actions of companies as having the capability to address environmental issues and risk profiles. Policymakers should develop target environmental regulations by distinguishing the extent of implementation of integrated environmental practices and emission reduction practices. Government and non-government organizations could consider offering financial incentives to support companies implementing environmental practices examined in this study.

These findings are useful to researchers, managers and policy makers who strive to understand the relationship among CO_2 emissions, environmental practices and financial performance. It is anticipated that this study will inspire future investigations to examine social or governance practices that help to address scope 1, 2, and 3 CO_2 emissions to achieve the emission reduction target of limiting the global average temperature increase to within 1.5°C.

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Appendix

Metrics for calculating the category scores in terms of emission reduction score, resource use score and environmental innovation score.

Emission reduction score (28 metrics)	**Resource Use score (20 metrics)**	**Environmental innovation score (20 metrics)**
Analytic Accidental Spills	Cement Energy Use	Agrochemical Products
Biodiversity Impact Reduction	Analytic Energy Use	Analytic Environmental Research and Development
Cement CO_2 Emission	Environmental Supply Chain Termination	Environmental AUM (Assets Under Management)
Climate Change Risks Opportunities	Environmental Management Team	Environmental Products
Analytic CO_2 Indirect Scope3	Environmental Materials Sourcing	Analytic Environmental Project Financing
Analytic Discharge Water System	Environmental Supply Chain Management	Fleet CO_2 Emissions
Emissions Trading	Environmental Supply Chain Monitoring	Fleet Fuel Consumption
EMS Certified Percentage	Green Buildings	Fossil Fuel Investment Policy
Analytic Environmental Expenditures	Land Environmental Impact Reduction	Hybrid Vehicles
Environmental Partnerships	Policy Energy Efficiency	Labeled Wood Percentage
Environmental Restoration Initiatives	Policy Environmental Supply Chain	Noise Reduction
Waste Reduction	Policy Sustainable Packaging	Nuclear Production
Analytic Flaring Gases	Policy Water Efficiency	Organic Products Initiatives
Analytic Hazardous Waste	Analytic Renewable Energy Use	Analytic Product Impact Minimum

Internal Carbon Price Tonne	Targets Energy Efficiency	Real Estate Sustainability Certification
NOxSOxEmissions Reduction	Targets Water Efficiency	Analytic Renew Energy Supply
Analytic NOxEmissions	Analytic Total Renewable Energy	Clean Energy Products
Analytic Ozone Depleting Substances	Toxic Chemicals Reduction	Revenue Environmental Products
Policy Emissions	Water Recycled	Sustainable Building Products
Analytic Self-Reported Environmental Fines	Analytic Water Use	Water Technologies
Analytic SOxEmissions		
Staff Transportation Reduction		
Targets Emissions		
Analytic CO_2		
Analytic Total Waste		
Analytic VOC Emissions		
Analytic VOC or PM Reduction		
Analytic Waste Recycling Ratio		

Note: The metrics for calculating emission reduction score, resource use score and environmental innovation score is provided by Refinitiv Eikon