UNIVERSITI TEKNOLOGI MARA

CARBON MARKET, GREEN TECHNOLOGY INNOVATION AND COMPANY PERFORMANCE IN CHINA

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Thesis submitted in fulfilment
of the requirements for the degree of
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ABSTRACT

China recently established a carbon trading market representing an efficient, market-driven environmental regulatory approach to mitigate Carbon Dioxide (CO_2) emissions. This study builds on China's emerging carbon trading market by utilizing innovation theory and Porter's hypothesis. It examines how carbon market mechanisms, including carbon finance, carbon price, and carbon trading policy, affect various aspects of company performance (economic and sustainability performance). It also considers the moderating role of green technology innovation, and the results are extended to China's carbon market prospects. A mixed research approach was employed in this study. Quantitatively, Difference-in-Differences (DID) and regression models assessed impacts on eight industries from heavy-polluting sectors across various provinces, comparing 2010-2022 data between trading and non-trading pilot companies. The quantitative findings exemplify the controversial nature of market-based environmental regulation (carbon market mechanisms) and Porter's hypothesis. The variability in results is mainly due to limitations observed in the initial pilot programs, including low carbon price and inadequate market liquidity. The national carbon market, launched in 2021, is still in its early stages, making it challenging to evaluate its long-term impacts. The quantitative research presents mixed findings on the relationship between the carbon market mechanisms, green technology innovation, and company performance. This study reveals that carbon finance, carbon price, and carbon trading policy all positively impact company performance, with green technology innovation further enhancing these relationships by significantly improving both economic and sustainable performance metrics. Qualitatively, semi-structured interviews were thematically analysed to outline opportunities and challenges as the mechanism evolves. Moreover, qualitative research has respectively analysed the political, economic, social, technological, legal, and environmental benefits, as well as the challenges, such as policy compliance costs, financing constraints, and low levels of green technology innovation, of carbon trading pilot companies and non-carbon trading pilot companies. The results of the qualitative analysis provide a multi-dimensional analysis of the development of China's carbon market, providing a comprehensive view of carbon trading pilot and non-pilot companies. The holistic research approach is essential for governments, companies, and society. This will assist government departments in strengthening the carbon market mechanisms, guiding companies to reduce emissions, establishing a sound monitoring and reporting system, and standardizing the behaviour of heavy polluters. Furthermore, it encourages businesses to invest in green technology and engage in carbon trading. This participation will be essential to transitioning the whole economic system to a low-carbon economy and successfully achieving the dual-carbon strategy goals.

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LIST OF ABBREVIATIONS

Abbreviations

EPI	Environmental Performance Index
IEA	International Energy Agency
ER	Environmental Regulation
ETS	Carbon Emission Trading System
ETSs	Emission Trading Schemes
NEPA	National Environmental Protection Agency
MRV	Measuring, Reporting, and Verifying
EU CETS	EU Carbon Emissions Trading System
EU-ETS	European Union Emissions Trading System
RGGI	Regional Greenhouse Gas Reduction Initiative
CCAT	California Cap-and-Trade Program
ACPS	Australian Carbon Price System
Tokyo-CAT	Tokyo Metropolitan Total Control and Trading Scheme
NZ ETS	New Zealand Carbon Trading System
CDM	Clean Development Mechanism
CETN	China Carbon Emissions Trading Network
JI	Joint Implementation
GSP	Generalized System of Carbon Preferences

OECD	Organization for Economic Co-operation and Development
ESG	Environmental Social Governance
NAP	National Allowance Plan
MSR	Market Stability Reserve
CET	Carbon Emission Trading
GTI	Green Technology Innovation
TFP	Total Factor Productivity
GTFP	Green Total Factor Productivity
R&D	Research and Development
EP	Environmental Performance
GF	Green Finance
CSR	Company’s Social Responsibility
SDGs	Sustainable Development Goals
PLSR	Partial Least Squares Regression
VAR	Vector Auto Regression
OECD	Organization for Economic Co-operation and Development
ICP	Internal Carbon Price
ERU	Emission Reduction Unit
AAU	Assigned Amount Unit
CCER	China Certified Voluntary Emission Reduction
DID	Difference in Difference

PSM	Propensity Score Matching
PSM-DID	Propensity Score Matching- Difference in Difference
DDD	Difference-in-Difference-in-Difference
CETP	Carbon Emission Trading Pilot
CCADs	China Carbon Accounting Database
GPRD	Green Patent Research Database
CNRDS	China Research Data Service Platform
WACC	Weighted Average Cost of Capital
IPCC	Intergovernmental Panel on Climate Change
CRC	Computer Resource Centre
QDA	Qualitative Data Analysis
CAQDAS	Computer-Assisted Qualitative Data Analysis Software
IID	Independent and Identically Distributed
NDRC	China's National Development and Reform Commission
CUFE	Central University of Finance and Economics
CEADs	China Carbon Accounting Database
MOST	Ministry of Science and Technology
ROA	Return on Assets
ROE	Return on Equity

CHAPTER 1

INTRODUCTION

1.1 Introduction

China is the world's leading country in Carbon Dioxide (CO_2) emissions and has adopted a proactive policy focused on developing a low-carbon economy and achieving its dual-carbon goals. Based on this background, the research question has been defined in terms of the problem statement, research gaps relevant to previous studies, and specific research questions and objectives. The significance of this research, its contributions, and its scope are clearly defined. This section also features an outline of the overall structure of the research work.

1.2 Research Background

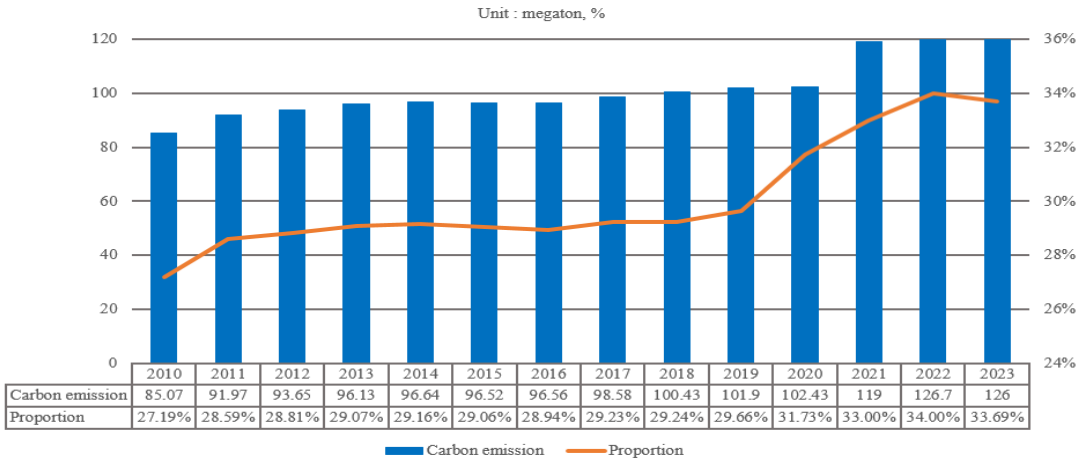
China's economy has experienced rapid growth since implementing reform and opening up policy when the socialist market economic system was established. It saw rapid growth for over four consecutive decades until it became the second-largest economy in the world in 2010. In particular, its Gross Domestic Product (GDP) increased from 368 billion yuan in 1978, accounting for 1.73% of the world's share, to 126,058.2 billion yuan in 2023, accounting for more than 17% of the global economy (China Economic Situation Report, 2023). Accordingly, it has created a miracle of economic growth and contributed greatly to the world economy.

Although the economy is growing rapidly, the issue of environmental pollution is becoming increasingly significant. On the one hand, China has adopted a crude approach to economic development, investing heavily in resources and relying on energy to develop its economy (Cheng et al., 2021). On the other hand, China has a low level of environmental consciousness. In the past, it was mainly concerned with solving the problem of food and clothing and achieving production. Thus, rapid economic recovery and development are necessary to meet basic needs for food, clothing, shelter, and transport, thus placing heavy emphasis on economic development at the expense of

environmental protection (Zhang, 2021).

Despite its economic progress, China ranks among the lowest in global environmental performance, placing 160th in the 2022 Global Environmental Performance Index (EPI). The country has consistently been among the top carbon emitters globally, with its CO_2 emissions rising annually (Carbon Emissions Trading Network, 2022). Among environmental pollution, the issue of greenhouse gas emissions, especially CO_2, which causes global warming, has received much attention.

Carbon Brief aggregated data suggesting the top ten countries in terms of cumulative global CO_2 emissions between 1850 and 2023, including the United States (US), China, Russia, Brazil, Indonesia, Germany, India, the United Kingdom (UK), Japan, and Canada, making up the top ten. As to the CO_2 Emissions Report 2023 released by the International Energy Agency (IEA), China's CO_2 emissions and global percentage of CO_2 emissions steadily rise each year (Figure 1.1). China's total CO_2 emissions reached 312.0 billion tonnes, accounting for 12% of worldwide emissions and contributing to a global temperature increase of about 0.1 degrees Celsius. These emissions have more than tripled since 2000. China now accounts for about a quarter of global emissions annually, surpassing the US as the world's top emitter, as detailed by Global real-time carbon data (2023). Table 1.1 displays global per capita CO_2 emissions, significantly greater than the global per capita emissions in 2023, at 4.675 tonnes worldwide and 7.8 tonnes in China (International Energy Agency, 2023).



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Carbon emission	85.07	91.97	93.65	96.13	96.64	96.52	96.56	98.58	100.43	101.9	102.43	119	126.7	126
Proportion	27.19%	28.59%	28.81%	29.07%	29.16%	29.06%	28.94%	29.23%	29.24%	29.66%	31.73%	33.00%	34.00%	33.69%

Figure 1.1 Carbon Emissions in China and Their Global Share from 2010 to 2023 (Unit: Billion Tons)

Source: Global real-time carbon data, 2023

Table 1.1

Global Per Capita CO_2 Emissions in 2023

	Country	Per Capita CO_2 Emissions (tons)	Total Emissions (billion tons)	Population (billion)
		4.675 tons per person in the world		
1	China	about 7.8	11.0	1.41
2	United States	about 15	5.0	0.335
3	India	about 2.3	3.3	1.438
4	Russia	about 13.9	2.0	0.144
5	Indonesia	about 7.1	2.0	0.281
6	Brazil	about 9	1.9	0.211
7	Japan	about 9.6	1.2	0.125
8	Germany	about 9	0.75	0.083
9	South Korea	about 12.6	0.65	0.052
10	Canada	about 14.9	0.6	0.04

Source: International Energy Agency, 2023

China’s economic development continues to be a primary concern as a growing nation. Economic growth will result in higher energy use and carbon emissions, putting China under intense pressure to reduce CO_2 emissions (Green & Stern, 2017). Furthermore, the ongoing development of global greenhouse gas emissions has exacerbated environmental challenges, and the need to build a low-carbon economy centered on energy conservation and reducing emissions has increased significantly (Zhu et al., 2019). The economic progress of China is directly opposed to the issue of environmental degradation. Hence, how to rationally choose the CO_2 emission reduction path to achieve a win-win situation for economic growth and carbon emission reduction is an urgent issue for the Chinese government to solve (Chen & Xie, 2022). To address the environmental crisis while sustaining economic growth, China introduced the carbon market mechanisms in 2013.

A carbon market system, often referred to simply as a carbon market, is an institutional framework for allocating, trading, and managing opportunities for carbon emissions through a market mechanism (Weng & Xu, 2018). This market-based regulatory system allows companies to trade carbon emission allowances, using economic incentives to encourage reductions in greenhouse gas emissions (Han et al., 2023). The carbon market enables carbon emissions to flow to companies with lower abatement costs through market mechanisms in order to achieve a more efficient allocation of resources. Correspondingly, carbon markets provide companies with flexible ways to reduce air pollution and help promote green and low-carbon development (Xu et al., 2023). Thus, the carbon market mechanism is considered an

important market-based environmental regulatory tool to balance economic growth and environmental sustainability.

The core components of the carbon market mechanisms include carbon finance, carbon price, and carbon trading policy. Carbon finance is a type of Green Finance (GF) that uses the carbon market as a platform for financing and investments to reduce greenhouse gas emissions, such as CO_2 (Jiang et al., 2023; Liu & Shen, 2011). The influence of carbon finance on company performance is evident in various ways. On the one hand, the creation of carbon finance facilitates a positive feedback loop of capital, stimulating investment in environmentally friendly projects and technology and enhancing the growth of sustainable industries and the green economy (Qian & Yu, 2023). On the other hand, carbon finance significantly influences sustainable performance. In addition, carbon finance offers financial assistance for environmentally sustainable green development initiatives (Ding et al., 2022) and facilitates the development of cleaner production methods by companies to decrease pollutant emissions. It also enhances human understanding of the environment, fulfils social duties, and encourages advancements in sustainable performance.

The carbon trading price (or carbon price) is the cost of emitting CO_2 and other pollutants into the atmosphere. First, the carbon price serves as the central mechanism of the carbon market. Fluctuations in the carbon price impact the economic performance of companies by affecting their cost of carbon emissions (Tang et al., 2022). When the cost of carbon is elevated, large polluters face higher expenses when purchasing carbon credits (Mo, 2023). Diminished economic profits create a compelling incentive for companies to lower carbon emissions by means of technological advancements, enhanced energy efficiency, and other strategies. This, in turn, reduces the financial burden associated with carbon emissions and ultimately enhances company performance and competitiveness (Bento et al., 2021). Moreover, empirical research has demonstrated that a decrease in carbon price does not have a beneficial impact on the value of companies, their competitiveness, or their ability to reduce emissions (Venmans et al., 2020).

Second, there exists a robust correlation between carbon price and sustainable performance. The increase in carbon price has compelled the company to heighten its focus on environmental preservation. Consequently, the company will assume greater social responsibility by actively engaging in projects to reduce carbon emissions and

adhere to its environmental protection policy. This proactive approach will enable the company to effectively adapt to fluctuations in the carbon price (Döbbeling-Hildebrandt et al., 2023). Additionally, implementing and fluctuating a carbon price motivates companies to develop a more extensive system for managing and controlling carbon emissions and a transparent method for disclosing carbon information, thereby enhancing the company governance framework (Du & Chen, 2021). Carbon price enhances a company's Environmental, Social, and Governance (ESG) performance (Jiang et al., 2022).

Carbon trading policy are a form of environmental mechanism that operates within a market-based framework. Carbon emissions trading aims to incentivize the reduction of carbon emissions and the development of a low-carbon economy through buying and selling carbon emission allowances and implementing carbon emission limits (Hua & Dong, 2019). As such, carbon trading policy significantly influences the financial prosperity of companies. In order to fulfill their environmental policy duties, companies engaged in carbon emissions trading are required to purchase or sell carbon credits depending on whether they have a deficit or excess of permits. The purchase of carbon credits by high-carbon emitting companies exceeding carbon emission allowances increases their daily operating costs and economic burden, with certain negative impacts on economic performance (Zhou et al., 2022). However, low-carbon emitting companies with a surplus of allowances can generate additional economic inflows by selling excess carbon credits and have some favorable impact on economic performance (Sun et al., 2022).

Carbon emissions trading policy significantly affects a company's sustainable performance. Companies have been compelled by pressure for carbon use allowances to lower carbon emissions through the use of cleaner energy sources, increased energy efficiency, and the development of green technologies (Zhou, 2023). Companies participating in carbon emissions trading will disclose carbon information in a timely manner, actively participate in emission reduction actions, fulfil their social responsibilities, and improve their company's governance structure (Tian et al., 2022). The implementation of carbon trading policy steers society towards a more ecologically conscious, effective, and enduring path.

Green technology innovation refers to the innovation of green technologies, products, and processes related to resources and the environment during production and

operation. This includes the essence of green technology innovation is to reduce the waste of resources and environmental pollution (Wang & Liu, 2021). In China, green technology innovation occurred in the early stages (1970s-1980s), growth (1990s-2000s), and acceleration (2000s to present). The first national conference on environmental protection was held in China in 1973, marking the beginning of the attention and importance of green technology innovation represented by environmental protection technology. China's first national conference on environmental protection scientific research was held in 1978, and the first national environmental science and technology plan was formulated, providing an initial policy framework for green technology innovation.

China committed to the Applied Science and Technology Program in 1988, particularly emphasising the fundamental significance of green innovation technologies. In 1996, the country prepared the plan for the Cross-Century Green Project, which identified the challenge of new green technologies that are indispensable for fighting pollution. Hence, the role of green technology innovation is emerging in enhancing the capacity of environmental governance. After entering the 21st century, the Chinese Government introduced important green technology innovation and aggressively introduced related policies and programs. In 2021, the two National People's Council meetings proposed greater implementation of the sustainable development strategy, accelerated promotion of green development, encouragement of the use of new green technologies, and growth of the green environmental protection industry. Subsequently, in August 2024, the Central Committee of the Communist Party of China and the State Council issued the "Opinion on Accelerating the Comprehensive Green Transformation of Economic and Social Development." It also emphasized the importance of green technology innovation play in including green play and clarified economic and social development changes.

Green technology innovation can significantly influence the relationship between carbon market mechanisms and company performance, and green technology innovation is a critical link between carbon market mechanisms and company performance. It is essential to enhance the functionality of the carbon financial system, as this will decisively drive the advancement of green technology. Moreover, green technology innovation adds to the growth and spread of carbon finance and provides more investment opportunities and financing channels for green projects. It also

alleviates financing constraints and helps the company enhance value and sustainable development (Xie et al., 2022).

Furthermore, green technology innovation is crucial for balancing the carbon price with the company's performance. Cost pressures from rising carbon price force companies to develop new green technologies and invest in Research and Development (R&D) and technical innovation to reduce costs and better adapt to national environmental policy (Anser, Abbas et al., 2021).

Green technology innovation has contributed positively to the operation of carbon trading mechanisms. Companies with higher levels of green technology innovation can receive more allowances or equity in the carbon market. In addition, green technology innovation help companies reduce carbon emissions through more efficient, environmentally friendly technology solutions (Qi et al., 2021). Assisting the company in achieving synergistic economic and environmental benefits, it aims to enhance the well-being and durability of the carbon market.

The effectiveness of these mechanisms (carbon finance, carbon price, and carbon trading policy) in improving company performance, both economically and sustainably, and the role of green technology innovation in weakening or enhancing the relationship between the two remains a subject of empirical investigation.

The carbon market mechanisms exemplify market-oriented environmental regulation. The relationship between environmental regulation and economic growth is widely debated. Three main hypotheses exist: the traditional hypothesis (compliance cost theory), Porter's (innovation compensation theory), and the uncertainty hypothesis. The traditional hypothesis centers on the idea that stringent environmental regulation is perceived as a constraint on companies. The company will experience increased financial and non-financial costs, reducing competitiveness and hindering economic growth. This situation is not conducive to the optimization of the company's value (Palmer et al., 2018).

Porter's hypothesis posits that well-designed and impactful environmental legislation can incentivize companies to bear the costs associated with environmental compliance by fostering innovation. This can lead to a mutually beneficial outcome for the environment and the economy (Porter & van der Linde, 1995). The uncertainty hypothesis posits that the correlation between environmental regulation and economic growth is indeterminate, with variation in environmental regulation, heterogeneity in

industry locations and degrees of economic development, and a non-linear relationship (Zhao et al., 2018). Overall, the debate on environmental regulation continues in the academic literature.

The relationship between environmental regulation and economic growth is uncertain due to differing theoretical frameworks. Therefore, further investigation and examination are required to ascertain whether China's carbon trading initiative will yield a dual benefit for the economy and the environment by capitalizing on the Porter effect (Shao et al., 2022; Färe et al., 2013). Furthermore, the moderating role of green technology innovation in this relationship has not been fully investigated, and these issues must be understood and addressed. Further analysis is required to summarize the potential problems encountered by China's Carbon market mechanisms during its development. Accordingly, this study addresses the existing research gaps by examining empirical evidence on the interconnections among the Carbon market mechanisms, green technology innovation, and other aspects of company performance (economic and sustainability).

Considering the complex interplay between carbon market mechanisms, green technology innovation, and company performance, this study adopts a mixed-method approach using qualitative and quantitative methodologies. The quantitative analysis section utilized the Difference-in-Differences (DID) model and multiple regression analysis. The DID model is a commonly employed quantitative research technique in economics, statistics, and sociology, mainly to evaluate policy effects (Fallis, 2013). This study employs the DID methodology to analyze and compare the changes in the company's performance following the implementation of carbon trading policy in both carbon trading pilot companies and non-carbon trading pilot companies. Additionally, this study investigates how green technology innovation influences and moderates the relationship between carbon market mechanisms and company performance.

The qualitative analysis used a thematic analysis of semi-structured interviews to summarize the opportunities and challenges facing the development of carbon market mechanisms in China. Through this integrated research approach, the effectiveness of market-based environmental policy is carefully analyzed. This leads to a new direction in environmental economics research and helps policymakers and industry stakeholders to develop more efficient market-based environmental strategies to safeguard economic growth and achieve sustainable development simultaneously.

1.3 Problem Statement

As China positions itself as a global economic leader, balancing rapid economic growth and environmental sustainability has become more crucial. The introduction of carbon markets represents a strategic attempt to mitigate environmental impacts without stifling economic progress. Nonetheless, the effectiveness of this approach is under intense scrutiny due to various operational and strategic uncertainties (Achievements and Prospect of China's National Carbon Market Construction, 2024).

China's rapid economic growth over the past few decades has led to significant environmental pollution issues. It is essential to explore whether carbon market mechanisms can support steady economic growth while reducing carbon emissions. Therefore, the central question this study aims to address is whether China's carbon market can genuinely create a harmonious relationship, a win-win situation, between economic growth and environmental performance.

This study was constructed on five significant issues as the basis for further investigation. The first main issue of this study is the uncertain impact of carbon finance on the company performance of carbon trading pilot and non-carbon trading pilot companies after implementing the carbon trading policy. Carbon finance is a nascent financial policy that has arisen alongside the practice of carbon emissions trading (Guo et al., 2022). However, the lack of long-term data makes it challenging to assess its full economic and environmental impact. That is, the nascent state of carbon finance offers both opportunities and risks. While it provides crucial funding for green projects and incentivizes the adoption of clean technologies, high compliance costs and the market's immaturity pose significant financial risks, particularly for high-emission companies (Jiang et al., 2023). Consequently, this duality creates uncertainty in carbon finance's impact on company performance, potentially deterring investment in innovative, long-term low-carbon projects.

The second main issue underpinning this study is the ambiguity of the effect of the carbon price on a company's performance in a carbon trading pilot versus a non-carbon trading pilot after implementing a carbon trading policy. The carbon price is at the heart of the carbon market mechanisms, whereby companies are required to pay for their carbon emissions by setting a market price for carbon credits. Rising carbon price

can increase the operating costs of high-carbon-emitting companies, prompting them to search for low-carbon alternatives. This includes improving energy efficiency, adopting cleaner sources of energy or investing in carbon-reducing technologies in order to reduce the cost of carbon emissions. Moreover, this cost pressure may also lead to a decline in profitability for some companies, affecting their economic performance. Some scholars have argued that the value of company shares moves inversely with the price of carbon (Krokida et al., 2020). Meanwhile, others have argued that a low price of carbon is not a good incentive to reduce carbon emissions and increase the company's value and that a higher price of carbon is a better incentive (Venmans et al., 2020). It is therefore necessary to further clarify the incentivizing or disincentivising effects of carbon price changes on company performance.

The third significant issue that serves as the foundation for this analysis is the ambiguity surrounding the economic and environmental implications of carbon trading programmers (Nie et al., 2021). If a company's carbon emissions are lower than its quota, it can obtain additional income from selling carbon emission rights and improve its performance. However, high-carbon emitting companies need to purchase additional emission rights, which increases their operating costs and thus negatively affects their performance (He et al., 2022). Whether the benefits of the company's emission reduction measures can compensate for the additional costs of following carbon trading, the company's choice to participate in carbon trading and adopt a low-carbon strategy is mostly based on this (Shen et al., 2019). The clear carbon trading effect further incentivizes companies to comply with environmental regulations. They actively participate in carbon trading and meet their environmental responsibilities, increasing company value and sustainable performance. Uncertainty about the consequences of carbon trading policy can reduce a company's incentive to reduce emissions. At the same time, uncertainty about the policy outlook can lead to a lack of sufficient incentive for companies to invest in reducing and lowering CO_2 emissions. Consequently, it is imperative to have a more profound comprehension of the role of carbon trading policy in carbon market processes and economic progress. Therefore, clarifying whether the carbon trading policy can have positive economic and environmental effects on carbon market mechanisms is necessary.

The fourth key issue identified as a foundation for this study is the inadequate assessment of the moderating function of green technology developments in

improving or decreasing the impact of carbon market mechanisms on company performance. Green technology innovation connects the carbon market mechanisms to company performance. This relationship operates in both directions.

On the one hand, green technology innovation provide incentives for companies to reduce carbon emissions, lower costs, increase productivity and ultimately improve their economic and environmental performance in the carbon market. On the other hand, green technology innovation may also weaken the impact of the carbon market mechanisms on company performance due to the large scale of upfront investment, long investment cycle, high cost, and the complexity of transforming innovation results (Sadawi et al., 2021).

Despite this dual influence, there is a lack of research on the relationship between advancements in green technology, the moderating effect within the carbon market mechanisms and the performance of companies. Elucidating the regulatory role of environmentally-friendly technologies innovation is crucial for improving the carbon market mechanisms and promoting the sustainable growth of the carbon market (Khanra et al., 2022; Wang et al., 2021).

The last crucial factor highlighted as the basis for this investigation is a dearth of literature on interviews to explore the opportunities and problems associated with China's carbon market growth. China has operated its carbon trading mechanism for over a decade (Zhao et al., 2024). During its development, the mechanism has encountered challenges such as financial and energy transformation, limited liquidity in the carbon market, low carbon price, and the need for improved policy and regulations (Wang et al., 2019). Hence, to provide insights and strategic direction for the future growth of the carbon market, it is imperative to describe the experiences and deficiencies of almost a decade of progress.

The ongoing debate and the outlined challenges highlight a significant gap in the literature and practical understanding of China's carbon market mechanisms. There is a pressing need to clarify how these mechanisms affect both the economic and sustainable performance of companies and to explore the moderating role of green technology innovation within this framework.

This study aims to bridge these gaps by employing a mixed-methods approach to analyze the long-term relationship between the carbon market mechanisms and company performance, integrating the moderating effects of green technology

innovation. The goal is to present quantitative and qualitative evidence of the effectiveness of market-based environmental regulation. This contributes significantly to the evaluation of Porter's hypothesis in the context of China's evolving environmental and economic landscape.

1.4 Research Gaps

Based on existing literature and previous research, there are still some gaps with the potential for further investigation. The following are the discussions.

a) Carbon finance and its impact on company performance. While carbon finance has been recognized for promoting technological innovation and enhancing environmental performance, there remains a notable gap in empirical evidence concerning its differential impacts on company performance in contexts with and without carbon trading policy. Prior literature has predominantly focused on the economic, environmental, and social effects of green finance (green bonds, green credit, green insurance, green financial policies, etc.)(Key past studies: Lee; Li et al., 2023; Qian & Yu, 2023), limited empirical evidence on the impact of carbon finance on company performance in Chinese carbon market. This study aims to address this gap by employing a continuous DID model to compare impacts between carbon trading pilot and non-pilot companies, offering a nuanced understanding of carbon finance's role within the carbon market mechanisms.

b) Dynamics of carbon price. Although the regulatory function of carbon price in controlling emissions is well-documented, the empirical relationship between carbon price and company performance remains underexplored. This is especially true concerning how fluctuations in carbon price influence both pilot and non-pilot companies engaged in carbon markets. Prior studies have often focused on the correlation between carbon price and stock price or emission levels (key past studies: Krokida et al., 2020; Bolton et al., 2023; Song & Liu, 2023). This study extends the existing literature by utilizing a DID model based on average carbon price to explore how changes in carbon price affect company performance, enhancing the understanding of carbon price's incentivizing or disincentivizing effects.

c) Effectiveness of carbon trading policy. The impact of carbon trading on economic and environmental outcomes is pivotal yet poorly understood in empirical terms. This gap is critical in understanding how carbon trading affects the economic and sustainable performance of companies. This study seeks to fill this gap by constructing company-level indicators to examine the dual impacts of carbon trading policy, aiming to validate Porter's hypothesis and the effectiveness of market-based environmental regulations. This will provide a clearer theoretical basis for the

development of the carbon market and its role in economic and environmental sustainability.

d) Moderating the role of green technology innovation. The dual role of green technology innovation as both a facilitator and a barrier to enhancing company performance within the carbon market has not been comprehensively explored. While the positive impacts are frequently highlighted, the significant investments and long gestation periods associated with green technologies pose challenges that may dampen their immediate economic benefits. Thus, by considering green technology innovation as a Moderating Variable (MV), this study aims to elucidate its complex interactions with the carbon market mechanisms. This addresses a critical gap in understanding how such innovations influence a company's short- and long-term performance.

e) Role of semi-structured interviews in understanding carbon market mechanisms. Despite the wealth of quantitative data on carbon markets, qualitative insights into the operational dynamics and developmental challenges of China's carbon market are limited. This study introduces a novel approach by integrating semi-structured interviews to complement quantitative findings. These interviews aim to delve deeper into the operational realities and strategic challenges stakeholders face, enriching the research with experiential insights and offering a more comprehensive view of the carbon market's trajectory over the past decade.

Table 1.2 lists the differences between this study and previous studies.

Table 1.2

Research Gaps

Category	Previous Studies	Research Gaps
Carbon finance impact	Focus on the economic, environmental, social and technological impacts of GF (key past studies: Yang & Luo, 2020; Lin & Bai, 2023; Guo et al., 2022; Li et al., 2023).	Carbon finance is an offshoot of GF. Explore the economic impacts and sustainable development implications of carbon finance.
Carbon price variability	The impact of the carbon price on stock price and carbon emission reduction (key past studies: Krokida et al., 2020; Bolton et al., 2023).	Exploring the impact of carbon price on economic performance and sustainable development performance.
Carbon trading policy	Single impact of carbon trading policy on the economy or the environment (key past studies: Yu et al., 2022; Li et al., 2022; Rahman et al., 2023; Liu et al., 2022).	Exploring the dual impacts of carbon trading policy on the economy and sustainable development.
Green technology innovation	No study has yet explored the weakening or enhancing role of green technology innovation in relation to carbon market mechanisms and company performance.	Exploring the relationship between carbon market mechanisms, green technology innovation, and company performance.
Qualitative insights	Qualitative insights into the operational dynamics and developmental challenges of China's carbon market are limited.	The analysis of semi-structured interviews summarizes the opportunities and challenges faced by China's carbon market over the past ten years of its development.

Figure 1.2 illustrates the fundamental idea of this study.

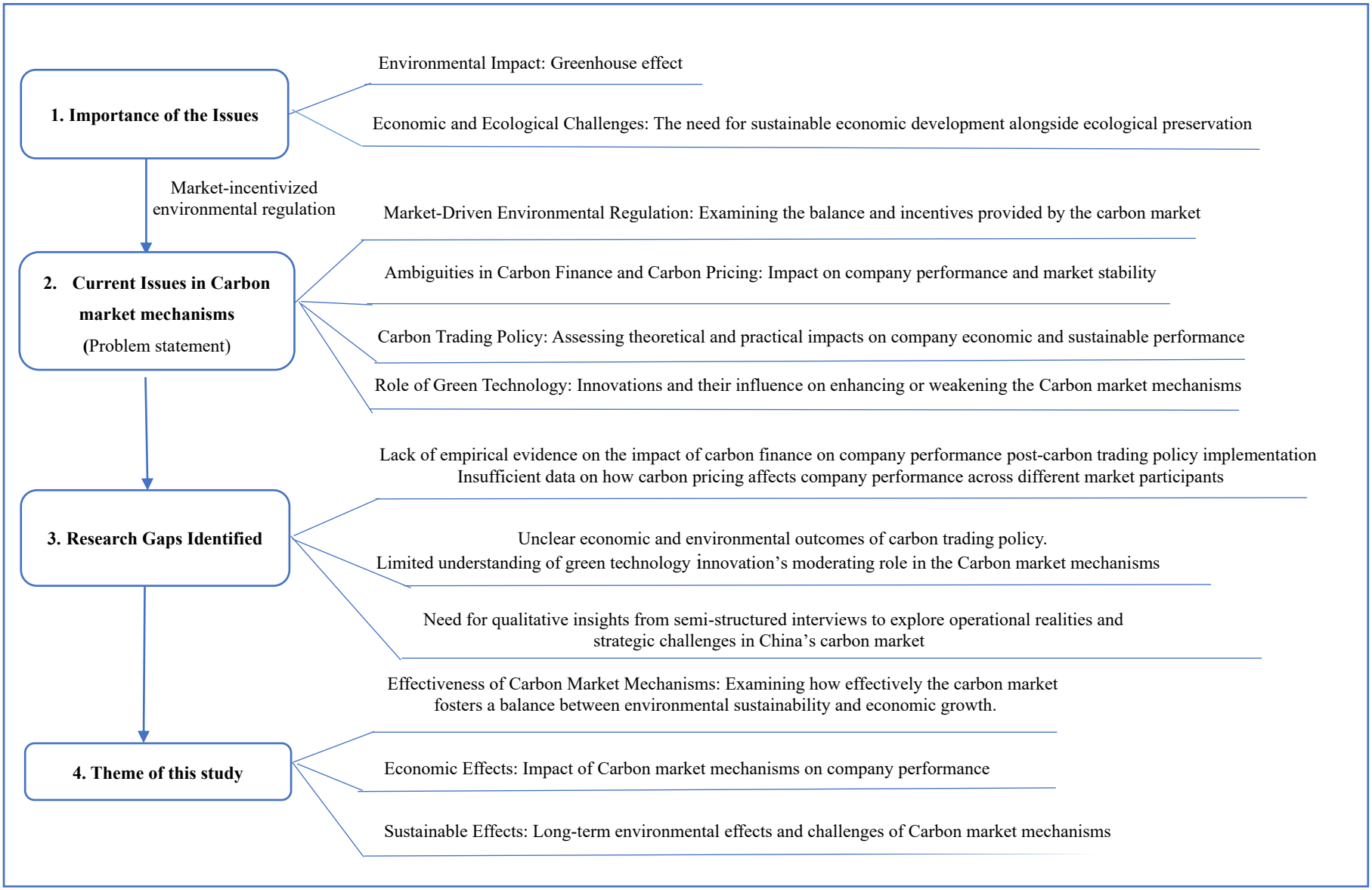


Figure 1.2 Main Ideas of This Research

1.5 Research Questions

This study investigates the complex interplay between several environmental sustainability metrics and how they affect a company's performance within the framework of the carbon market in China. The following research questions guide an empirical investigation and analysis.

1. What are the different impacts of the carbon market mechanisms (i.e., carbon finance, carbon price, and carbon trading policy) on the company performance (economic and sustainability) of heavily polluting industries before and after the implementation of carbon trading policy among the pilot and non-carbon trading pilot companies?

2. What are the different impacts of green technology innovation on the relationship between carbon market mechanisms (carbon finance, carbon price, and carbon trading policy) and company performance (economic and sustainability) of heavily polluting industries before and after the implementation of the carbon trading policy between pilot and non-carbon trading pilot companies?

3. How does implementing carbon market policy affect the company performance of high-polluting industries - pilot and non-carbon trading pilot companies?

1.6 Research Objectives

This study aims to understand the complex relationships between several environmental sustainability criteria and their impact on company performance in the Chinese carbon market. To achieve this overarching goal, the research delves into the following specific objectives:

1. To examine the differential impacts of carbon market mechanisms (carbon finance, carbon price, and carbon trading policy) on company performance (economic and sustainability) of heavily polluting industries before and after carbon trading policy implementation, compared between pilot and non-carbon trading pilot companies.

2. To analyse green technology innovation moderates the impacts of carbon market mechanisms (carbon finance, carbon price, and carbon trading policy) on company performance (economic and sustainability) of heavily polluting industries before and after carbon trading policy implementation, compared between pilot and non-carbon trading pilot companies.

3. To investigate how implementing carbon market policy impacts the company performance in high-polluting industries, comparing pilot and non-carbon trading pilot companies.

Table 1.3 contains the mapped information for this research study.

Table 1.3

Mapping of Research Study

Category	Research Problems	Research Gaps	Potential Solutions	Research Questions	Research Objectives
1a. Carbon finance impact	Ambiguity in the impact of carbon finance on company performance post-implementation in pilot vs. non-pilot companies.	Lack of robust evidence on the differential impacts of carbon finance.	Apply 'Strong Porter Theory' to hypothesize that strict environmental regulations drive innovation, offsetting compliance costs.	What are the differential impacts of carbon finance on company performance in pilot vs. non-pilot companies' post-policy implementation?	Examine the differential impacts of carbon finance on the economic and sustainability performance of companies in pilot vs. non-pilot settings post-policy implementation.
1b. Carbon price variability	Uncertainty in the effects of carbon price changes post-implementation in pilot vs. non-pilot companies.	Insufficient empirical evidence on how carbon price variability affects company performance differently in pilot and non-pilot groups.	Utilize Innovation Theory to explore how carbon price influences company innovation and adaptation strategies.	How do changes in carbon price affect company performance in pilot vs. non-pilot company's post-policy implementation?	Analyze how carbon price variability influences the economic and sustainability performance of companies in pilot vs. non-pilot settings post-policy implementation.
1c. Carbon trading policy	Uncertainty around the economic and environmental consequences of carbon trading policy.	Empirical data is needed to confirm or disprove Porter's hypothesis regarding carbon trading policy.	Use a mixed-methods approach, including DID model, regression analysis, and semi-structured interviews.	What are the economic and environmental impacts of carbon trading policy on companies in pilot vs. non-pilot settings?	Investigate the dual impacts of carbon trading policy on company performance in pilot vs. non-pilot settings, validating Porter's hypothesis.
2. Green technology innovation	Inadequate assessment of green technology's role in modifying the impacts of carbon market mechanisms.	Research lacks focus on the moderating role of green technology in influencing company performance under carbon market mechanisms.	Conduct extensive examinations of how green technology innovation influence the effectiveness of carbon market mechanisms.	How does green technology innovation moderate the impacts of carbon market mechanisms on company performance in pilot vs. non-pilot companies?	Analyze how green technology innovation affects the economic and sustainability impacts of carbon market mechanisms on company performance in pilot vs. non-pilot settings.
3. Qualitative insights	Lack of qualitative insights into the operational challenges and opportunities of China's carbon market.	Need for qualitative studies to provide deeper insights into the challenges and opportunities of carbon market development in	Conduct semi-structured interviews to gather qualitative data on the advancement prospects and obstacles in China's carbon	How does the implementation of carbon market policy impact company performance in high-polluting industries in	Investigate the qualitative impacts of carbon market policy implementation on company performance in high-polluting industries in

	China.	market.	pilot vs. non-pilot settings?	pilot vs. non-pilot settings.

Source: Developed by the researcher for the purpose of this research

1.7 Significant of Study

Achieving sustainable development requires striking the correct balance between safeguarding the environment and promoting economic expansion. This study holds great relevance as it offers valuable insights that can aid China in its shift towards a low-carbon economy.

a) Assist companies in shifting towards a low-carbon economy. Directing the environmental management and policy of companies, as well as implementing strategies to reduce emissions, by providing a theoretical understanding of the connection between environmental regulations and company performance, assists companies in effectively strategizing their low-carbon development trajectories and meeting carbon emission reduction goals. This includes achieving a mutually beneficial outcome for both low-carbon initiatives and overall growth (Liu, Zhou, et al., 2020; Zhu et al., 2019). In addition, it provides more robust empirical evidence to evaluate Porter's hypothesis and contributes to enhancing comprehension of market-based environmental regulation by scientifically and rationally devising environmental management measures. This, in turn, fosters green technology innovation and proposes efficient technology operation plans (Wang et al., 2022; Wang & Liu, 2021).

b) An investigation into the effects of carbon finance and carbon price (Chen & Zhang, 2022). This study examines the role of carbon finance and carbon price in the carbon market mechanisms. It clarifies the directing and motivating functions of carbon price and carbon finance, which are critical for improving the carbon market mechanisms and promoting its consistent and healthy growth (Li et al., 2021).

c) Guidelines for effective policy design. It guides government departments in designing scientifically sound environmental regulatory policies. It helps government departments to establish and improve environmental regulation in a targeted manner based on the adaptive behavioral responses of companies under environmental regulation. It also applied appropriate methods and tools to regulate, incentivize, and guide companies to reduce emissions and provide theoretical support and policy recommendations for constructing an ecological civilization in China (Calel, 2013; Wen et al., 2020).

d) Promoting green technology innovation in the Chinese market. Green technology plays a crucial role in the advancement of a company, emphasizing the

significant impact and value of innovative green technologies. In particular, it encourages companies to invest more in green technologies and R&D for technological innovation. In addition, establishing a green economy and boosting performance through green technology innovation in carbon market mechanisms (Zhang et al., 2022; Zheng et al., 2021).

e) Provide recommendations for the future progress of China's carbon market. The field interview approach is employed to succinctly analyze the opportunities and problems that the development of China's carbon market faces. It also aims to indicate the path for the future of carbon market development and offer insights into the advancement of the global carbon trading market (Zhang et al., 2020).

1.8 Motivations of the Study

This study is motivated by a multifaceted desire to enhance understanding and policy effectiveness in China's carbon market. Key motivations include:

a) In-depth analysis of carbon market mechanisms and green technology. To comprehensively analyse how the interplay between carbons market mechanisms and green technology innovation influences company performance. This exploration aims to identify strategies companies can adopt to thrive under market-based environmental regulations while advancing sustainable technological innovations.

b) Validation of market-based environmental regulations. As the world's largest carbon emitter, China presents a unique context for assessing the effectiveness of carbon market mechanisms. This study seeks to provide empirical support for Porter's hypothesis, which posits that stringent environmental regulations can stimulate innovation and yield competitive advantages. Notably, validating this hypothesis within the Chinese context will contribute to the global discourse on crafting effective market-based environmental policy.

c) Balancing environmental protection with economic growth. The research aims to explore strategies that achieve a balance between environmental sustainability and economic development. It investigates how environmental regulations can be designed to support economic growth while fostering a transition towards a greener,

low-carbon economy. This is crucial for ensuring that China's sustainable development strategies can serve as a model for other nations striving for similar goals.

1.9 Contributions of the Study

Original contributions in several vital areas have come from this work, including conceptual, theoretical, methodological, empirical, and managerial aspects. To summarize the research outcomes, Table 1.4 presents the levels and domains of the research achievements.

Table 1.4

The Study's Level and Scope of Contributions

		Level of Contribution	
		Replication	**Extension**
Area of contribution	Conceptual	Explain the concepts of carbon finance, carbon price and carbon trading (key past studies: Guo et al., 2022; Yang & Luo, 2020; Jiang et al., 2023)	Deepens understanding of how carbon finance, pricing, and trading operate under the broader umbrella of carbon market mechanisms, highlighting nuances specific to China's regulatory environment.
	Theoretical	Discusses Porter's hypothesis and innovation theory in relation to environmental regulation (key past studies: Lanoie et al., 2008; Nie et al., 2021; Wang et al., 2019)	Lays a robust theoretical framework to validate Porter's hypothesis within the specific context of China, considering its status as a major carbon emitter and its unique market conditions. Deepens theoretical discussions on market-based environmental regulations and further develops the green innovation theory, exploring both economic and environmental impacts.
	Empirical	Focuses on the effects of GF on economic and environmental performance, examining impacts of carbon trading policy on various performance metrics (key past studies: Yang & Luo, 2020; Lin & Bai, 2023; Guo et al., 2022; Li et al., 2023)	This study utilizes a mixed research methodology to investigate the effects of carbon market mechanisms on economic performance and sustainable performance. It compares the performance changes of carbon trading pilot companies with those of non-carbon trading pilot companies. Additionally, the study explores the influence of green technology innovation on these relationships and summarises the opportunities and challenges associated with the development of carbon markets. It also offers significant insights into the complex interplay between environmental regulation, economic growth, and sustainable development, providing essential references for both company practice and policy decision-making.
	Methodological	Validating the relationship between carbon trading policy and company performance using DID model (key past studies: Song & Liu, 2024; He et al., 2022; Zhao et al., 2024)	1. Using continuous DID model to verify the relationship between carbon finance and company performance. 2. Using continuous DID model to verify the relationship between carbon price and company performance. 3. Semi-structured interview fieldwork to investigate the impact of carbon trading policy on carbon trading pilots and non-carbon trading pilots. 4. Mixed Research Methods. Enhances methodological approaches by integrating quantitative models with qualitative fieldwork, offering a comprehensive view of the carbon market's operational dynamics.
	Managerial	Put forward policy suggestions from the government, company, society, and other levels (key literature: Liu & Liu, 2022; Song et al., 2020; Tang et al.,	1. Government: Improve market-based environmental regulatory policy and guide companies to reduce emissions through policy incentives to achieve

2020)	synergistic economic and environmental development. 2. Company: Actively participate in green technology innovation R&D and investment to increase innovation production, improve innovation performance, and promote cost and carbon emission reductions. 3. Social: Promote a society-wide transition to low-carbon economic development.

1.10 Scopes of the Study

The scope of quantitative research: In order to perform pilot trading, China set up carbon exchanges in nine provinces and cities, including Shenzhen, Beijing, Shanghai, Tianjin, Hubei, Chongqing, Guangdong, Fujian, and Sichuan. China started implementing a Carbon Emission Trading (CET) system in 2013. These provinces are omitted since the carbon trading pilot in Fujian and Sichuan, both non-quota trading markets, began late. This study focuses on the listed companies in the seven pilot provinces and cities. Accordingly, this study uses unbalanced panel data. The study period is limited to the years 2010 to 2022 (e.g., Zhang et al., 2018; Zhou et al., 2020; Sun et al., 2022).

The scope of qualitative research: The qualitative component comprises 30 semi-structured interviews evenly divided between representatives from carbon trading pilot companies and non-carbon trading pilot companies. This approach ensures a balanced view of experiences and perceptions regarding the implementation and impacts of carbon trading policy.

1.11 Definition of the Constructs Used in This Research

Table 1.5 provides definitions for major terms used in this investigation, enhancing subsequent comprehension of the essential terminology employed in this study.

Table 1.5
Definition of the Constructs Investigated in This Study

Construct	Definition	Relevant Studies
Carbon market mechanisms	The carbon market mechanisms encompass several financial instruments and trading activities designed to reduce greenhouse gas emissions. These include financing for low-carbon projects and trading carbon emission rights and their derivatives.	Xu (2021); Han et al. (2023); Long et al. (2024)
Carbon finance	Carbon funding has developed within the framework of worldwide climate change, encompassing all financial measures intended at restricting and diminishing greenhouse gas emissions.	Guo et al. (2022); Yang & Luo (2020); Jiang et al. (2023); Li & Liu (2011)
Carbon price	Carbon emission rights trading market price.	Tang et al. (2022)
Carbon trading policy	CET, commonly referred to as the cap-and-trade system or total quantity control and emission trading mechanism, involves the distribution of a set total amount of carbon emission allowances within a particular jurisdiction and a defined period of time.	Chapple et al. (2013); Liu et al. (2015); Lo (2012); Ma et al. (2020); Oestreich & Tsiakas (2015); Sun et

	These allowances are distributed in the form of quotas to individuals or organizations, granting them legitimate carbon emission rights. Thanks to this mechanism, these rights can be exchanged amongst market players in a manner similar to commodities. The purpose of setting an emission cap is to utilize market processes in order to achieve carbon emission reduction goals at a reasonable cost by guaranteeing that real carbon emissions do not exceed the established limit. In this study, the carbon trading policy refers to implementing carbon emissions trading.	al. (2022); Hua & Dong (2019)
Green technology innovation	Technical innovations related to resource and environmental aspects primarily involve product technologies and process innovations that help reduce environmental pollution and minimize resource waste in the production and operational processes.	Pacheco et al. (2017); OECD (2010); Leitner et al. (2010); Pacheco et al. (2017)
Economic performance	This study measures economic performance using Economic Value Added (EVA), which is a company's net operating profit after tax minus the cost of capital.	Matsumura et al. (2010); Zhang et al. (2018); He et al. (2022)
Sustainable performance	Sustainable performance is an integrated concept covering various economic, social, environmental, and resource measures.	Kovilage (2021)

1.12 Thesis Organization

The thesis is divided into seven chapters. Chapter 1 explores the historical background of the topic, research questions, research aims, research gaps, and the study's importance and contribution. Chapter 2 discusses the overall status of company performance in heavily polluting industries and the development and establishment of China's carbon market system. Chapter 3 covers the theoretical foundation, literature evaluation, and hypothesis development. Chapter 4 comprehensively explains the mixed research design, DID modelling, variable measurement, and regression equations. Chapter 5 presents the results of the quantitative analysis and discussion. Chapter 6 presents the results of the qualitative analysis. Chapter 7 provides the study's findings, suggestions for policy, and suggestions for future research. The organization of this paper is displayed in Figure 1.3.

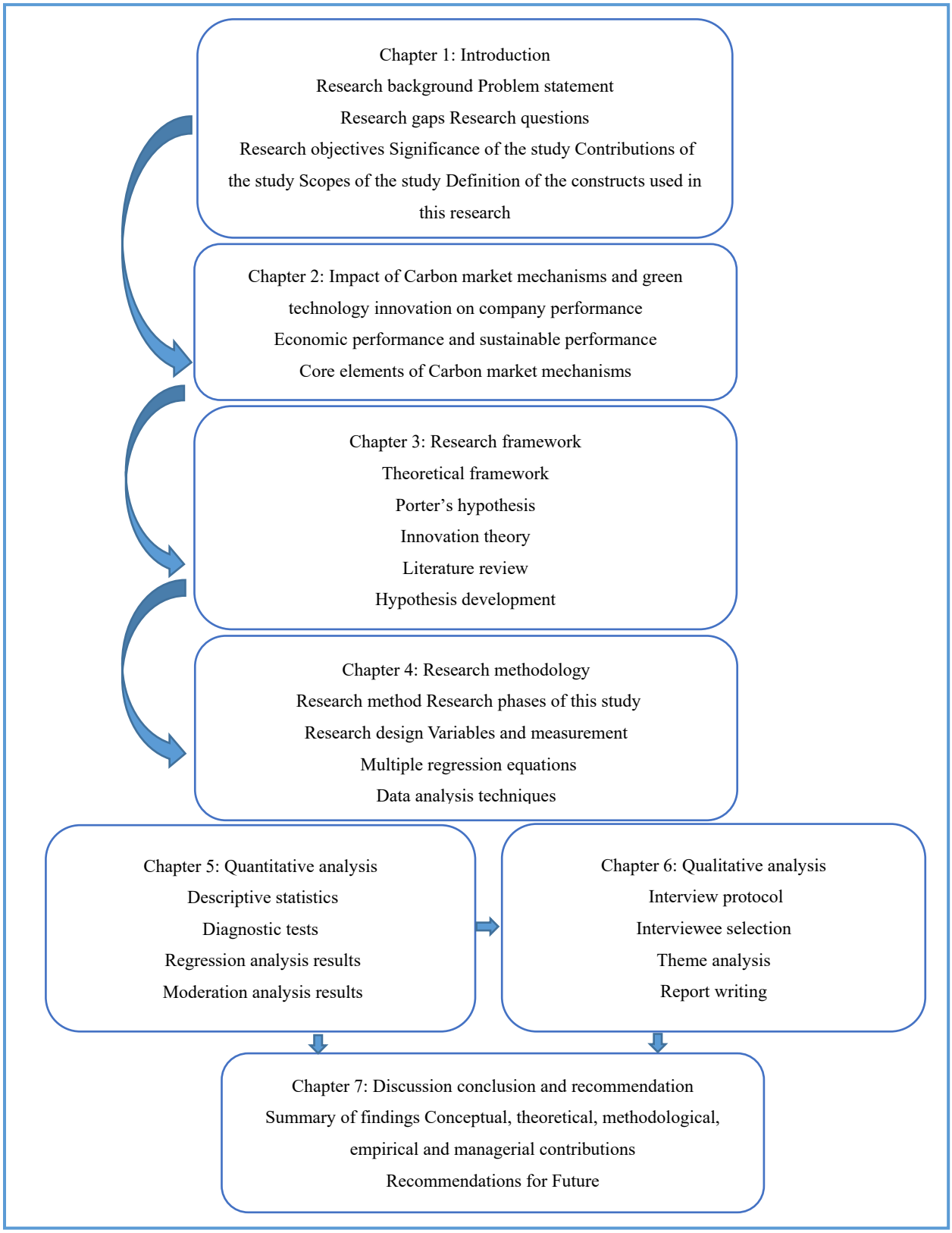


Figure 1.3 Thesis Structure

1.13 Chapter Summary

This chapter delineates the research context of the dissertation. Then, it highlights the practical problems encountered during the research within the context of China's progress in transitioning towards a low-carbon economy. It also elaborates on the research objectives, research significance, research scope, innovation points of the research, and research contributions. Following this, it summarizes the research framework of the dissertation and defines the core concepts involved in the article. The next chapter discusses the overall status of company performance and the evolution and development of carbon market mechanisms in China's heavily polluting industries.

CHAPTER 2

IMPACT OF CARBON MARKET MECHANISMS AND GREEN TECHNOLOGY INNOVATION ON COMPANY PERFORMANCE

2.1 Introduction

This chapter comprises six sections: Section 2.2 addresses company performance within the framework of sustainable performance; Section 2.3 provides a realistic overview and historical development of China's carbon market mechanisms, including carbon finance, carbon price, and carbon emissions trading; Section 2.4 discusses the evolution of green technology innovation policy and the moderating influence of green technology innovation; and Section 2.5 summarizes research regarding the effects of China's carbon market mechanisms on company performance. The chapter is ultimately summarized.

2.2 Company Performance in the Context of Sustainability

This section details the economic and sustainable performance of companies and the challenges facing both from a number of perspectives.

2.2.1 Economic Performance

Economic performance denotes the outcomes and advantages attained by a corporation in its economic endeavors over a certain timeframe through the efficient allocation and usage of diverse economic resources (Kumar & Chakraborty, 2024). The economic performance of carbon trading pilot companies in the carbon market encompasses both general company economic performance and its integration with carbon emission reduction, carbon asset management, and other carbon market-related

factors (Qi et al., 2021). This is analyzed through the lenses of carbon cost and revenue, resource utilization efficiency, and overall profitability.

Carbon costs include the acquisition cost of carbon allowances, investments in energy-efficient and emission-reducing technologies, and expenses related to the procurement of carbon reduction equipment. Suppose the company can successfully decrease these expenditures. In that case, it is considered a favorable indicator of economic performance (Brouwers et al., 2018). In particular, carbon revenue mostly derives from carbon quota trading and Certified Emission Reduction (CER) revenue, namely the income generated by the company from selling surplus quotas in the carbon market through energy conservation and emission mitigation, as well as revenue from the sale of CER (e.g., CCERs) (Klenert et al., 2018).

Resource utilization efficiency assesses how effectively a company employs diverse resources (e.g., energy, raw materials, and carbon allowances). This is indicated by increased economic value per unit when the company achieves greater economic output with reduced resource inputs (Qi et al., 2021).

Regarding overall profitability, net profit is the final after-tax earnings of the company, factoring in the relevant carbon costs and advantages. Profitability metrics include Return on Assets (ROA), Return on Equity (ROE), and Economic Value Added (EVA) (Fan et al., 2019).

Carbon trading pilot companies encounter many problems regarding economic success, specifically in cost control, risk management, and data administration.

The cost management challenge is defined by the unpredictability of carbon allowance prices (Venmans et al., 2020), the substantial expenses associated with retrofitting technologies to mitigate emissions, and the escalation of compliance and administration expenditures. If a corporation's real carbon emissions exceed the carbon permits given by the government, the company must acquire more allowances in the carbon market, resulting in elevated carbon costs. Thus, companies must invest significantly in technical innovation and equipment upgrades to mitigate carbon emissions, which will impose short-term financial strain and consequently impact economic performance (Liu et al., 2021). Furthermore, to comply with legal mandates, carbon trading pilot companies must allocate substantial people, material, and financial resources to monitor, report, and verify carbon emissions data (Brouwers et al., 2018). The heightened regulatory costs will constrict the profit margins of the companies (Han

et al., 2024).

Challenges in risk management are evident in the volatility of prices in the carbon market and the potential for alterations in laws and regulations (Hwang et al., 2023). China's carbon market remains nascent, characterized by immaturity and significant price volatility (Tian et al., 2024). Notably, significant volatility in carbon price will heighten the risk of uncertainty regarding the company's financial performance. The government will consistently modify and enhance the carbon trading regime in alignment with carbon emission reduction objectives. This necessitates companies to recalibrate their carbon emission reduction strategies and targets (Wang & Wang, 2016).

Data management challenges manifest in the complexities of data accounting and concerns over data quality and integrity (Ahsan et al., 2024). Accurately quantifying carbon emissions data is challenging, particularly for businesses with intricate processes, such as petrochemicals and chemicals, where it is challenging to assess the carbon emissions of each individual operation (Han et al., 2017). Certain companies disseminate erroneous or fabricated carbon emissions statistics, which will incur penalties from regulators and tarnish the company's name and image (Shi et al., 2023).

2.2.2 Sustainable Performance

Sustainable performance is a comprehensive measure of a company's synergistic development in the Environmental, Social, and Governance (ESG) dimensions (Sun et al., 2024). This study analyses the ESG dimensions in the context of the carbon market.

The environmental considerations include reducing carbon emissions, optimising energy structure, and enhancing the environmental management system. The effectiveness of carbon emission reduction quantifies the extent to which a corporation has decreased its real carbon emissions. The measurement criteria encompass absolute emission reduction, relative emission decrease, and carbon intensity (Fan et al., 2023). The optimization of the energy structure is evidenced by the decreased reliance on high-carbon energy sources (e.g., coal) and the advancement of clean energy sources such as solar, wind, and hydropower (Xu & Lin, 2016). At the same time, the enhancement of the environmental management system pertains to the creation of a thorough and

efficient framework for monitoring, assessing, and reporting carbon emissions (Wang et al., 2020).

The social dimension is defined by a minimal carbon supply chain and heightened low-carbon employee involvement. The low-carbon initiative in the supply chain indicates that the pilot company influences both upstream and downstream supply chain entities to advance the low-carbon development of the entire supply chain (Qu et al., 2021). Thus, employees are urged to engage in internal low-carbon activities to enhance their environmental understanding and involvement (Liu et al., 2024).

Governance is evidenced by enhancing carbon strategy and target establishment, carbon management structure, and carbon information dissemination. The company's carbon strategy and target setting are evident in the establishment of explicit long-term, medium-term, and short-term objectives for carbon emission reduction, which are integrated into the overall strategic development plan (Wang et al., 2023).

Carbon management organization construction denotes the development of a dedicated carbon management department by the company tasked with overseeing the management of carbon assets and facilitating carbon training (Blumberg & Sibilla, 2023). The corporation shall promptly and accurately report carbon emission statistics and reduction initiatives to the public, enhancing the transparency of carbon information disclosure.

Carbon trading pilot companies encounter numerous problems regarding sustainable performance. Some include pressures on abatement technologies and costs, demands of the energy transition, insufficient ESG governance frameworks and decision-making processes, as well as inadequate information sharing and transparency (Yao et al., 2023).

Reducing carbon emissions necessitates sophisticated technological assistance, including energy substitution and carbon capture and storage. This is marked by substantial expenditures, extended Research and Development (R&D) timelines, and challenges in the implementation of outcomes (Wilberforce et al., 2019). Concurrently, pilot companies in carbon trading may experience a deficiency in money and technology, hindering the rapid and effective implementation of new technologies and adversely impacting environmental performance enhancement (Hu & Chen, 2019). Within the carbon trading market, companies must expedite the shift from conventional high-carbon energy sources to greener alternatives, hence facing pressure to reform their

energy portfolios (Xu & Liu, 2023).

Several carbon trading pilot companies have yet to develop a robust ESG governance framework and lack a specialized ESG management department or team, leading to insufficient organizational safeguards for ESG decision-making and execution (Hsueh, 2019). Notably, variations exist in ESG information disclosure between regions and industries, and the requirements for disclosure lack uniformity in the ESG Practice of Domestic Listed Companies. Moreover, certain companies deliberately reveal or obscure unfavorable information, and instances of false and inaccurate disclosures occur, undermining the transparency and reliability of carbon reporting (Yin et al., 2023).

2.3 The Evolution and Impact of Carbon Market Mechanisms

This section delineates the evolution and effects of carbon finance, carbon price, a nd carbon trading, which are fundamental elements of carbon market systems.

2.3.1 Carbon Finance

Carbon finance has emerged as a response to global climate change and a catalyst for implementing appropriate policy. The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) was established in Kyoto, Japan, in December 1997 at three meetings of UNFCCC participating countries and entered into force in February 2005 (Sato et al., 2022). Against this background, emissions trading, joint implementation and the Clean Development Mechanism (CDM) proposed in the Kyoto Protocol have laid a solid foundation for the emergence and development of carbon finance. Correspondingly, the carbon trading market has become an essential vehicle for development (Report, 2012).

Carbon finance refers to the investment and financing activities that emerged from the Kyoto Protocol, or carbon financing and trading of carbon substances. Specifically, it refers to financial activities such as direct investment and financing, carbon trading and bank lending that serve technologies and projects that limit greenhouse gas emissions, among other things (Zhou et al., 2024). Carbon finance is a

branch of finance developed on the basis of traditional finance to meet environmental objectives such as climate change mitigation and carbon reduction. It is an extension of traditional finance in terms of environmental defense in the 19th century.

Furthermore, carbon finance has its own characteristics in terms of objective level, project scope, policy and planning, risk characteristics and continuous improvement. The main objectives of the carbon economy are to address climate change, reduce carbon emissions, support the growth of low-carbon industries and industries through finance, and promote economic transformation towards growth with carbon low and encourage green development (Yang et al., 2022). Notably, the business scope of carbon finance is relatively specialized. It mainly focuses on environmental protection areas such as carbon emission right trading, investment and financing of low-carbon technologies, as well as projects involving financial products such as carbon spot, carbon futures, carbon options, carbon insurance and carbon funds. In addition to being regulated by traditional financial regulations, carbon finance is also subject to policies and regulations related to environmental protection and climate change. This includes the carbon emissions trading system and green credit policy (Liaw, 2020). Beyond traditional financial risks, carbon finance also faces special risks related to climate change and policy changes, such as carbon price fluctuations and policy uncertainty (Yang et al., 2022).

2.3.1.1 Carbon Finance Market

In this study, carbon finance is divided into carbon finance markets and carbon finance products. Carbon financial markets are divided into primary and secondary markets (Figure 2.1), which must be developed in a coordinated manner to fulfil their functions.

The primary market refers to the carbon emission issuance market or primary market, which is the market formed by the first allocation or sale of carbon emission rights to companies. This includes the issuance of project emission reductions and the allocation and auction of carbon allowances (Zhou & Li, 2019). The main participants in this market are governments and companies. In particular, the government is responsible for formulating policies, laws, and regulations and setting up trading platforms. Meanwhile, companies are those involved in control and those required to

fulfil their emission reduction obligations (Chen & Wu, 2023).

The secondary market encompasses carbon spot, carbon futures, carbon options, carbon swaps, carbon index trading products, carbon asset securitization, carbon bonds and carbon funds. The main players in this market include governments, commercial banks, insurance companies and companies. Commercial banks provide financing and related support services for emission reduction projects through carbon finance products, while insurance companies provide insurance services. The financing and support services include carbon pledges, carbon buybacks, carbon trusteeships, and carbon funds (Yang & Luo, 2020).

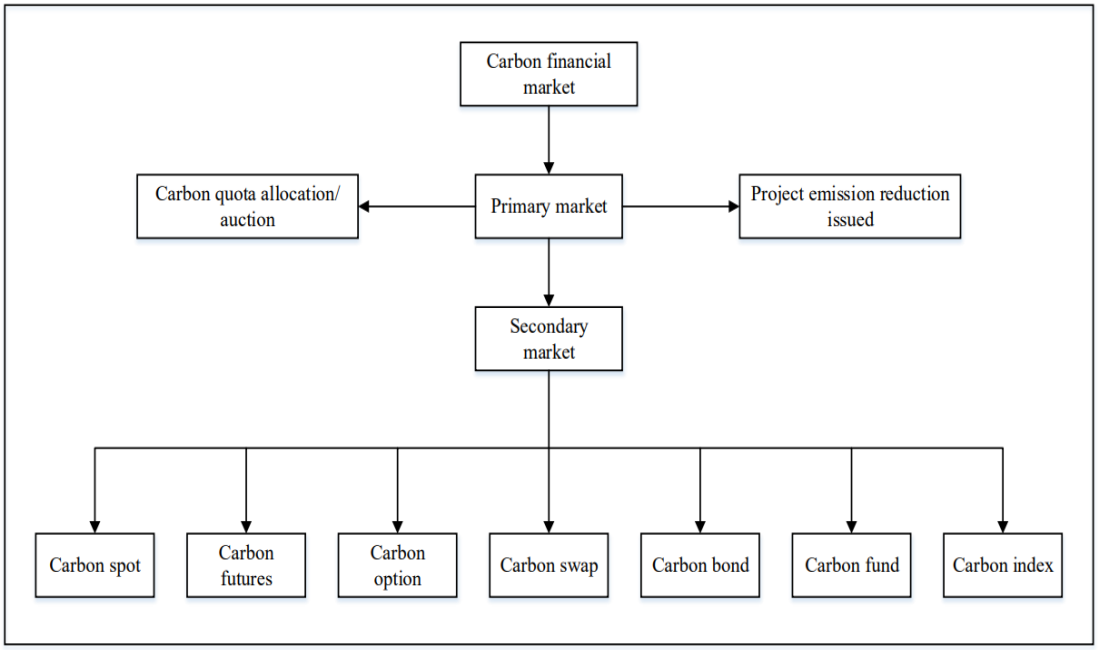


Figure 2.1 Carbon Finance Market Structure

Source: Global asset management.

2.3.1.2 Carbon Financial Products

Carbon financial products are the mapping of mainstream financial products in the carbon market, and the abundance of carbon financial products can help promote the establishment of a sound carbon financial market system and broaden the depth and breadth of the market. Carbon financial products are traded by various types of subjects

in the carbon financial market and are classified in multiple ways according to different perspectives. In this study, carbon financial products are classified into three categories: trading, financing and support from a functional point of view.

Firstly, carbon financial trading instruments include carbon futures, carbon forwards, carbon swaps and carbon options. Carbon futures refers to trading Carbon Dioxide (CO_2) emission rights between buyers and sellers, as opposed to carbon spot, with delivery of the underlying material at a specified date in the future (Hwang et al., 2023). Note that carbon forwards and carbon futures are similar in nature, mainly since carbon forwards have a standard determined by private negotiation between the parties to the transaction and lack the standard of carbon futures. Carbon swaps generally refer to the sale of carbon allowances in the current period in exchange for the delivery of China Certified Voluntary Emission Reduction (CCER) and a certain amount of currency in the forward period or the sale of CCER in the current period and the acquisition of the corresponding amount of carbon allowances in the forward period (Hou et al., 2020). Conversely, carbon options, which are more flexible than carbon futures, are options that are granted to buyers and sellers based on a pre-agreed agreement whereby the buyer pays a certain amount of premium to the seller (Wang et al., 2022).

Secondly, the financing tools of carbon finance include carbon pledges, carbon repurchases and carbon trusteeships. The carbon pledge is the full name of the carbon asset pledge, indicating that a company uses the carbon assets it has already acquired or will acquire in the future as a pledge or collateral for financing. At the same time, carbon custodianship suggests that a company hands over the operation of its carbon allowance assets to an intermediate management structure, earning a corresponding capital gain.

Thirdly, the supporting tools of the carbon financial market refer to carbon indices and carbon insurance. Carbon indices refer to the carbon market value index and the carbon liquidity index, depicting the trend of the carbon emissions trading market based on the three perspectives of carbon trading price, trading volume and liquidity. Correspondingly, investors can analyse the operation of the carbon emissions market with the help of carbon indices (Trouwloon et al., 2023). In contrast, carbon insurance is set up in response to the risks associated with the carbon financial market. It is a form of insurance for the delivery of project emission reductions or capital guarantees. In the long term, the state needs to promote the establishment of a

professional risk assessment organization and facilitate the construction of the corresponding laws and regulations (Kaarakka et al., 2022).

According to the 2023 China Carbon Market Annual Report released by the Green Finance Research Institute of the Central University of Finance and Economics (CUFE), the annual report reveals that the current development of carbon financial instruments in China presents two notable features, namely significant differences in product maturity and uneven regional development. In terms of product exploration, China has explored relatively more carbon market financing tools and support tools. However, the overall scale of these tools is still relatively small, and a mature model that can be replicated and scaled up has yet to be formed. In contrast, the development of trading tools is still in the early stages of exploration, especially in the field of carbon futures, which is still blank and mainly related to the development stage of China's carbon market. Currently, China's carbon market is relatively primitive in terms of trading methods. It lacks the mainstream trading methods of modern financial markets, such as continuous trading and pooled bidding, limiting the frequency of spot trading and market activity. In addition, the breadth and depth of China's carbon market are insufficient. That is, the carbon market covers a limited number of industries and emission-control companies, and the market participants are obviously insufficient and have a single structure. At the same time, the market often demonstrates the tidal phenomenon of rising volume and low trading after the compliance period. The combination of these factors has led to a lack of effectiveness in the Chinese carbon market. This, in turn, has affected the launch and development of carbon futures and other trading tools in China.

The 2023 China Carbon Market Annual Report released by the Green Finance Research Institute of the CUFE, the annual report suggests that in terms of regional development, the regional pilot carbon market is ahead of the national carbon market in terms of practical innovations in various types of financial instruments. Among them, five regions, namely Beijing, Guangdong, Shenzhen, Hubei and Shanghai, are in the leading position in terms of exploration, with layouts in the three major types of tool segments: financing, trading and support. Overall, although the current development of carbon financial instruments still has problems, such as significant differences in product maturity and unbalanced regional development, some pilot regions have made positive progress in product innovation and market mechanism improvement. In the

future, with the gradual establishment and improvement of mechanisms such as compensated allocation and market stability, as well as the continuous optimization of the investor structure, carbon financial instruments are expected to achieve a broader and higher level of development. This aims to provide strong support for the efficient operation of the carbon market and achieving emission reduction targets. Table 2.1 provides the carbon financial product services conducted by each carbon trading pilot in China.

Table 2.1

Main Operational Carbon Financial Products in China's Carbon Market

Carbon Finance Product Categories		**Carbon Finance Practices in China's Major Carbon Markets**							
Carbon market finance tools	Carbon bonds	National	Beijing	Shanghai	Guangzhou	Hubei	Shenzhen	Tianjin	Chongqing
	Carbon asset pledge financing	√					√		
	Carbon asset buyback	√	√	√	√	√	√	√	√
	Carbon asset custody		√	√	√		√		
Carbon market trading tools	Carbon forwards				√	√	√		
	Carbon future			√	√	√			
	Carbon options		√				√		
	Carbon swaps		√						
	Carbon credits and loans								
Carbon market support tools	Carbon index		√	√	√				
	Carbon insurance			√	√	√			
	Carbon fund		√	√		√	√		

Source: International Institute of Green Finance, Central University of Finance and Economics.

2.3.2 Carbon Price

Carbon price, which captures the external cost of greenhouse gas emissions, is used to internalize the external cost of carbon emissions and aims to assign a clear economic cost to greenhouse gas emissions (Mehling & Tvinnereim, 2018). Based on the polluter pays principle, pricing carbon and other greenhouse gases emphasizes that polluters should bear the economic costs of the environmental damage they cause and can provide incentives for companies and individuals to reduce their greenhouse gas emissions. This contributes to the fight against climate change and reducing carbon emissions (Kesor, 2022).

Carbon price mainly includes direct carbon price and indirect carbon price. Direct carbon price is a way to directly regulate greenhouse gas emissions by explicitly setting a price on carbon emissions, which mainly includes carbon tax and ETS (Liu & Wu, 2017). Meanwhile, an indirect carbon price indirectly influences the costs and behavior of carbon emissions through other policy measures. These measures do not directly put a price on carbon emissions but aim to reduce them by influencing energy prices, consumption behavior and technology choices, and include, inter alia, subsidies, standards, regulations and energy taxes. Furthermore, the direct carbon price has strong economic incentives by directly regulating carbon emissions through clear price signals. In contrast, the indirect carbon price has flexibility and breadth by influencing the costs and behavior of relevant activities to achieve emissions reductions (Cotton & Trück, 2011). A combination of the two can be more effective in combating climate change and achieving Sustainable Development Goals (SDGs) (Hagmann et al., 2019).

Carbon market price (carbon price) refers to the actual price at which carbon permits or credits are traded in each carbon market based on supply and demand. The price reflects the amount market participants are willing to pay for the right to emit or reduce a certain amount of greenhouse gases at a given time (Chung et al., 2018). Moreover, carbon price provides market participants with a clear economic signal of the marginal cost of carbon emissions, which can fluctuate in response to changes in policy, technological advances, market expectations and other economic and environmental factors (Richstein & Neuhoff, 2022).

2.3.2.1 Factors Affecting Carbon Price

Factors affecting carbon price are manifold, including macroeconomics, energy prices, supply and demand, political factors, climatic factors and price of related products. These factors interact with each other to determine the price trend in the carbon market (Peter Simpa et al., 2024).

a) Macroeconomic

During economic booms, companies are more profitable, and demand for carbon credits increases, driving up the price of carbon. During recessions, demand decreases, and the price of carbon then falls (Jia, 2023).

b) Energy price

Fluctuations in energy prices (e.g., oil, coal, natural gas and electricity prices) can affect a company's production costs and profits, affecting the demand for and price of carbon credits (Yang et al., 2019). For example, higher prices for fossil fuels such as coal and oil may increase the cost of abatement for companies, thereby increasing the demand for carbon credits.

c) Supply and demand

Prices in the carbon trading market are mainly determined by supply and demand. When the demand for carbon credits exceeds the supply, the price will rise; conversely, when the supply exceeds the demand, the price will fall (Wang et al., 2020). This pricing mechanism helps to incentivize companies to reduce greenhouse gas emissions. The supply of carbon products is mainly from countries' national quota schemes, while the demand comes from individual companies and organizations within the schemes. In addition, governments influence the market supply, and hence the price of carbon trading, by adjusting, for example, the total carbon emission limits and the way in which allowances are allocated (Li et al., 2023).

d) Climatic factors

The relationship between weather factors and the price of carbon credits is very close, affecting the price indirectly, mainly through changing the demand for carbon credits. In addition to the need to burn fossil fuels for heating in cold weather, other weather factors, such as wind speed and rainfall, can impact the efficiency of power plants in generating electricity. This, ultimately, affects the demand for fossil fuels and

carbon emissions (Sitarz et al., 2024).

e) Policy factors

As a special market guided by national or international policy, market participants need to pay attention to changes in national quota schemes, linkage mechanisms and international emission reduction agreements, which will affect the space and price in the carbon trading market (Dolphin et al., 2020).

2.3.2.2 Developments in Carbon Price

Figure 2.2 illustrates that Beijing possesses the highest average annual carbon price from 2013 to 2023, with a range of RMB 50 to 101 per ton and a mean carbon price of approximately RMB 66.37 per ton. The average yearly carbon price in Shenzhen exhibits a U-shaped trend and ranks second nationally, with an average carbon price of approximately RMB 40.46 per ton. The average annual carbon price in Guangdong also follows a U-shaped trend and ranks third in the country, with an average carbon price of about RMB 38.56 per ton. At the same time, the average yearly carbon price in Shanghai ranges from RMB 29 to 63 per ton, with a mean of approximately RMB 37.44 per ton, making it the fourth highest in the nation, and it has consistently risen since 2016. The average carbon price in Hubei Province is approximately RMB 29.07 per ton, consistently increasing since 2017. The average carbon costs in Tianjin and Chongqing were RMB 23.19 per ton and RMB 21.85 per ton, respectively.

The average carbon price of the carbon trading pilots remains significantly lower than that of other nations. For instance, the carbon price in international carbon trading markets, such as the European Union, has just surpassed 50 euros per ton, approximately tenfold the carbon price in China. The World Bank: State and Trends of carbon price 2021 indicates that China's carbon price potential remains underexploited (Luo et al., 2021). Additionally, studies indicate that reduced carbon price fail to enhance the pricing mechanism of the carbon market (Yang et al., 2022). Consequently, the long-term escalation of carbon price is essential for incentivizing companies to adopt emission-reducing decisions and effectively leverage the carbon price mechanism.

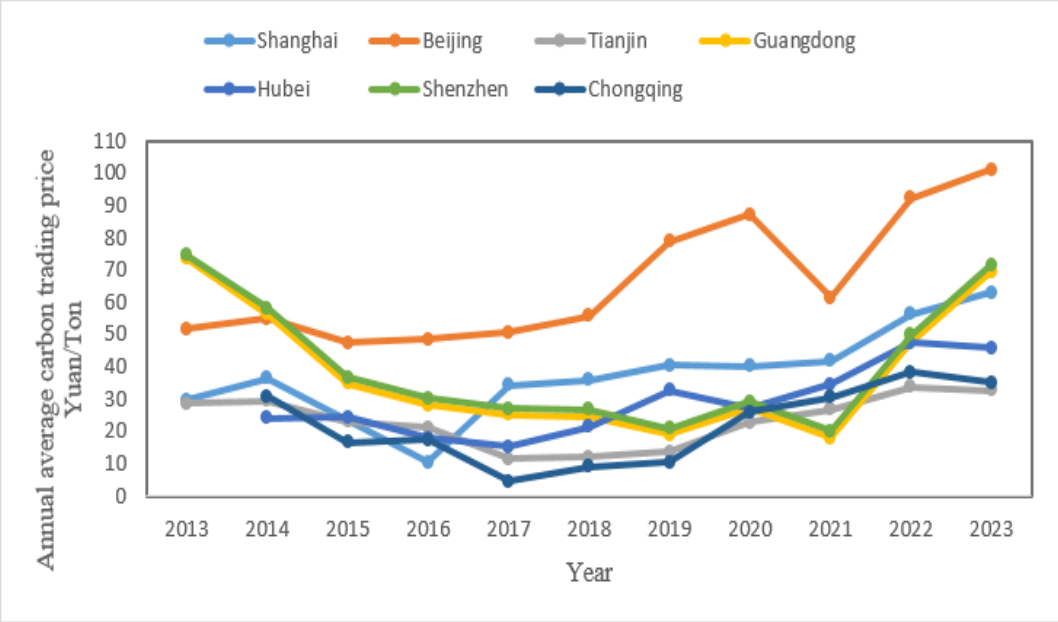


Figure 2.2 Average Carbon Price of Carbon Trading Pilots in 2013-2023 (Unit: Yuan/Ton)

Source: Carbon emissions trading (2024)

2.3.3 The Evolution of Carbon Trading Policy

2.3.3.1 Carbon Emissions Trading Principles

The concept of carbon emissions trading originated in the 1990s when economist Dales introduced the idea, drawing from Coase's theory of property rights and the concept of externalities in environmental harm (Coase, 1960). In 1968, the American economist Dales, in his paper "Pollution, Property, and Price: Policymaking and Economics," first proposed a related design for emissions trading, defining an emissions right as the right of a right holder to emit a pollutant into the environment, subject to the conditions outlined in the law (Dales, 1968; Dales, 2002). Thus, the government grants or sells pollution licenses to companies, and companies can purchase and sell pollution permits via market transactions, thereby minimizing the cost of emission reduction and achieving optimal allocation of resources. Emissions trading is an essential environmental economic policy in market economies, and the United

States (US) National Environmental Protection Agency (NEPA) first applied it to the treatment of air and river pollution. In the 1990s, the US successfully decreased sulfur dioxide emissions by implementing an emissions trading system. Furthermore, the US actively promoted the adoption of emissions trading in Germany, the United Kingdom (UK), Australia, and other nations sequentially (Stavins, 1998; Ellerman et al., 2002).

Carbon emissions trading is a market-based economic approach used to address climate change. It involves establishing a price on CO_2 in order to reduce emissions of this greenhouse gas (Chen & Lin, 2021). Carbon emissions trading, or cap-and-trade, refers to establishing the quantity of carbon emission allowances permitted within a specific jurisdiction within a defined timeframe. This includes allocating the total amount in the form of allowances to individuals or organizations, offering them the legal right to emit carbon. Additionally, market mechanisms allow these rights to be traded like commodities between participants in a trading market. This ensures that actual carbon emissions do not exceed the total amount of emissions limited or are offset with other complementary trading instruments. Consequently, carbon emission control objectives are achieved in a cost-effective manner (Hua & Dong, 2019).

Currently, most countries utilize the Cap and Trade approach, which is based on the fundamental concept of the government establishing a yearly target for reducing the overall quantity of carbon emissions based on environmental capability. The system assigns or sells allowances to companies, which can be purchased and traded by companies and investors in the market. Accordingly, companies that have lower CO_2 emissions than their allowances are able to sell their allowances, and those whose actual emissions are higher than their allowances must buy allowances for the excess emissions in order to fulfil their compliance obligations (Sato et al., 2022; Zhao et al., 2016). This institutional setup creates incentives for companies with low costs of reducing emissions to optimize their efforts in reducing emissions. Moreover, companies with high abatement costs will decide to buy quotas for compliance, resulting in equal marginal abatement costs across all companies. This ensures that the entire market achieves the abatement target at the lowest cost, ensuring Pareto optimality (Narassimhan et al., 2018). Figure 2.3 depicts the carbon market's structure.

The carbon trading system (ETS) utilizes a market mechanism to allocate

environmental resources by limiting their usage. The ETS operates as follows: initially, the government sets a cap on the total quantity of emissions allowed within a certain compliance period (Ye et al., 2013). Furthermore, inside the ETS, companies are allowed to implement three distinct categories of measures aimed at reducing emissions: Trade of quotas (Scheelhaase et al., 2016), limitations in production or advancements in technology (Yu et al., 2020). Upon the conclusion of the compliance period, the third-party organization carries out the task of Measuring, Reporting, and Verifying (MRV) to evaluate the emission reductions and emissions of companies (Tang et al., 2020; Munnings, Morgenstern, Wang, & Liu, 2016). Carbon emissions trading facilitates the attainment of Pareto optimality (Dales, 1968). China's status as the largest worldwide emitter of greenhouse gases makes it crucial for the country to prioritize the adoption of carbon emissions trading in order to actively participate in international climate governance (Tang et al., 2017).

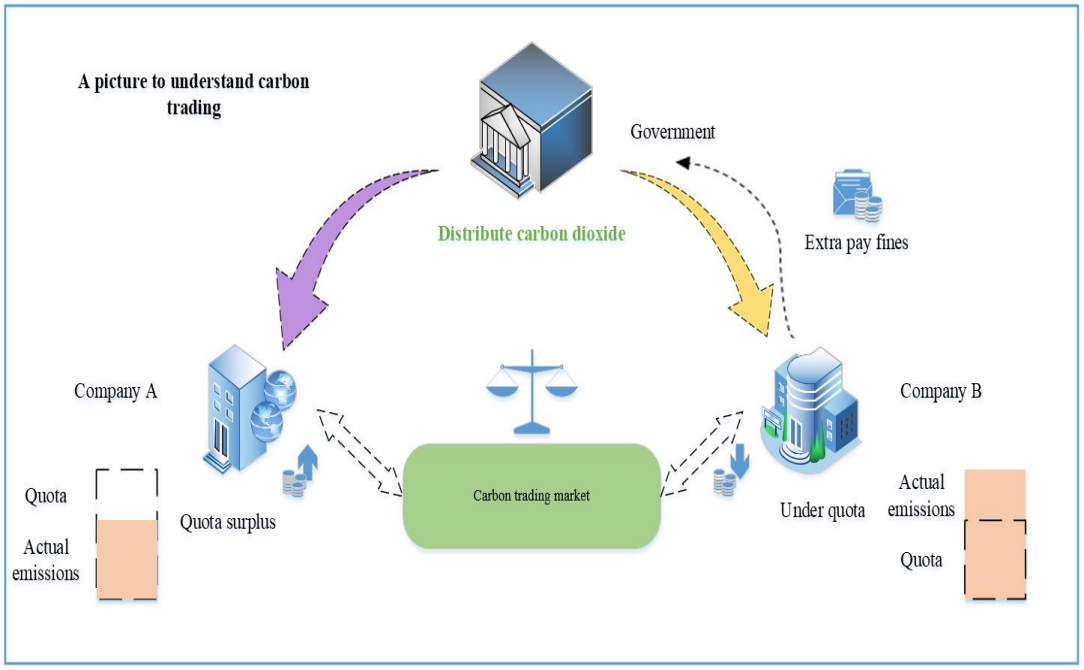


Figure 2.3 Structure of Carbon Trading Market

Source: US Environmental Protection Agency (EPA)

2.3.3.2 Development of Global and Chinese Carbon Market

Between 2002 and 2023, multiple carbon trading systems were established across four continents. There were 28 carbon trading schemes in operation worldwide as of January 2023, and there were over 20 more in the process of being developed or designed. At present, carbon markets are responsible for 17% of global greenhouse gas emissions, 33% of the population, and 55% of Gross Domestic Product (GDP), with implementation regions moving progressively from developed to poor nations (Effectiveness and Prospects of China's Carbon Market, 2024). The worldwide carbon trading system primarily comprises the European Union Emissions Trading System (EU-ETS), which was the first of its kind in the world, as well as the US Regional Greenhouse Gas Reduction Initiative (RGGI) and the US California Cap-and-Trade Program (CCAT), Australian Carbon Price System (ACPS), Tokyo Metropolitan Total Control and Trading Scheme, Japan (Tokyo-CAT), and New Zealand Carbon Trading System (NZ-TS), to name a few (Perdan & Azapagic, 2011). Regional carbon markets have also been established in other regions, such as Tokyo and Saitama Prefecture in Japan, South Korea and Kazakhstan. The fundamental reason for the blossoming of regional carbon markets is that countries worldwide agree with the carbon market's mechanism for reducing emissions. They have vigorously promoted and constructed carbon markets, resulting in today's booming situation (The Foresight Economist, 2022). The development of the global carbon trading market is illustrated in Figure 2.4.

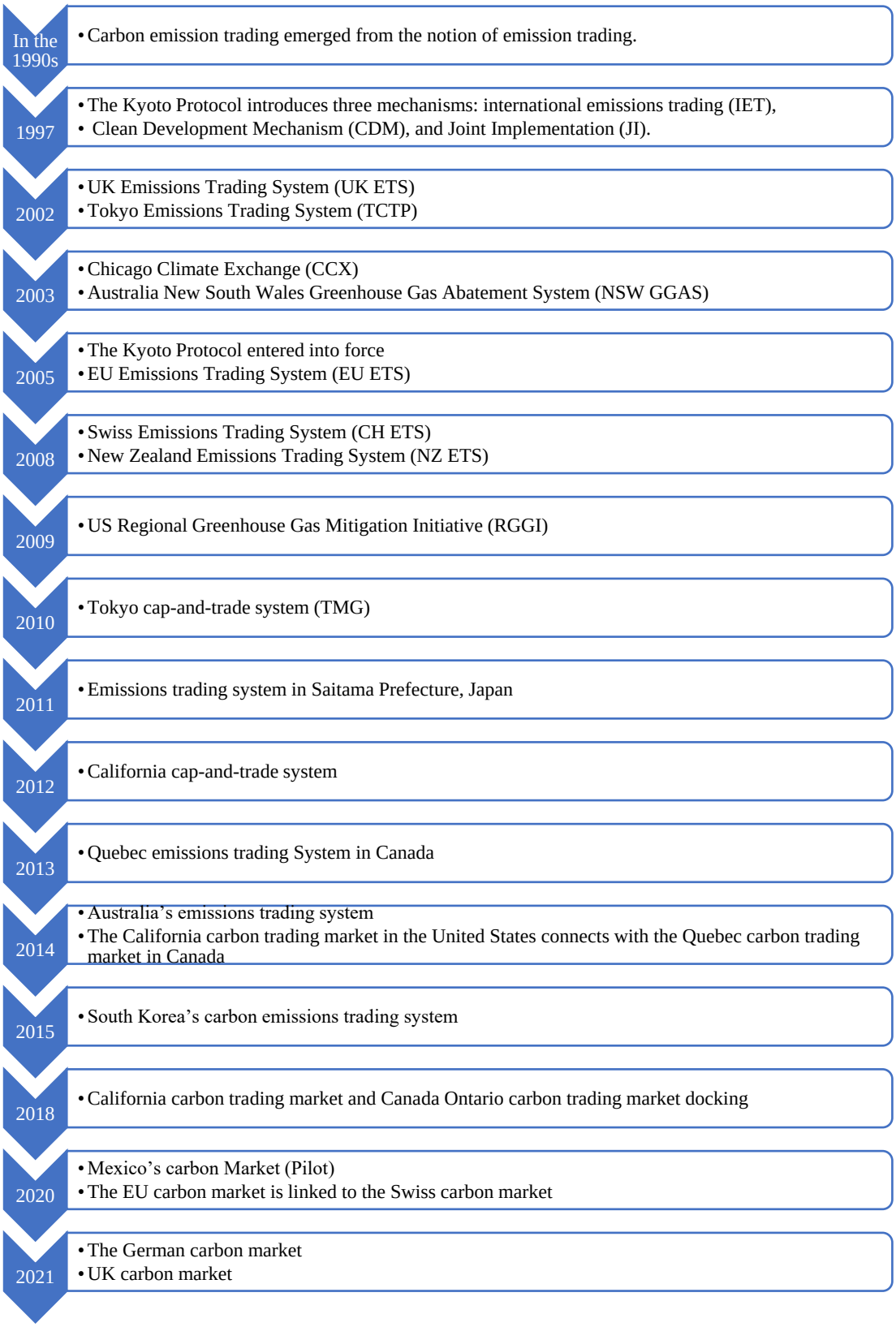


Figure 2.4 Global Carbon Market History

Source: Global carbon trading status and outlook (2023)

During the United Nations General Assembly on September 22, 2020, China's General Secretary Xi Jinping announced that China will increase its domestic contribution, enforce stricter policy and regulations, strive to peak its CO_2 emissions by 2030 and work towards achieving carbon neutrality by 2060 (Song et al., 2020). The dual-carbon strategic aim, often known as dual-carbon, is a carbon reduction objective introduced by China that involves two distinct phases. Dual carbon is a shortened form of the expressions Carbon Peak and Carbon Neutral (Global Times, 2023). A carbon peak is the moment when the emissions of CO_2 stop increasing and reach their maximum amount, after which they gradually decrease. Meanwhile, carbon neutrality is achieved when the net release of CO_2 into the atmosphere, caused by human activities within a particular area and timeframe, is offset by the amount of CO_2 absorbed from the atmosphere, usually by tree planting. This balance allows for the achievement of zero net CO_2 emissions. In essence, this implies that for the environment to attain a state of zero emissions, there must be a reduction or elimination of the quantity of carbon generated (Global Times, 2023). China's dedication to tackling climate change is evidenced by these endeavors.

In 2011, in accordance with the directives of the 12th Five-Year Plan Outline, a carbon emissions trading market was established in a gradual manner. Seven provinces and municipalities in China, including Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong, and Shenzhen, have initiated pilot programs for carbon emissions trading. The carbon pilot program encompasses eight industries known for their significant contribution to pollution: petrochemicals, chemicals, building materials, iron and steel, nonferrous metals, paper, electric power, and aviation (China's Plan for National Economic and Social Development, 2011). Since 2013, seven local pilot carbon markets have been established to facilitate trading greenhouse gas emissions. These markets have effectively encouraged pilot provincial and municipal companies to reduce their emissions. Additionally, they have developed a system, gained valuable experience, and set the groundwork for the national carbon market. The Sichuan Joint Environmental Exchange was created on May 6, 2016, as the 8th carbon trading pilot program in China. In December 2016, the province of Fujian initiated its carbon trading market, making it China's 9th carbon trading pilot programmer. Figure 2.5 provides the

date of the establishment of the China Carbon Exchange.

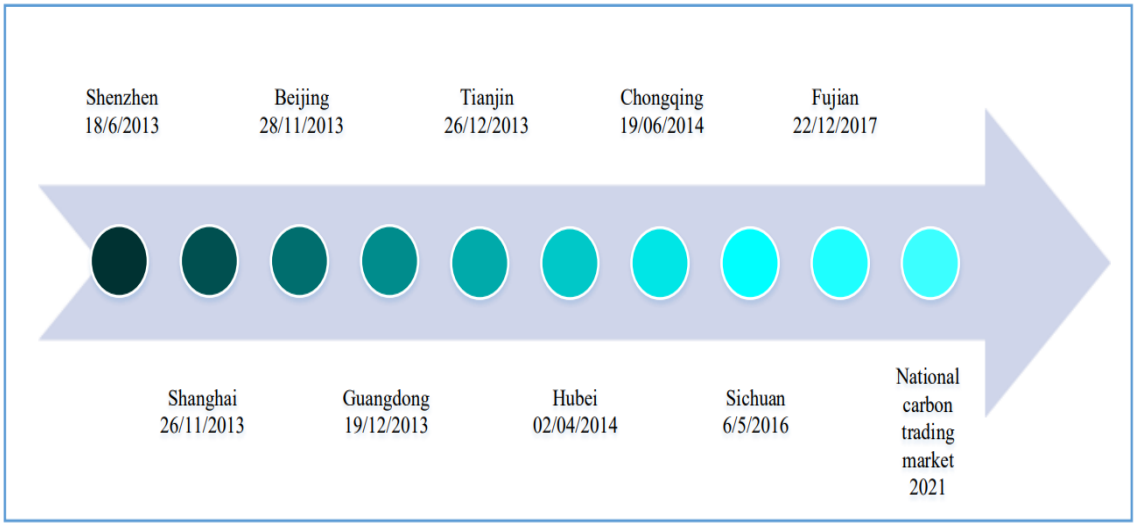


Figure 2.5 Date of Establishment of Carbon Emissions Exchange

Source: Carbon emissions trading (2021)

In December 2017, the National Development and Reform Commission (NDRC) issued the National Carbon Emission Trading (CET) Market Construction Program (Electric Power Sector) with the endorsement of the State Council (National Development and Reform Commission, 2017). This marks the official launch of China's carbon emissions trading system and the finalization of its comprehensive design (Jiang et al., 2018). The inaugural compliance cycle of the national carbon market will commence by the conclusion of 2020, with the Ministry of Ecology and Environment unveiling the Measures for the Administration of Carbon Emissions Trading (for Trial Implementation) and releasing the Implementation Plan for the Setting and Allocation of Total National CET Allowances for 2019-2020 (Power Generation Sector). The national carbon emissions pricing market used a dual-track strategy of local and national markets and began online trading on July 16, 2021. During the 14th Five-Year Plan era, the national carbon market will incorporate eight main emitting industries in a descending sequence of significance: petrochemicals, chemicals,

building materials, iron and steel, nonferrous metals, paper, electric power, and aviation. The power generation industry will be the initial sector to be incorporated into the national carbon market, with more than 2,000 emission units of high importance (Song et al., 2020). As of 31 December 2024, the cumulative turnover of carbon emission allowances in the national carbon market was 630 million tons, with a cumulative turnover of RMB 43.033 billion. China's carbon market is anticipated to become the largest global market for greenhouse gas emissions. Figure 2.6 portrays the history of the development of China's carbon emissions trading market.

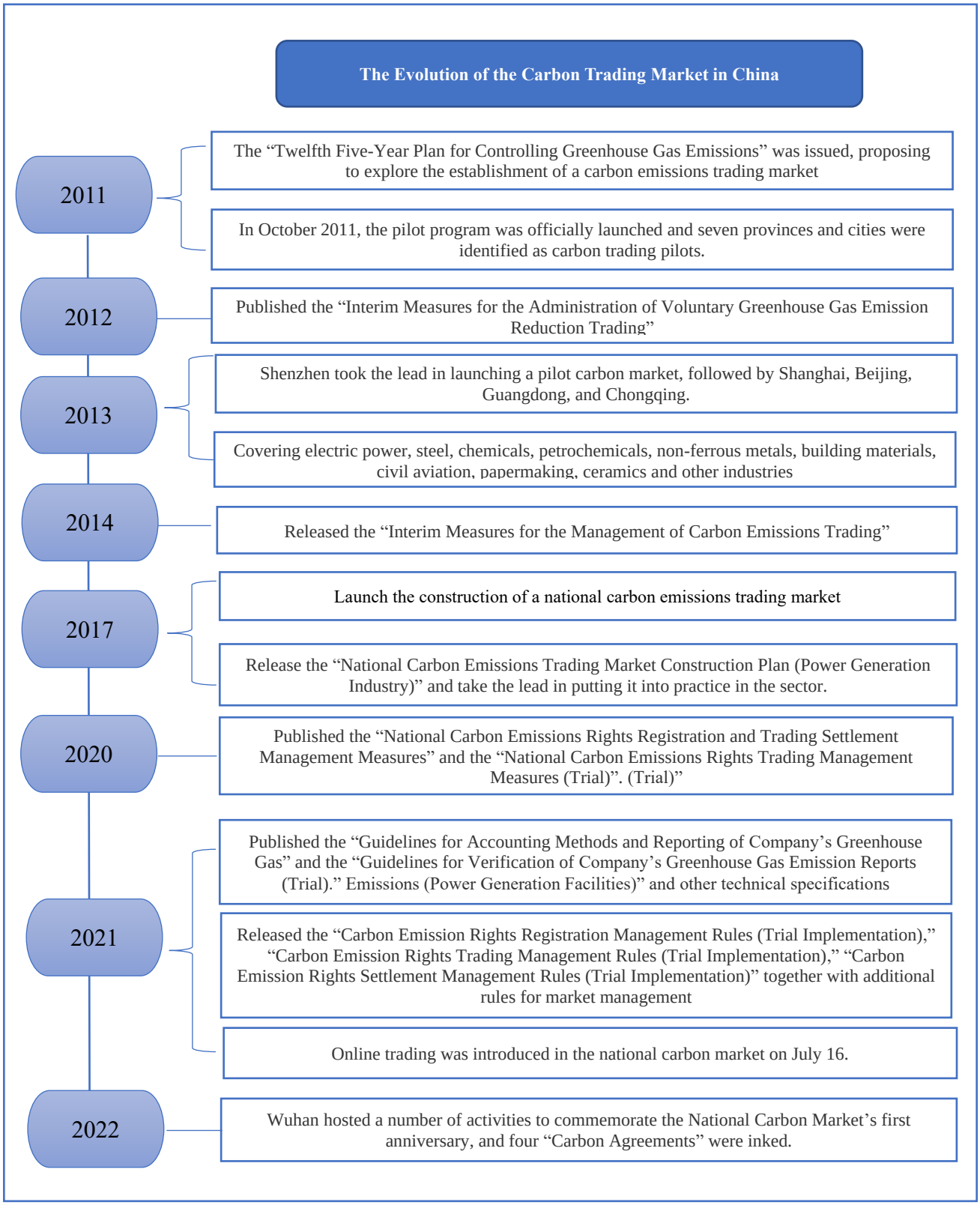


Figure 2.6 The Development of the Carbon Trading Market in China

2.4 Green Technology Innovation: A Catalyst for Performance

This section describes the development of the green technology innovation policy, the current status of green technology innovation, its regulatory role, and examples of green technology innovation.

2.4.1 Development of Green Technology Innovation Policy

Green technology innovation has emerged in the context of advocating energy saving and emission reduction, low carbon and environmental sustainability. It aims to transform the current crude production and operation mode, mitigate climate problems, and ensure the successful realization of the dual-carbon target. The concept of green technology was first proposed by Braun and Wield in 1994. They believed that green technology is a general term for technologies, processes, and products that reduce environmental pollution and energy consumption (Braun & Wield, 1994). Green technology innovation is a kind of technological innovation that is different from general technological innovation. It is a kind of management and technological innovation aiming to protect the environment (Nuryakin et al., 2022).

With China's increasing emphasis on environmental protection, the concept of green technology has been introduced into the country. The Organization for Economic Co-operation and Development (OECD) describes green technology innovation in a broader sense: any technology, process or form of industrial organization that reduces the impact on the environment, either intentionally or unintentionally, and protects or improves the environment (OECD, 2009). In 2019, the Chinese government provided a detailed definition of green technology in its Guidance on Building a Market-Oriented green technology innovation System. It refers to emerging technologies that reduce consumption, reduce pollution, improve ecology, promote the construction of an ecological civilization, and achieve harmonious coexistence between human beings and nature. This includes technologies in the fields of energy conservation and environmental protection, clean production, clean energy, ecological protection and restoration, urban and rural green infrastructure, and eco-agriculture. It also covers product design, production, consumption, recycling and other aspects.

This study considers green technology innovation as an innovative activity based on the application of new knowledge and technology through the improvement of new processes and the creation of new products. It aims to reduce the consumption of resources and energy in the company's production process, to avoid, mitigate or eliminate the pollution and destruction of the ecological environment caused by the production and operation, and ultimately to realize the company's economic value and environmental value.

The history of the policy development related to green technology innovation in China is displayed in Figure 2.7. The 2008 Beijing Olympic Games advocated the Green Olympics, popularized the green concept and promoted a green civilization. As China's crude economic growth in the early days of reform and opening up triggered serious environmental problems, the Fifth Plenary Session of the 18th CPC Central Committee creatively put forward the concept of green development among the five major development concepts. In 2019, the report of the 19th CPC National Congress put forward the "Guiding Opinions on Building a Market-Oriented green technology innovation System." It highlights that green technology innovation is increasingly becoming a vital driving force for green development and an essential support for promoting high-quality development. Moreover, it stresses that it is necessary to stimulate the market demand for green technology as a breakthrough and to accelerate the construction of a green technology innovation system with the company as the main body.

In February 2021, the State Council issued the "Guiding Opinions on Accelerating the Establishment of a Sound Green, Low-Carbon and Cyclical Economic System." It proposed to encourage the R&D of green and low-carbon technologies and accelerate the transformation of scientific and technological achievements in order to build a market-oriented green technology innovation system. In December 2022, the NDRC and the Ministry of Science and Technology (MOST) jointly issued the "Implementation Plan for Further Improving the Market-Oriented green technology innovation System (2023-2025)" to give full play to the key supportive role of green technologies for green and low-carbon development. It also aims to promote the formation of a new pattern of green technology innovation. Since the imbalance and insufficiency between China's economic, social, and ecological development remain

prominent, the successive introduction of a series of policy documents reflects the government's emphasis on green technology innovation. These policies have helped to promote industrial transformation and advance the construction of an ecological civilization.

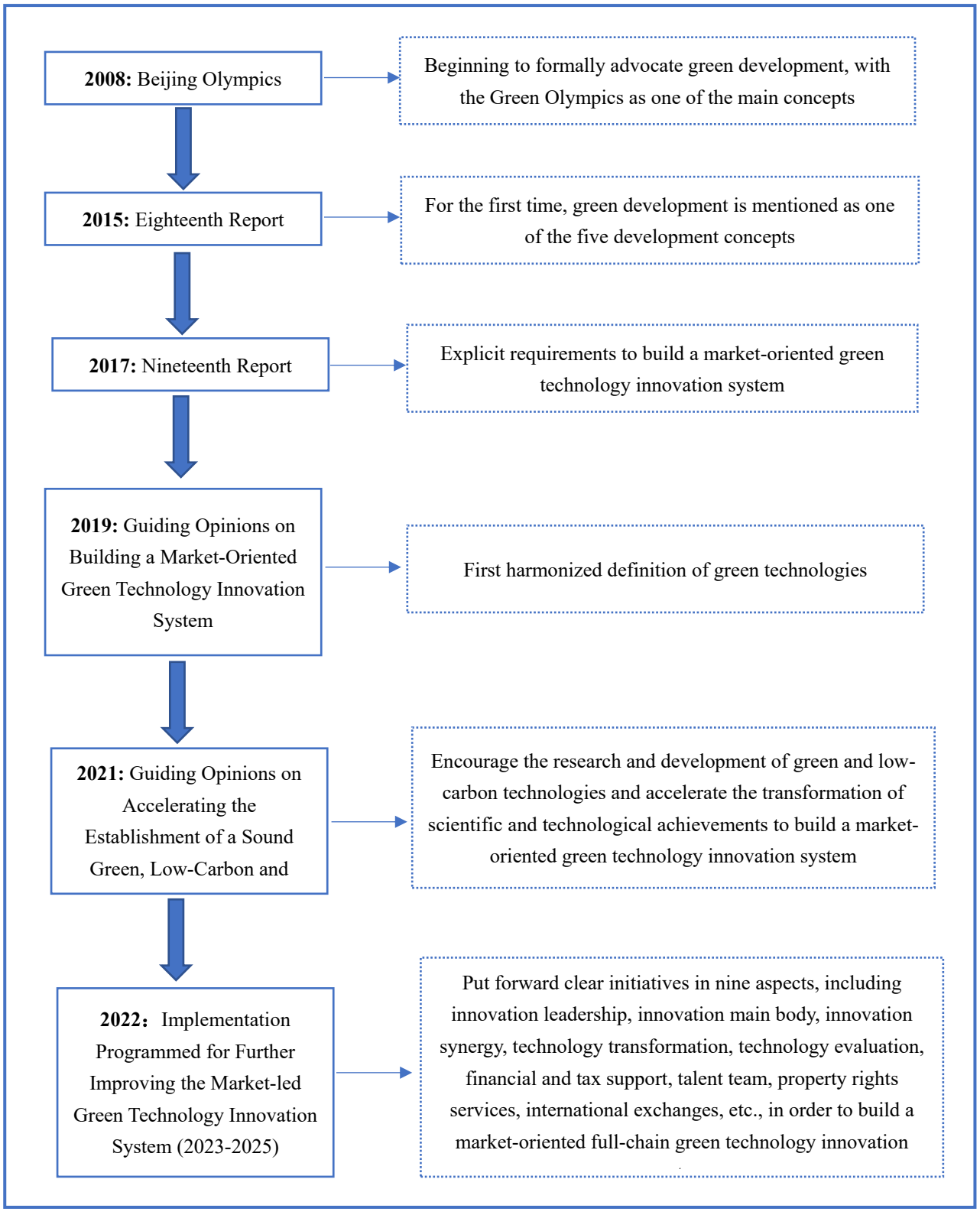


Figure 2.7 History of Green Technology Innovation Policy

2.4.2 Current Status of Green Technology Innovation

Within the framework of the carbon market, the company's green technical innovation exhibits a favorable dimension, although it also encounters obstacles. The advantageous aspect is observed in the heightened incentive for innovation, the generation of innovative outcomes, and the rise in the number of participating entities.

Carbon markets increase companies' incentives to innovate. Through the establishment of total carbon emission objectives and the allocation of quotas, the carbon market has created an environment where carbon emissions incur costs and carbon reductions yield rewards (Cui et al., 2022). Companies' motivation to evade the expenses associated with acquiring carbon permits beyond their allotment or to capitalize on the advantages of selling surplus allowances may result in heightened innovation in green technologies and, thus, reductions in carbon emissions (Zhao et al., 2024).

Since the inception of the carbon market in 2013, the high-carbon energy sector has realized several advances (Liu et al., 2020). Many companies have augmented their R&D efforts and applications in renewable energy, including wind power and photovoltaics (He et al., 2021). Certain organizations have achieved advancements in solid waste resource utilization technology, while others have persistently enhanced their pollution control technologies. This includes electric dust removal, desulfurization, and denitrification. As a result, the standard of process technology has been enhanced (Fang et al., 2023).

Since the inception of the carbon market, there has been a steady rise in the number of participants. It has broadened from the original electric power sector to encompass significant emission industries, including iron and steel, cement, and chemicals (Rissman et al., 2020). In addition, an increasing number of organizations recognize the significance of reducing carbon emissions and innovating green technology. This is with some small and medium-sized companies actively pursuing avenues for enhancing green technology innovation (Zhang et al., 2019).

Obstacles to green technology innovation include the need for further technological advancements, a lack of capital and skilled personnel, and implementation challenges. There are technical hurdles that must be overcome. Despite

some progress in crucial areas such as carbon capture and storage technology, significant challenges remain, including high costs and suboptimal efficiency (Wilberforce et al., 2019). Furthermore, many green technology research institutions are underdeveloped, exhibiting a scarcity of original innovations, while reliance on imports and other bottlenecks continues for essential technologies (Wang et al., 2024).

The lack of financial resources and skilled professionals is a significant barrier to green technical innovation. This type of innovation requires substantial capital investment, involves a lengthy timeline, and faces challenges in achieving desired outcomes. Additionally, many organizations struggle with insufficient financial resources (Khan et al., 2022). Moreover, advancing green technology innovation demands interdisciplinary and cross-sector expertise. The shortage of skilled experts in these areas limits the potential for progress (Cunha et al., 2014).

Barriers to the translation of results are also a challenge for green technology innovation. The R&D cycle for green and low-carbon invention patents is protracted and costly (Yang et al., 2021). Additionally, the process of result transformation encounters hazards such as market acceptability and technological iteration, making it challenging to convert outcomes effectively (Pei & Wang, 2022).

2.4.3 The Moderating Role of Green Technology Innovation

Green technology innovation serves a significant moderating function between carbon market mechanisms (including carbon finance, carbon price, and carbon tradin g regimes) and company performance (including economic and sustainable performan ce) (Figure 2.8), as detailed below:

a) Carbon Finance, Green Technology Innovation and Company Performance

Innovations in green technology enhance the efficiency and effectiveness of finance (Yang & Masron, 2022). Carbon finance offers financial assistance for the company's green technology innovation, which is applicable to the R&D of low-carbon technologies and the acquisition of environmental protection equipment, among other uses. This enhances resource utilization efficiency, decreasing production and

operational costs and improving economic performance (Hu et al., 2021). In other words, green technology innovation helps companies diminish their reliance on conventional energy sources, mitigating environmental risks. It cultivates a positive social image, attracts environmentally conscious investors and customers, and enhances sustainable development capabilities (Zhou & Cui, 2019).

Green technology innovation fosters the development and implementation of financial products. The outcomes of green technology innovation can serve as a foundation for producing carbon financial products, including novel financial instruments derived from a company's reductions in carbon emissions (Zhao & Hu, 2024). Additionally, this enhances the carbon finance market and introduces new funding avenues and risk management instruments for companies, thereby improving their economic and sustainable performance (Brahmi et al., 2023).

b) Carbon Price, Green Technology Innovation and Company Performance

Innovations in green technology assist companies in managing cost concerns. As the carbon price escalates, the expense associated with carbon emissions amplifies (Ellis et al., 2020). A corporation with sophisticated green technical advancements, such as effective carbon capture and storage systems, can decrease its required carbon permits, cut expenses, and sustain or enhance its economic performance (Feng & Lei, 2024). Simultaneously, green technical innovation enables companies to create more competitive low-carbon products and services within a high-carbon price framework, access new markets, and improve sustainable performance over time (Tvinnereim & Mehling, 2018). When carbon price decline, companies with green technology innovation can sustain reduced carbon emissions due to their technological advantages, hence securing a competitive edge in the market (Lilliestam et al., 2021).

Green technology innovation directs resource distribution and the trajectory of innovation. Carbon price fluctuations act as a market indicator, directing companies to allocate resources towards the innovation of green technologies (Tian et al., 2022). To respond to fluctuations in carbon price, the company will augment its investment in R&D of energy-efficient, clean energy, and other green technologies, optimize resource allocation efficiency, and facilitate technological advancement. This, ultimately,

improves its immediate economic performance and establishes a foundation for long-term sustainable development (Xu et al., 2023).

c) Carbon Trading Policy, Green Technology Innovation and Company Perform ance

Innovations in green technology facilitate regulatory compliance and enhance revenue generation (Zhang et al., 2019). Evidence from Chinese listed companies, stringent carbon trading regulations mandate that companies diminish carbon emissions. Companies excelling in green technology innovation can meet their emissions reduction goals via technical solutions, evading penalties for excess emissions, and monetizing surplus carbon allowances in the market for enhanced revenue and economic performance (Yu et al., 2022). From a sustainable performance standpoint, the company's proactive engagement with carbon trading policy to implement green technology innovation will facilitate the industry's green transformation. It also allows the company to sustain its leadership in the overarching trend of sustainable development(Li et al., 2023).

Green technology innovation facilitates industrial advancement and collaborative development. The carbon price regime has incentivized companies to use green technical innovations and advance industrial upgrades towards low carbon and environmental sustainability (Anser et al., 2021). Thus, by fostering collaboration and sharing technological advancements across companies, green industrial clusters are established to enhance the industry's overall competitiveness and attain collective advancements in economic and sustainable performance (Lv & Bai, 2021;Gao et al., 2022).

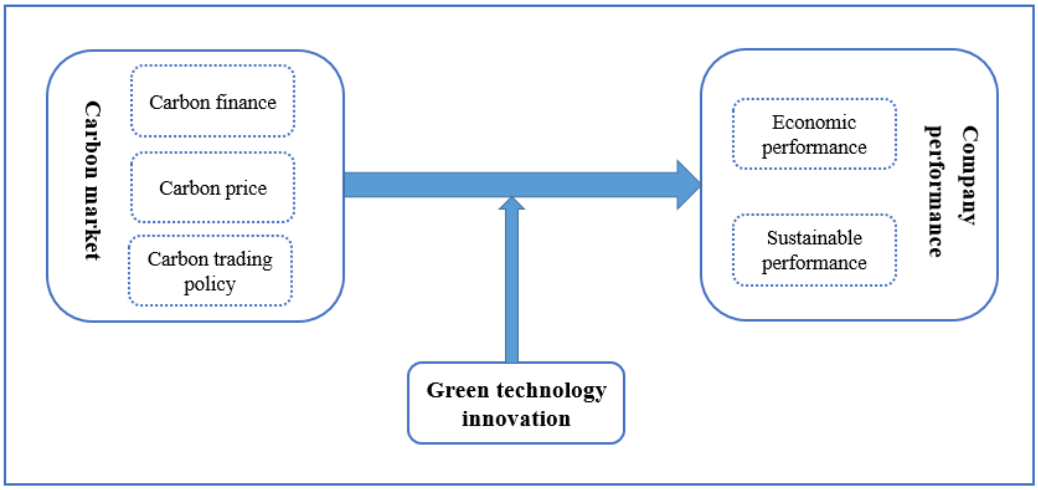


Figure 2.8 The Relationship between Carbon Market, Green Technology Innovation and Company Performance

2.4.4 Green Technology Innovation Case

As a leading technology company in China, Tencent actively responds to the national dual-carbon goal and promotes green and low-carbon transformation through technological innovation and capital investment. Carbon Quest is a billion-dollar funding programmer initiated by Tencent in the field of Carbon Capture, Utilization and Storage (CCUS). It aims to accelerate the research, development and application of CCUS technologies through flexible catalytic capital and open solicitation of project proposals for innovative technologies to push forward cutting-edge technologies towards large-scale application in 2030 and ultimately realize the reduction of emissions by 10 million tons of emission reduction (Carbonx program, 2024).

Tencent has provided financial support through the Carbon Finder programmer to help develop and promote CCUS technology. Although Tencent's Carbon Hunt programmer itself is not directly involved in the innovation of carbon financial products, it indirectly promotes the development of the carbon financial market by funding the research, development and application of CCUS technology. For example, as CCUS technology matures and is applied on a large scale, the cost of carbon capture and storage will decrease, thereby increasing the activity and liquidity of the carbon trading

market (Tencent, 2024).

The scaling up of CCUS technology can help reduce carbon emissions and thus positively impact the price of carbon. As carbon emissions decrease, carbon price may fall, depending on the supply and demand in the carbon market and the government's policy direction (Liu et al., 2018). Tencent's promotion of CCUS technology through the Carbon Hunt programmer will help stabilize the carbon price and reduce the company's exposure to the risks associated with carbon price volatility (Ruttinger et al., 2021).

Tencent's Carbon Finder programmer is closely related to the country's carbon trading policy. By funding the research, development, and application of CCUS technology, Tencent helps promote the implementation and improvement of carbon trading policy. As CCUS technology is applied on a larger scale, companies will have more opportunities to participate in carbon trading and thus reap the economic benefits of lower carbon emissions (Tencent, 2024).

Tencent has demonstrated its strong commitment and practical actions towards green and low-carbon transformation through the Carbon Finder programmer, which helps to enhance the company's brand image and social reputation. With the scaled application of CCUS technology, Tencent is expected to gain more business opportunities and partners to drive the company's business growth and value (Greig & Uden, 2021).

Tencent is actively fulfilling its social responsibility and promoting a green and low-carbon transition through the Carbon Finder programmer, which helps to enhance the company's ESG performance. With the rise of ESG investing, Tencent's superior ESG performance will attract more investors and partners to drive the sustainable development of the company's business (Tencent, 2024).

In this case, green technology innovation (i.e., the development and application of CCUS technologies) plays an essential moderating role in the carbon market mechanisms and company performance. By funding the R&D and application of CCUS technologies, Tencent promotes a green and low-carbon transition, enhances its company value, and optimizes ESG performance. This moderating effect reflects the critical role of green technology innovation in promoting the green and low-carbon transformation of the economy and society.

2.5 Research on the Interplay in China

Since the establishment of the EU carbon market in 2005, scholars have conducted extensive research on the topics of Green Finance (GF), carbon price, and carbon trading policy. Although previous studies have focused on developed economies, such as the EU member states, the US, Australia, and South Korea, they lacked an exploration of the interplay between China's unique economy and environmental regulation.

The development of China's carbon market has a unique context as well as realistic opportunities and challenges. Carbon finance and carbon price have unique impacts on heavily polluting industries and require more localized research considering China's unique policy environment and economic structure. This study focuses on the real-world context of China's carbon market mechanisms and explores the effectiveness of market-based environmental regulation in China. Table 2.2 summarizes research on carbon market mechanisms in China over the past three years.

Table 2.2
Recent Carbon Market Mechanisms Studies in China

No.	Author(s)	Area of Research	Sample and Year	Methodology	Results
1.	Xu et al. (2023)	Green finance on green technology innovation	1,079 companies from A-share listed industrial companies between 2009 and 2019	DID model and multiple regression analysis	Pilot GF policy not only promotes technology diffusion and the ESG scores of industrial companies but also reduces the carbon emission intensity of companies.
2.	Chen et al. (2022)	Green Financial Reform and ESG Performance	1,106 A-share listed companies from the CSMAR database between 2014 and 2020	DID model and multiple regression analysis	The establishment of the GF Reform and Innovation Pilot Zone Policy helps companies achieve higher ESG scores.
3.	Song & Liu (2023)	Carbon trading price and stock price	752 sample data from Shanghai and Shenzhen A-share listed companies between 2016 and 2020	VAR (Vector Auto regression Model) model and multiple regression analysis	Carbon trading prices have a diminishing effect on stock prices.
4.	Wu (2022)	Price and scale effects of China's	Sample of 1,835 counties in 30 provinces	DID model and multiple regression	Increased price and volume of ETS pilot transactions have a

		CET system pilots on emission reduction	between 2009 and 2017	analysis	sustained and significant impact on CO_2 emission reductions.
5.	Feng et al. (2024)	The role of carbon price signal in green innovation	Shanghai and Shenzhen a-share listed companies from the CSMAR database and official ETS websites between 2010 and 2020	Time-varying DID model and multiple regression analysis	Carbon price significantly promotes green innovation for both patents and utility models.
6.	Yu et al. (2022)	Emission trading system on carbon emission reduction and financial performance improvement	1027 a-share listed companies in the industrial sector during the period of 2010–2017 from the CSMAR database	Propensity score matching (PSM) and DID model and multiple regression analysis	The implementation of the pilot ETS has improved companies' financial performance and achieved carbon emission reductions.
7.	He et al. (2022)	Emission trading scheme and company value	1,267 listed companies from the local government's public documents and official ETS websites between 2005 and 2018	PSM-DID model and multiple regression analysis	ETS have an average short-term negative impact on company value.
8.	Zhang et al. (2023)	CET Policy on ESG Performance	Data on A-share listed companies in Shanghai and Shenzhen between 2011 and 2019	DID model and multiple regression analysis	The emission trading policy significantly improves the company's ESG performance.

2.6 Chapter Summary

This section presents the current state of company performance and the evolution of carbon market mechanisms (including carbon finance, carbon price, and carbon trading policy) within the sustainable development framework. It subsequently examines the progression of China's green technology innovation policy and elucidates the regulatory function of green technology innovation, accompanied by real-world examples. Finally, the research on the impact of carbon market mechanisms on firm performance is summarized. The following chapter presents this study's theoretical framework, conceptual framework, hypothesis formulation, and research framework.

CHAPTER 3

RESEARCH FRAMEWORK

3.1 Introduction

This chapter provides an overview of the theoretical basis for the study, the conceptual framework, hypothesis development, and the research framework. The chapter is partitioned into seven sections. Section 3.2 explains the underlying principles and concepts on which the study is based, i.e., Porter's hypothesis and innovation theory; Section 3.3 provides the conceptual framework, i.e., company performance (economic performance and sustainable performance) and carbon market mechanisms (carbon finance, carbon price, and carbon trading policy); Section 3.4 is the overview of carbon market mechanisms and company performance. Section 3.5 presents the key factors affecting carbon trading pilots and non-carbon trading pilots. Section 3.6 makes presumptions about the interaction of the company's performance, green technology innovation, and carbon market mechanisms. Section 3.7 is the framework of the study and the justification of the framework, and Section 3.8 summarizes the chapter.

3.2 Theoretical Framework

There are numerous theories about the link between carbon market mechanisms, green technology innovation, and company performance. For example, the theory of sustainable development, the theory of environmental value, the theory of externalities, and the Coase Theorem, amongst others, and this section describe the most appropriate theories for this study, namely, Porter's hypothesis and the theory of innovation.

3.2.1 Porter Hypothesis

This section describes the implications of Porter's hypothesis, the debate over Porter's hypothesis and the application of Porter's hypothesis to this study.

3.2.1.1 Implications of Porter's Hypothesis

Environmental regulation's ability to foster economic growth has been a hotly debated academic topic. According to Porter (1991), implementing appropriate environmental regulations can motivate companies to engage in more innovative activities, leading to higher production. Thus, companies can reduce the costs associated with environmental protection and improve their profitability in the market (Porter, 1991). In 1995, Porter and van der Linde further argued, through a case study, that strict and appropriately designed environmental regulations can incentivize the company to innovate and that the dividends from innovation can partially or fully offset environmental compliance costs. This enhances the company's performance and fosters a mutually beneficial scenario for both the environment and the economy (Porter & van der Linde, 1995). According to this perspective, it is known as Porter's theory. It provides a novel perspective on the relationship between environmental regulation and economic growth.

In 1997, Jaffe and Plamer classified Porter's hypothesis into three categories: the narrow Porter's hypothesis, the weak Porter's hypothesis, and the strong Porter's hypothesis. The narrow Porter's hypothesis posits that flexible regulatory approaches, particularly economic instruments, have a greater capacity to stimulate companies to innovate and are more efficacious than conventional types of regulation (Lanoie et al., 2007; Ambec & Barla, 2001). Weak Porter's theory posits that the existence of adequately suitable environmental regulations can incentivize companies to partake in new endeavors. However, it remains uncertain whether such inventive activity is advantageous or detrimental to companies (Palmer & Jaffe, 1997). The main contention of Porter's limited and feeble ideas is that environmental regulatory measures place extra external burdens on companies. This, in turn, drives them to undertake creative endeavors. Nevertheless, the company's innovative endeavors are marked by lengthy investment cycles, substantial investment expenses, and significant risks. Consequently, whether these innovative activities can result in economic efficiency or improved competitiveness is uncertain. Additionally, it is challenging to establish a connection between environmental regulatory policy and the company's performance.

Strong Porter's theory posits that environmental regulatory laws can effectively stimulate environmental protection and foster the development of green technical innovation within companies. The gains resulting from these innovative initiatives can, on the one hand, contribute to the expenses associated with environmental regulatory measures. Additionally, it can optimize production efficiency, bolster the company's competitive advantage in the market, elevate performance standards, and achieve mutually beneficial outcomes in terms of both environmental and economic performance (Huiban et al., 2018). Table 3.1 and Figure 3.1 explain the three types of Porter's valence theory.

Table 3.1
Classification of Porter Hypothesis

Narrow Hypothesis	**Porter**	Flexible regulatory policies, especially economic means, can stimulate companies to innovate and are more effective than traditional regulatory forms (Lanoie et al., 2007; Ambec & Barla, 2001).
Weak Hypothesis	**Porter**	Effective environmental legislation can stimulate innovation, but it does not dictate whether innovation is beneficial or detrimental to a company (Palmer & Jaffe, 1997).
Strong Hypothesis	**Porter**	Implementing reasonable and stringent environmental laws can stimulate technology advancements. The advantages resulting from companies' technical innovations will compensate for the costs associated with environmental compliance and yield additional benefits (Huiban et al., 2018).

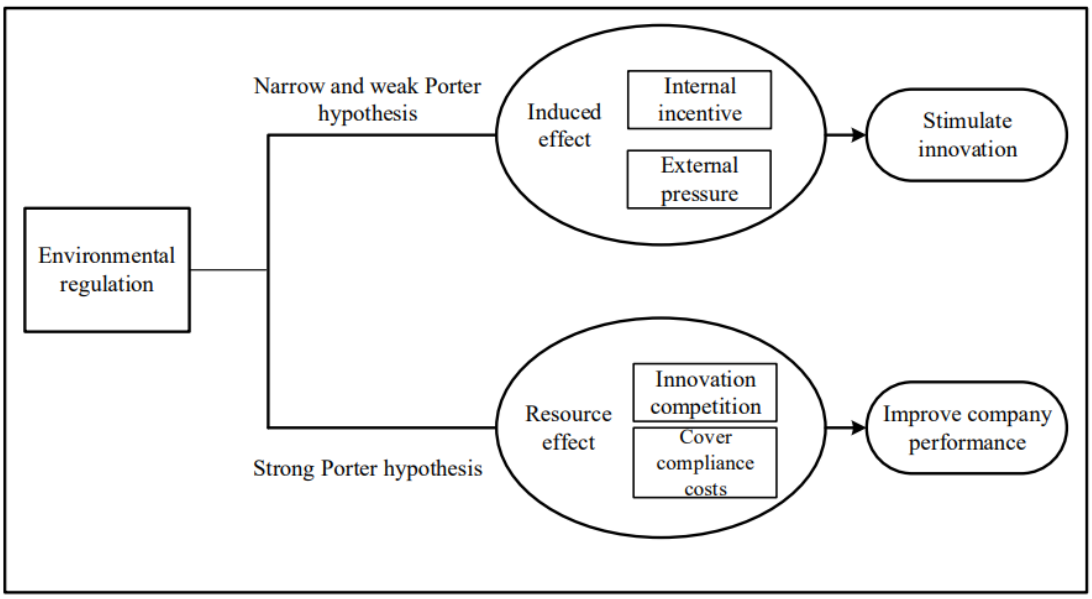


Figure 3.1 Porter's Hypothesis

China has three distinct types of environmental regulations: command-and-control, market-based, incentive-based, or voluntary environmental regulation are all possible (Wang et al., 2022c). A policy tool known as "market-based environmental regulation" makes use of market forces to address environmental preservation (Albrizio et al., 2017). This form of regulation incorporates the external costs associated with environmental pollution and ecological harm into the production costs and pricing of companies through the use of economic mechanisms. This includes sewage charges, environmental protection taxes, sewage permits, Carbon Emission Trading (CET), and licensing and trading of energy-use rights. Furthermore, this guides companies to reduce pollution emissions, improve resource use efficiency and promote green production and consumption (Xie et al., 2017). China's existing carbon market mechanisms is a system of environmental rules that rely on market activities, comprising carbon finance, carbon price, and carbon trading policy (Shen et al., 2019).

The analysis is grounded in the strong Porter's hypothesis, which offers a theoretical framework for comprehending how carbon market processes impact company performance. Carbon market mechanisms impose explicit limits on carbon emissions for companies, along with transaction costs such as carbon price. These mechanisms might be considered a type of environmental control (Schneider, 2022; Du & Chen, 2021). To comply with carbon market laws and further decrease the expense of emission reduction, the company has been compelled to augment its investment in Research and Development (R&D) and actively pursue technical innovation (Wang et al., 2020). The company aims to enhance its value by utilizing technological advancements. This includes developing environmentally friendly products and enhancing manufacturing efficiency and energy use. It encourages proactive engagement in fulfilling social responsibilities, upgrades the company's governance structure, and improves performance in Environmental, Social, and Governance (ESG) matters. This is in addition to the ultimate goal of achieving reductions in greenhouse gas emissions and transitioning to a low-carbon economy (Xiao et al., 2021; Gu et al., 2022).

Overall, the strong Porter's hypothesis asserts that the carbon market

mechanisms, by providing clear environmental norms, stimulate companies to undertake technological innovation through financial incentives. It also reduces the cost of abatement and enhances economic performance and market competitiveness. This market mechanism promotes environmental sustainability while enhancing economic efficiency. Specifically, in this study, companies are incentivized to seek green technology innovation to reduce carbon emissions and cut costs, thereby increasing company value and ESG scores under the carbon market mechanisms. The strong Porter's hypothesis offers a theoretical framework for analyzing the correlation between carbon market mechanisms (such as carbon finance, carbon price, and carbon trading policy) and the company's performance (including company value and ESG scores).

3.2.1.2 The Porter Hypothesis Debate

Porter's hypothesis, formulated three decades ago, has sparked an ongoing interest in studying the interplay between environmental regulation, innovation, and a company's success. In different countries, different industries and regions present differences and complexity, and thus far, have not reached a consistent conclusion. There are three views.

a) Porter's Hypothesis (Innovation Compensation Theory, Porter's Hypothesis Is Valid)

More research on the strong Porter's hypothesis in recent years has revealed positive effects, with stringent environmental regulations further promoting the company's green innovation, productivity gains, and carbon emission reductions. Wang et al. (2019) decided to utilize panel data from the industrial sector of countries that are members of the Organization for Economic Co-operation and Development (OECD). The study reported that environmental policy positively impacts green productivity growth when the level of environmental regulatory stringency is below 3.08. When environmental regulatory policies are sufficiently strict, the negative impact of compliance costs surpasses the positive impact of innovation offsets, resulting in an

undesirable outcome. Meanwhile, Liu et al. (2020) observed that environmental regulation measures have a significant positive impact on green innovation in China.

In the article by Ai et al. (2020), the authors discovered that environmental regulation positively contributes to a company's Total Factor Productivity (TFP). Moreover, there is a positive correlation between environmental regulation and the long-term survival of a company. According to Peng et al. (2021), implementing market-based environmental regulations can greatly enhance the overall efficiency of industrial companies across all sectors. This advantage is particularly pronounced for private companies that already have greater productivity levels and lower pollutant intensity. At the same time, Tong et al. (2022) emphasized that environmental regulation indirectly contributes to Green Total Factor Productivity (GTFP) by raising the level of eco-technology. Strict environmental regulations have significantly increased green productivity in China. According to Cheng and Kong (2022), utilizing a blend of command-and-control and market-based environmental laws is more advantageous for GTFP than solely relying on one form of policy. The enforcement of environmental standards in China has a beneficial impact on the growth of GTFP. Additionally, the amount and quality of foreign direct investment act as a mediator in the relationship between Gross Domestic Product (GDP) and GTFP growth, as stated by Luo et al. (2023).

b) Traditional Hypotheses (Compliance Cost Theory, Porter's Hypothesis does not Hold)

According to neoclassical economics, environmental regulation results in higher costs and expenses for companies hampers their ability to innovate in environmentally friendly ways, diminishes their competitiveness, and negatively affects economic growth (Ramanathan et al., 2010; Palmer et al., 2018). That is, the Porter's hypothesis is invalid. He et al. (2021) highlighted the interconnectedness of financial limitations, environmental laws, and green innovation. They discovered that a modified form of Porter's hypothesis, which suggests that environmental regulations might stimulate innovation, is inapplicable. Instead, they observed that environmental rules negatively impact R&D investments and hinder the generation of patents. In

addition, certain researchers argue that environmental regulations have an adverse effect on production. Hence, Tang et al. (2020) have presented evidence that supports the assertion that command-and-control environmental regulation has a substantial and enduring negative effect on a company's TFP. A comprehensive analysis of data from 37 industrial sectors in China revealed that air regulations exert a suppressive impact on TFP (Ma et al., 2020). Between 2008 and 2016, He et al. (2020) selected financial data from manufacturing companies registered under China's Shanghai and Shenzhen A-share companies. The study demonstrated that environmental legislation adversely affects the financial performance of manufacturing companies. Additionally, it disproved Porter's premise in the context of China's manufacturing industry.

c) Uncertainty Hypothesis (The Validity of Porter's Hypothesis is Ambiguous)

The uncertainty hypothesis advocates for the implementation of Porter's hypothesis, considering variations in environmental regulation, geographical differences, levels of economic growth, ownership characteristics, and regional disparities, as well as recognizing the presence of a non-linear relationship. In other words, Porter's hypothesis is uncertain.

The magnitude of this varies based on the diversity of environmental control. Song et al. (2020) observed that during the first phase of economic development, environmental regulations that the government imposes have a more significant influence on promoting green innovation than environmental regulations based on market mechanisms or voluntary. The variation depends on the ownership type and the diversity within different regions. He et al. (2020) proposed that the impact of environmental legislation on company performance differs depending on the kind of company ownership.

Other studies have argued that the relationship between environmental regulation, green innovation, and company performance is not simply linear, suggesting a non-linear relationship. Ma et al. (2022) provided evidence for the proposition made by a specific individual that there exists an inverted U-shaped relationship between official environmental regulation, informal environmental regulation, and GTFP. Meanwhile, Zheng et al. (2023) identified a U-shaped correlation between

environmental regulation and GTFP in the Yangtze River Economic Belt. In the context of green innovation, a phenomenon known as a single-threshold effect can be noticed. This effect refers to the situation where the beneficial influence of promoting green innovation decreases after the degree of green innovation input exceeds a specified threshold value.

In the past 30 years since the formulation of Porter's hypothesis, several studies have confirmed or disproved Porter's hypothesis from the theoretical or empirical point of view. Research conducted both domestically and internationally has evolved from first examining the correlation between two variables to encompassing additional control factors and Moderating Variables (MVs), to name a few. The generated findings are growing more extensive, incorporating a single positive and negative correlation and encompassing threshold effects, U-shaped connections, and other similar phenomena. The arguments for Porter's hypothesis are presented in Table 3.2.

Table 3.2
Porter Hypothesis Debate

View	Main Content
Porter's hypothesis	Implementing rational and rigorous environmental rules can stimulate eco-friendly advancements, and the advantages of these advancements will offset the expenses associated with environmental compliance while also providing extra benefits.
Traditional hypothesis	Environmental regulation can lead to increased costs and expenses for companies, inhibit the ability to innovate in a green way, reduce the competitiveness of companies, and have a negative impact on economic development.
Uncertainty hypothesis	The variation depends on the geographical heterogeneity, namely the differing levels of regional economic growth.
	Varies according to the heterogeneity of environmental regulation: command, market, and voluntary environmental regulation.
	Industry heterogeneity leads to differences in the type of company ownership.
	The correlation between environmental regulation, green innovation, and company performance is intricate and not readily comprehensible. The graph illustrates a relationship that has a U-shaped pattern.

Table 3.3 presents a succinct summary of the meta-regression analyses conducted between 2013 and 2023 to examine the effects of environmental regulation on company performance and technological innovation.

Table 3.3

Meta-analysis Studies that Examine the Correlation Between Environmental Regulation and Company Performance

Study	Area of Investigation	Meta-Regression Analysis (sample)	Period of Study	Result
Albertini (2013)	The relationship between managing the environment and achieving financial success.	52 studies plus 205 effect sizes, sample sizes, statistical artifacts, and moderator factors	Between 1975 and 2011 (35 years)	Positive relationship.
Hang et al. (2019)	Environmental performance and financial performance	893 empirical projections derived from 142 studies	Between 2012 and 2018 (6 years)	The correlation between environmental performance and financial performance is contingent upon the specific time frame.
Sun & Zhu (2023)	Examining the impact of environmental rules on technological advancement.	1,276 estimates reported in 49 studies	Between 1997 and 2019 (22 years)	Environmental laws seldom ever have an impact on technological innovation.
Döbbeling-Hildebrandt et al. (2023)	Effectiveness of carbon price	483 effect sizes were collected from 980 causal ex-post evaluations across 21 carbon price systems	Between 1990 and 2022 (32 years)	Despite its low level, the implementation of a carbon tax has helped to reduce carbon emissions.
Ren & Chen (2023)	Environmental regulation on company green technology innovation	39 independent research papers	Between 2006 and 2020 (14 years)	Significant positive correlation.

Due to differences in research samples, research methodologies, and differences in industry type and degree of regulation, the results of the meta-analysis present more controversial conclusions, such as positive correlation, negative correlation, or no effect, based on three theories. This includes the traditional hypothesis (the cost of compliance theory), Porter's hypothesis (the compensation for innovation theory), and the uncertainty hypothesis. Focusing on the real-world context of the heavily polluting industries in China's carbon market, this study incorporates a wider range of variables such as carbon finance, carbon price, green technology innovation, economic performance, and sustainable performance. This study also employs Difference-in-Differences (DID) and continuous DID modeling in a multi-dimensional way to explore

the relationship between environmental regulation and economic growth and to support the development of the theory with more quantitative results.

3.2.1.3 The Porter Hypothesis Theory Applied in the Study

Porter's hypothesis suggests that appropriate environmental regulations can promote green innovation and enhance company performance (Porter & van der Linde, 1995). Stringent environmental rules impede the company's ability to compete and motivate the organization to pursue technology advancements and improve production and overall efficiency. This results in a symbiotic outcome in which both the preservation of the environment and the advancement of the economy are successfully accomplished. In addition, the transmission mechanism of environmental legislation, which involves green innovation, can lead to economic growth. The Porter effect of environmental regulation is displayed in Figure 3.2. Carbon finance, carbon price, and carbon trading policy belong to market-based environmental regulation policy, and the realization mechanism of the Porter effect of carbon finance, carbon price and carbon trading policy will be elaborated on in the following section.

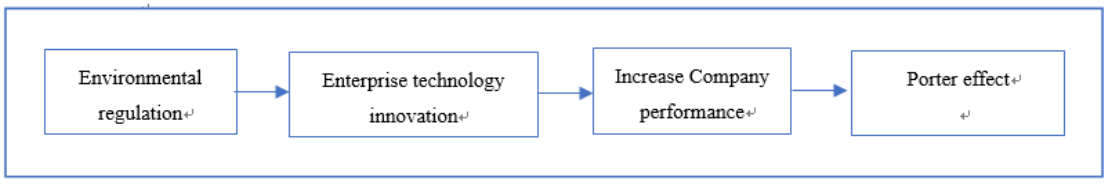


Figure 3.2 Consequences of Environmental Regulation Porter Effect

The Porter effect of carbon finance is centered on the use of financial instruments to drive companies to adopt technological innovations that lead to improved company performance. The main logic is that, firstly, carbon finance creates economic incentives. Through market-based mechanisms such as carbon trading and carbon credits, companies are able to obtain economic gains or financing opportunities through carbon financial instruments, easing their financial pressure on green technology innovation. Second, financial incentives drive innovation. The benefits and financing power of carbon finance increase the ability and incentives of companies to

innovate and invest in green technologies and low-carbon projects, which in turn increase productivity and reduce carbon emissions (Han et al., 2022). Finally, innovation leads to improved economic and sustainable performance. Green technology innovation ultimately enable companies to improve resource efficiency, reduce production costs, achieve greater economic returns in the carbon finance market, and achieve carbon emission reduction targets (Jiakui et al., 2023).

The Porter effect of a carbon price is centered on the economic pressure exerted through the carbon price mechanism to force companies to upgrade their technological innovation capabilities, improving long-term economic and sustainable performance. The main idea is that, firstly, carbon price increases cost pressures. Companies face higher production costs or profitability pressure due to increased carbon emission costs. Second, cost pressures force technological innovation. In order to reduce the costs associated with carbon emissions, companies are forced to adopt green technologies or improve production efficiency, which in turn drives technological innovation (van den Bergh & Savin, 2021). Finally, technological innovation enhances productivity and resource efficiency. Innovation enables companies to achieve similar or even higher outputs with less energy and resource inputs while reducing pollution and carbon emissions (Lv & Bai, 2021). Driven by the carbon price mechanism, innovation helps companies reduce their compliance costs and makes them more competitive in the global marketplace, bringing long-term economic and environmental benefits (Peng et al., 2022).

The core of the Porter effect of carbon emissions trading lies in improving company performance through internalizing environmental costs, technological innovation and efficiency improvements. Figure 3.3 illustrates the mechanism by which Porter's effect of CET is achieved. Firstly, environmental cost pressures drive innovation. Environmental expenses determine the level of pressure. CET aims to internalize the expenses linked to environmental consequences by setting a cap on carbon emissions and enabling the trade of carbon emission rights as a marketable product. All carbon allowances in the Carbon Emission Pilot Areas are initially allocated free of charge and are available to every company. Moreover, companies with a surplus of allowances can sell the excess for additional revenue. In contrast, those with a shortfall of allowances will need to purchase additional allowances to incur

additional costs (Yang et al., 2020). Carbon trading provides companies with clear economic incentives, i.e., cost savings for reducing carbon emissions (through the sale of excess emission credits) and additional costs for exceeding emission limits (purchase of emission credits) (Dong et al., 2019). This method encourages companies to investigate solutions to cut their carbon emissions, such as technological innovations and energy efficiency improvements.

Secondly, technological innovation and efficiency gains lead to improved company performance. Faced with the strain of CO_2 emissions trading, the company will actively seek technological innovation to reduce carbon emissions. These include increased investment in environmental protection, new cleaner technologies, improved production processes, and more environmentally friendly raw materials (Guo et al. 2017). These technological innovations help companies reduce carbon emissions, increase productivity, and reduce costs, enhancing their competitiveness.

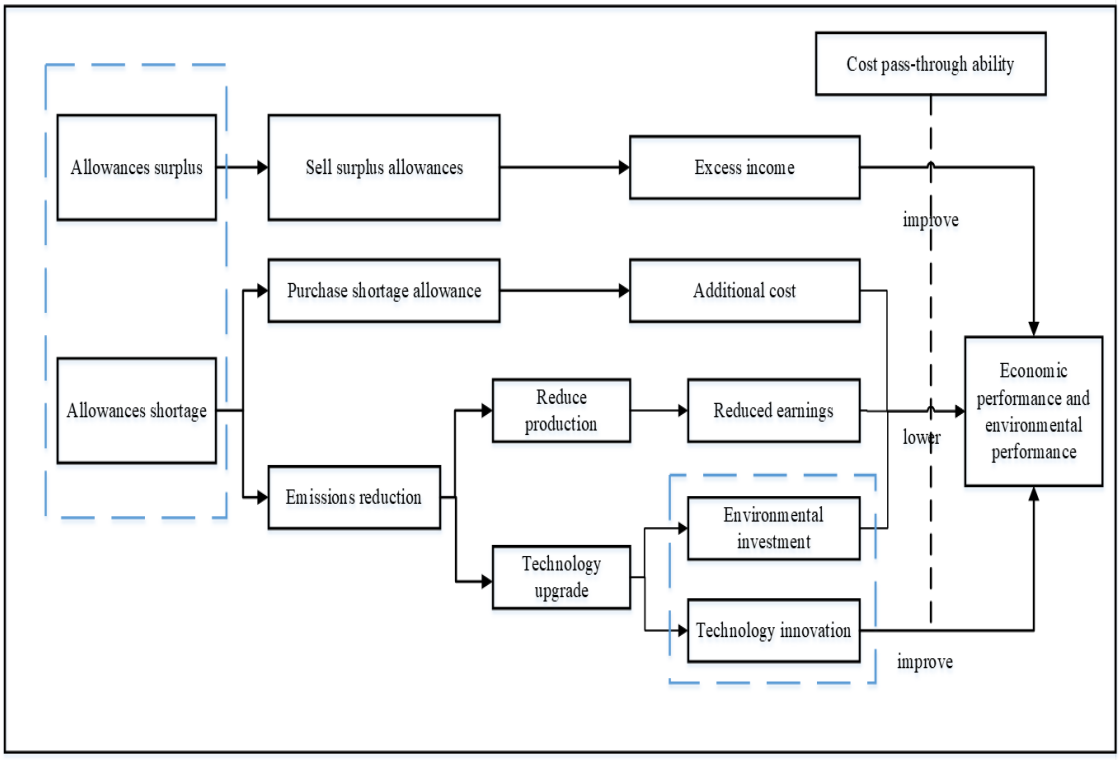


Figure 3.3 Implementation Mechanism of the Porter Effect of Carbon Emission Trading

3.2.2 Innovation Theory

This section describes the implications of innovation theory and the application of innovation theory to this study.

3.2.2.1 Implications of Innovation Theory

In 1911, the famed Austrian-American economist Joseph Alois Schumpeter developed the theory of innovation in his work The Theory of Economic Development (Schumpeter, 1911). The book's author defined innovation as a novel method of producing goods or services. This involves rearranging and introducing new elements and conditions into the production system. The author also asserted that innovation is the fundamental driver of economic growth and advancement. According to Schumpeter, economic progress is based on technology and production techniques rather than capital and labor. Similarly, for companies, in a wave of innovation, backward companies will be eliminated one after another. In contrast, companies with high innovation will be left behind, and the entire market will continue to be optimized for development. Notably, Schumpeter's distinctive and innovative theories have established his unique position in the study of the history of the development of economic thought.

According to the split of innovation content, Schumpeter identified four forms of innovation: Product innovation, green innovation, market innovation, and institutional innovation (Schumpeter, 1911). The application of green innovative theory is the main emphasis of this work. Green innovation theory is developed on the basis of innovation theory, focusing on the consideration of ecological and environmental benefits (Kemp & Foxon, 2007). As individuals' comprehension of innovation expands, they increasingly prioritize the seamless company of economic, ecological, environmental, and social advantages. Furthermore, innovation encompasses all stages of a product's life cycle (Gjalt et al., 2008; European Commission, 2008).

In a broad sense, green innovation theory includes green technology innovation theory. Both green innovation theory and green technology innovation theory aim at the sustainable development of the environment, society and economy. They are also

committed to solving environmental problems and promoting the development of the economy in the direction of green, low-carbon and circular development through innovative means (Vence & Pereira, 2019). In particular, green innovation involves technological innovation, product design, environmental management, business models and other aspects of innovation. In contrast, green technology innovation focuses more on the technological aspects of innovation (Lu et al., 2022). Green technology innovation is an integral part of green innovation, and its results can promote the deepening and development of green innovation theory. Simultaneously, the guidance of green innovation theory provides direction and support for green technology innovation.

3.2.2.2 Innovation Theory Applied in the Study

First, green technology innovation is critical to both the carbon market mechanisms and company performance. Notably, the carbon market mechanisms have a direct impact on the development of environmentally friendly technology. Green technology innovation decreases CO_2 emissions by encouraging the use of eco-friendly technologies, accelerating the progress of renewable energy sources, and improving energy efficiency. This solution allows organizations to enhance their acquisition of carbon credits in the carbon market and reduce the costs associated with carbon emissions (Li et al., 2022). Additionally, green technology innovation plays a crucial role in ensuring the long-term stability and growth of the carbon market by offering technological assistance. It promotes the healthy development and virtuous cycle of the carbon market (Liu & Li, 2022).

Second, green technology innovation positively affects company performance. On the one hand, green technology innovation develops clean energy through technological investment, technological improvement, and technological innovation. This reduces the cost of carbon reduction, thereby improving the company's economic efficiency (Qi et al., 2021). However, as the public becomes more environmentally aware, more consumers and investors pay more attention to a company's ESG performance. In essence, companies with better sustainable performance attract more consumers and investors, increasing their market competitiveness and investment share

(Lan et al., 2022).

Furthermore, green technology innovation enhances the contribution of carbon market mechanisms to company performance. Green technology innovation is a crucial method and technological resolution for organizations to decrease emissions (Jiang et al., 2022). The organization mitigates carbon emissions by implementing environmentally friendly technical advancements and acquires additional carbon emission allowances to reap commercial advantages. Moreover, reducing the cost of carbon will improve CTFP and gain a competitive advantage in the carbon market (Liu & Li, 2022). Concurrently, green technology innovation helps the company establish a better social image to enhance environmental benefits and further advance sustainable performance.

In conclusion, green technology innovation theory is a theoretical framework for technological innovation that emphasizes resource conservation, environmental protection, and the virtuous circle of sustainable development. Green technology innovation bridges and links between carbon market mechanisms and company performance. Correspondingly, this study uses green technology innovation as an moderator variable, and green technology innovation theory is applied.

3.3 Conceptual Framework

This section describes the basic concepts of company performance (economic performance and sustainable performance).

3.3.1 Company Performance

A company's performance can be categorized from a number of perspectives, and the following are some common ways of categorizing it: According to the object of performance evaluation, it can be divided into organizational performance and employee performance (Davis & Kay, 1990). According to the time division of performance evaluation, the concept can be categorized into sustainable performance and short-term performance (Bourne & Franco, 2003). There are two types of performance evaluation indicators: financial and non-financial (Brown & Laverick,

1994). According to the performance evaluation method, it can be divided into quantitative performance and qualitative performance (Jarvis et al., 2000).

In this study, company performance is classified as economic and sustainable performance. The measures are Economic Value Added (EVA) and ESG score.

3.3.1.1 Economic Performance

The economic success of a company pertains to the company's financial contribution and influence. It is a widely used comprehensive performance evaluation system that provides companies with scientifically sound and objective results (Dechezleprêtre et al., 2023). This is expressed in terms of the economic wealth that the company creates for its stakeholders during a specific duration. The evaluation of a company's economic performance focuses on the level of the company's financial efficiency and asset operations, level of indebtedness and solvency, development capacity and growth potential, enabling companies to measure their own economic development results more easily. It aims to formulate a more scientific, rational and efficient company management strategy (Kvach & Ilina, 2013).

A company's economic performance is mainly reflected by economic indicators such as EVA, net profit, return on net assets, return on total assets, total asset turnover, current asset turnover, gearing ratio, interest earned multiple, sales (operating) growth rate, and capital accumulation ratio. These reflect the efficiency of the company in the allocation and utilization of resources (Zhang & Ma, 2021).

This study uses the EVA indicator to assess the efficacy of the company's economic progress. EVA is a financial metric that represents a company's net operating profit after tax, subtracted by the cost of capital. More precisely, it computes residual income by subtracting the entire amount of invested capital (which includes both stock and debt) from the net operational profit after tax. EVA and its improvement is an essential indicator for the overall evaluation of the operator's efficient use of capital and value creation for the company (Sharma & Kumar, 2010; Jakub et al., 2015).

EVA is directly tied to a company's financial statistics, including return on investment and return on net assets. As financial ratios increase, EVA also increases. Likewise, a reduction in the expense of funding, as indicated by metrics like the

Weighted Average Cost of Capital (WACC) and the cost of equity capital, results in an increased EVA. When the rate of return is higher than the rate of capital, increasing the quantity of capital invested will lead to the generation of a larger EVA by the company (Lovata & Costigan, 2002; Kyriazis & Anastassis, 2007).

3.3.1.2 Sustainable Performance

Sustainable performance is an integrated concept covering various economic, social, environmental, and resource measures (Kovilage, 2021). It reflects the projects or organization's concern for and contribution to environmental protection, social responsibility, and future development while pursuing economic benefits. Moreover, sustainable performance is more concerned with the long-term profitability and stability of the company as well as adaptation and harmonious co-existence with the environment.

Sustainable performance and ESG scores are closely linked. The quantitative expression of sustainable performance can be expressed in terms of ESG scores (Minutolo et al., 2019). ESG evaluates the sustainability of a company's operations and the company's social value in three dimensions: environmental, social and company governance (Rajesh & Rajendran, 2020). ESG scores are usually calculated based on a combination of quantitative and qualitative indicators from publicly available information about listed companies (Paolone et al., 2024; Zhang et al., 2023). In line with this, the researcher evaluates different companies based on ESG scores in a comprehensive manner (Fandella et al., 2023). ESG scores, which evaluate a company's operational sustainability, will prioritize the long-term worth of the company and the sustainability of that value (Wang & Wang, 2022). To motivate the company to improve the weaknesses involved in ESG and to stimulate continuous improvement in the company's sustainable development (Zumente & Lāce, 2022). This study employs ESG scores as a surrogate indicator of company sustainability performance. A higher ESG score indicates greater sustainability for the organization, whereas a lower ESG score suggests that the company should enhance its ESG performance (Baratta et al., 2023).

3.3.2 Carbon Market Mechanisms

This section describes the basic concepts of the core elements of a carbon market mechanisms (carbon finance, carbon price, and carbon trading policy).

3.3.2.1 Carbon Finance

In 1998, Jose Salazar (1998) initially introduced the notion of environmental finance and provided a definition for it, which served as the basis for the further advancement of carbon finance. Carbon finance originated from the advancement of environmental finance theory in the late 20th century. Labatt (2011) asserted that carbon finance is a derivative of environmental finance. The primary purpose of carbon finance theory is to minimize the degradation of the atmosphere and decrease greenhouse gas emissions (Xu & Liu, 2023). Meanwhile, Cowan (1998) explained that environmental finance, which combines environmental economics with finance, can be used to finance the growth of the environmental economy, benefiting both the environment and finance. The concept of utilizing financial tools to promote green industries and restrain non-environmentally friendly companies aimed at attaining both environmental and economic sustainability was first introduced in the debate.

Carbon finance was initially described by the World Bank in 2006 as the funding of projects that produce or have the potential to provide reductions in greenhouse gas emissions through the acquisition of greenhouse gas emission reductions (Carbon Finance Unit Annual Report, 2006). Tang et al. (2012) suggested that more renewable energy could be stimulated by issuing an additional carbon finance instrument. Furthermore, Zhang et al. (2017) examined the influence of environmental innovations and structural adjustments on the decrease of carbon emissions. Similarly, Stern (2017), for the first time, conducted a detailed examination of the threat of climate change to human life and major variables relating to the reasons for the emergence of carbon finance.

Carbon finance encompasses investment activities involving financial instruments and derivatives that are based on carbon emission rights. These investments are made within the global climate change framework, utilizing the carbon trading

market as a platform and operating under the guidance of applicable laws and regulations (Jiang et al., 2023). At present, academics lack agreement over the definition of carbon finance, which is widely acknowledged to encompass both a broad and a narrow idea. Carbon finance encompasses various financial operations that aim to decrease greenhouse gas emissions. These activities are collectively known as carbon finance (Guo et al., 2022). In a specific sense, carbon finance pertains to the financial practice of exchanging carbon emission rights in carbon trading markets (Yang & Luo, 2020).

In the context of this study, carbon finance refers to a broad range of financial actions specifically designed to restrict and decrease the release of greenhouse gas emissions. It encompasses trading carbon emissions and carbon derivatives, financing low-carbon projects, and developing low-carbon technologies to reduce greenhouse gas emissions.

3.3.2.2 Carbon Price

The carbon price is the primary and most dynamic component of the carbon market, serving as its central mechanism (Tang et al., 2022). The carbon price represents the cost of emitting CO_2 and other greenhouse gases into the environment. Carbon markets are market-based environmental mechanisms that use pricing to minimize carbon emissions. The carbon price can be set through a carbon tax or a cap-and-trade system (carbon trading), in which companies are limited in the amount of carbon they can emit and can buy or sell carbon permits (World Bank, 2021).

The carbon trading price formation is categorized into two groups based on the distinct trading methods: one is in the carbon trading market, the buyer and seller through continuous public bidding, in the transaction volume and transaction price agreed upon the offer (Ji et al., 2018). The other is in the carbon trading market, where the buyer and seller, through continuous public bidding, are in the transaction volume and transaction price agreed upon in the offer (Lu et al., 2020). The other is formed in the voluntary carbon market and the Clean Development Mechanism (CDM) primary market if the two parties to the transaction agree on the price and emission reduction project as specified in the contract. The buyer controls the transaction's pricing (Huang

& He, 2020).

The carbon price in the carbon market serves as an intricate and ever-changing price indicator, offering feedback on information. The fundamental purpose of the carbon market is to utilize the market mechanism, namely the carbon price, to offer direction for energy conservation and reduce emissions in companies with large levels of carbon emissions (Zhu et al., 2019). The carbon price in the carbon market is established through the interaction of supply and demand. Specifically, when there is an excess supply of carbon allowances compared to the demand, it results in a reduction in the carbon price. Carbon price fluctuate based on the relative scarcity of carbon allowances compared to their demand. Indeed, both lower and higher carbon price levels are detrimental to the efficiency of the carbon market (Ma & Kuo, 2021). A lower carbon price fails to sufficiently motivate high-carbon emitting companies to decrease their carbon emissions and, therefore, hampers the full use of the carbon market's price regulation function. Note that implementing a higher carbon price can substantially impact the company's production expenses, which is unfavorable for the company's expansion and does not offer any incentives (Wu et al., 2023). Currently, China's carbon trading market is imperfect, and carbon price are prone to substantial fluctuations and instability. Consequently, there is significant ambiguity surrounding the carbon price indication (Tang et al., 2020).

3.3.2.3 Carbon Trading Policy

Carbon trading policy is a crucial market-oriented environmental regulatory system to manage and reduce greenhouse emissions, including CO_2. The primary objective of the carbon trading policy is to facilitate the functioning of the carbon emissions trading market. Setting a cap on carbon emission rights allows the buying or selling of carbon emission allowances between emission subjects. Carbon trading policy aims to meet carbon reduction targets by providing economic incentives for companies to cut their CO_2 emissions (Xie & Wang, 2022).

Since 2013, several provinces and cities in China, such as Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong, and Shenzhen, have initiated regional carbon trading policy (Carbon emissions trading, 2021). These pilot regions have

actively engaged in the exploration and implementation of carbon emission pricing, forming the necessary foundation for the establishment of a nationwide carbon market. In July 2021, China inaugurated its nationwide carbon emissions trading market, signifying a significant milestone in China's carbon trading endeavors. Currently, there is a substantial advancement in the power generation industry, and as the company progresses, there are plans to expand into more energy-intensive sectors (Carbon emissions trading, 2021).

3.3.3 Green Technology Innovation

The popular conception of innovation originated from the starting point of combining technology and economics, represented by Joseph Schumpeter, the founder of modern innovation theory (Schumpeter, 2021). On the other hand, green innovation is a word for management science and technology published in 2016. Innovation is the use of new products, services, processes, marketing methods, and company activities to make changes to products, services, and performance. Technological innovation is the innovation of processes and products by developing or implementing technologies to optimize performance and outcomes (Yasmeen et al., 2020; Frondel et al., 2007).

Green technology has been around since the 1960s when Western nations began to realize the significance of environmental protection and enacted regulations that prompted companies to invent new technologies to reduce environmental pollution (Wang & Liu, 2021). Green technologies are technologies, methods, or products that minimise resource and energy use and environmental degradation (Braun & Wield, 1994). In the study conducted by Cruz-Cázares et al. in 2013 from a product life cycle perspective, green technology innovation encompasses developing novel ideas and concepts for green technology, introducing related products to the market, and reducing costs incurred throughout the product life cycle. According to Acosta et al. (2015), green technology innovation encompasses the development of green products and related hardware or green systems and related software. It aims to reduce the impact on natural ecology and environmental resources brought about by the production and consumption of products. It also improves the efficiency of environmental management to meet environmental protection requirements. Chiou et al. (2011) categorised green

technology innovation into three levels, depending on the context of the technology choice: firstly, end-of-pipe technology innovation, dealing with the pollution that has already been generated; secondly, green process innovation: innovation in the production process; and thirdly, green product innovation: preventing and reducing pollution throughout the entire life cycle of the product (Table 3.4).

Table 3.4
Specific Contents of Green Technology Innovation

Green Technology Innovation	**Concrete Content**
Technological innovation in end-of-pipe management	Recycled, reused and remanufactured materials
	Focus on the use of pollution treatment equipment
	Investing in waste, pollution control projects or technologies
	Conducting environmental reviews of manufacturing operations
Green Product Innovation	Selection of environmentally friendly product materials in product improvement and design processes
	Adoption of biodegradable packaging for existing or new products
	Evaluation of the product's ease of recycling, reuse and decomposition during product improvement and design processes
	Use of fewer resources in product improvement and design and adoption of green product labelling
Green Process Innovation	Low energy consumption: the production process reduces the use of water, electricity, coal, oil and other energy sources
	Effective reduction of hazardous substances and waste emissions during the manufacturing process
	Use of recycled materials, recycling processes, environmentally friendly processes or technologies
	Promotion of energy conservation and environmental protection inside and outside the company

There are three intrinsic dimensions to measuring green technology innovation: the technological innovation dimension, i.e., it must be an innovation; the eco-technology dimension, i.e., its innovative targets must include green technologies that are conducive to improving environmental protection and ecology; economic efficiency dimension, i.e., it must achieve good economic efficiency; maximize economic, ecological and social efficiency (Wang & Liu, 2021; Lin et al., 2022).

Green technology innovation is distinguished by energy efficiency, environmental preservation, recycling, inventiveness, and comprehensive advantages. To accomplish environmentally friendly production, green technology innovation is centered on enhancing energy efficiency and reducing energy consumption and pollutant emissions (Cai et al., 2021). Focusing on recycling resources, converting

waste into reusable resources, and reducing the exploitation of and dependence on new resources. It involves technological innovations and innovations in new company models, management styles, and production flows to meet sustainable development needs (Xu et al., 2022). Building on this, green technology innovation seeks to advance sustainable development by integrating economic, social, and environmental advantages.

Green technology innovation is limited by challenging technology R&D and a lack of financial investment. Green technology innovation usually involves multiple disciplines, such as environmental, energy, and material science. The knowledge and technology in these fields are complex and constantly updated, requiring developers to have interdisciplinary knowledge and capabilities (Dalvi-Esfahani & Nilashi, 2022). Particularly, the R&D of green technologies requires considerable financial investments, including equipment purchases, staff salaries, and experimental materials (Jaffar et al., 2022). Moreover, owing to technological uncertainties, there may be multiple failures and repetitive experiments during the R&D process, exacerbating the expenses associated with R&D.

Challenges to green technology innovation include technological bottlenecks, marketing, and competitive pressures. During the course of developing green technology, it is vital to constantly break through technological barriers and improve the technology's practicality and reliability (Saha et al., 2021). Although promoting green products in the market is complex, it is necessary for the company to strengthen brand building and market publicity to improve the consumers' recognition and embrace environmentally-friendly items. In light of the ongoing advancements in green technology and the intensifying market competition, it is imperative for the organization to consistently enhance its technical proficiency and market competitiveness (Guo et al., 2018).

Based on the study's focus, green technology innovation refers to technological advancements that specifically address the utilization of resources and environmental concerns. Technologies can contribute to the preservation of the environment and promote sustainable development in energy efficiency, environmental preservation, renewable energy, eco-friendly production, and the circular economy.

3.4 Overview of the Relationship between Carbon Market Mechanisms, Green Technology Innovation and Company Performance

This section reviews the literature on the relationship between carbon market mechanisms and company performance, as well as the relationship between carbon market mechanisms, green technology innovation, and company performance.

3.4.1 Overview of Carbon Market Mechanisms and Company Performance

This section includes literature on the relationship between carbon finance, carbon price, carbon trading policy and companies' economic performance and sustainable performance.

3.4.1.1 Overview of Carbon Finance and Company Performance

Green Finance (GF) is a financial concept and methodology designed to promote environmental conservation and sustainable development. It covers all economic activities, such as green credit, bonds, equity, insurance, and trusts, that promote environmental sustainability, mitigate climate change, and optimize the efficient utilization of resources (Lee & Lee, 2022). On the other hand, carbon finance is a specific manifestation of GF in the area of climate change. It mainly focuses on financial activities related to carbon emission rights, such as carbon emission rights trading, carbon asset pledge financing, and carbon bonds (Xu & Liu, 2023). Carbon finance is an essential component of GF and a subset of GF. Due to the limited availability of literature on carbon finance, this part mostly relies on the existing literature that explores the connection between GF and a company's performance while conducting the literature review on the correlation between carbon finance and company performance.

a) Overview of Carbon Finance and Economic Performance

Carbon finance plays a crucial role in the worldwide effort to shift towards a low-carbon economy by concentrating on reducing greenhouse gas emissions (Wang,

2021). However, although carbon finance and low-carbon development has steadily been the center of attention of the world community, domestic and international research in the relevant sectors remains rare (Xue & Liu, 2022). Studies on the correlation between GF and economic growth have uncovered a strong connection between the two. Effective financial development improves the profitability of investments, stimulates economic growth, and supports the shift towards a low-carbon economy (Li & Di, 2021). As a system intended to facilitate the coordination of environmental protection and economic growth, the GF has emerged as a significant instrument for establishing a carbon trading market and promoting sustainable development (Zhang & Ke, 2022). Fatica and Panzica (2021) explored the potential of green bonds in combating climate change. They discovered that those green bonds that are not refinancing in nature demonstrate greater efficiency in reducing emissions. This further validates the practical value of financial instruments such as green bonds in promoting climate-friendly economic activities.

In summary, GF initiatives such as green bonds, green credit, GF legislation, and carbon finance are crucial to lowering carbon emissions and boosting long-term economic growth. Carbon finance can facilitate the transition towards sustainable economic growth. Shift from the traditional mode of industrial development based on high energy consumption and emissions to a low-carbon, environmentally friendly, and efficient mode of industrial development. This contributes to the economy's green transformation and long-term growth.

b) Overview of Carbon Finance and Sustainable Performance

Multiple research has investigated the correlation between GF and ESG scores, particularly in relation to the emergence of GF policy in China's green economy. Scholars have demonstrated direct causality and a positive correlation between GF policy and companies' ESG performance through quasi-natural experimental methods (Lei & Yu, 2024). Using meta-analysis, Xu et al. (2020) revealed that GF promotes companies' green performance with heterogeneity in company type and region. In accordance with research conducted by Wang and Wang (2022), adhering to good ESG policy enhances the likelihood of listed companies issuing green bonds. It also

facilitates a rise in the number of green bonds issued by these companies. Moreover, Guo et al. (2022) proposed that GF has been suggested to decrease carbon emissions in the Yangtze River Economic Belt. Considering this perspective, GF plays a significant role in reducing carbon emissions.

However, some scholars have argued that GF does not promote carbon emissio n reduction and sustainable performance. As a market-based regulation, GF negatively impacts green innovation while raising the financing threshold. Although improving e nergy efficiency can reduce energy consumption per unit of output and facilitate the re alization of emission reduction, the increased financial pressure also makes it more ch allenging to adopt energy-saving technologies. For heavily polluting companies, the g reen credit policy may lead them into a vicious circle of failing to reduce pollution em issions (Xue et al., 2023).

In conclusion, most studies indicate that GF will achieve carbon emission reduction through financial incentives and green innovation, promote ESG performance improvement, and continue to promote the coordinated development of economic growth and environmental protection.

3.4.1.2 Overview of Carbon Price and Company Performance

a) Overview of Carbon Price and Economic Performance

From the existing research literature, researchers have concluded that there are positive and negative correlations between the impacts of carbon price on economic performance (Table 3.5). According to the classic hypothesis theory, the carbon price and company value are negatively correlated. Experts contend that the underdeveloped nature of China's carbon market mechanisms has a significant adverse effect on the stock value of energy-listed companies in various carbon trading pilot locations in China. This effect is mostly attributed to the carbon price (Zhang et al., 2018). Krokida et al. (2020) emphasized that a rise in the cost of CO_2 emission permits could adversely affect overall equities returns in European stock markets.

According to Porter's hypothesis, carbon price positively impacts economic performance. In accordance with research conducted by Bento and Gianfrate (2020), companies increasingly recognize the significance of climate issues on their financial

performance. They are actively integrating Internal Carbon Price (ICP) mechanisms and climate considerations into their company strategies. Carbon price can change a company's cost structure, as they affect a company's investment preferences and the cost of producing its products, which in turn impacts profits (Zhang et al., 2018). In the article by Zhang et al. (2018), carbon price affects a company's profitability through various paths, including investment preferences, production costs and cost structure. In other words, the carbon price measures a company's economic performance and influences its operational decisions. Joltreau and Sommerfeld (2019) discovered that the carbon price implemented by the EU-ETS did not have a substantial detrimental effect on company competitiveness during the first phase (2005-2012). Furthermore, they predicted that this pricing mechanism would not negatively impact the company's competitiveness during the third and fourth phases (2013-2030). The implementation of this system has already resulted in significant emission reductions. Pursuant to Mo (2023), the view is that the carbon price mechanism can indirectly enhance companies' productivity and market competitiveness through technological progress and environmental efficiency. This discovery accompanies the beneficial influence of environmental legislation on the value of companies. It also offers a fresh viewpoint on the correlation between the carbon price and a company's success.

Table 3.5
Impact of Carbon Price on Economic Performance

View	Main content
Negative impacts	Carbon price reduces economic performance
Positive impacts	Carbon price increases economic performance

Collectively, these evaluations indicate that fluctuations in carbon market price and implementing an ICP mechanism can substantially impact a company's operating efficiency, production costs, and potential market value. Therefore, in order to have an impact on financial performance, it is crucial for companies in severely polluting industries to take carbon price into account.

b) Overview of Carbon Price and Sustainable Performance

The implementation of carbon price mechanisms, such as carbon taxes and

emissions trading systems, has been observed as an essential strategy to incentivize the reduction of greenhouse gas emissions (Döbbeling-Hildebrandt et al., 2023). Wu et al. (2020) discovered that the relationship between energy price and carbon price has motivated highly polluting sectors to modify their energy usage by adopting cleaner energy sources and decreasing the release of greenhouse gases. Carbon price, knowledge spillovers, and trademark applications effectively reduce carbon emissions (Anser, Khan, et al., 2021). Another study by Wu (2022) proposed that the increase in China's carbon trading price and the growth in trading volume have played a crucial role in transforming the energy system and have had a lasting and substantial effect on reducing CO_2 emissions. The study noted that it is possible to achieve the same result even with a relatively modest carbon price, combined with progressively tighter emission caps and the use of auction revenues for emission reduction projects. It also significantly reduces greenhouse gas emissions, thus simultaneously realizing the so-called double dividend effect - environmental improvement and economic benefits (Narassimhan et al., 2018).

Li et al. (2022) studied China's electricity market reform and carbon trading price and discovered that only when the carbon price is greater than 300 yuan/TCO_2 can carbon emission reduction be promoted. According to Zhu et al. (2022), implementing an ICP resulted in a decrease in carbon emissions per unit of staff and carbon emissions per unit of revenue by 13.5% and 15.7%, respectively. Carbon price incentivizes the development of low-carbon solutions and the reduction of greenhouse gas emissions using market-based environmental regulations (Jiang et al., 2022). China is now constructing a domestic CET market and drawing inspiration from successful models like the European Union's Emissions Trading Scheme (EU-ETS) to turn the company's carbon price into everyday production and consumption choices (Chai et al., 2022).

In conclusion, the carbon price mechanism is a crucial market-based mechanism for controlling carbon emissions. A well-designed carbon price system regulates carbon emissions, encourages the transition to a more sustainable energy mix, and fosters economic growth. Other than that, it can achieve synergistic sustainable development with environmental benefits and economic gains.

3.4.1.3 Overview of Carbon Trading Policy and Company Performance

a) Overview of Carbon Trading Policy and Economic Performance

With the widespread use of market-incentivized environmental regulation in environmental protection, scientists have begun to conduct substantial research into the economic and environmental effects of ETS. The study primarily examines the EU and China markets, and the modifications made to the architecture of each country's CET mechanism have led to three distinct results, as outlined below.

According to the theory of the uncertainty hypothesis, the impact of carbon trading legislation on economic performance is negligible. The carbon trading scheme has limited influence on company value due to inequalities in the allocation of initial quotas, the price of reducing carbon emissions, and the unpredictable nature of the carbon market. In a study by Nie et al. (2021), the analysis observed that implementing environmental control measures did not significantly impact the regional Porter's effect. This is attributable to the fact that the pilot CET strategy, which led to the pollution haven effect, counteracted the positive effects of Porter's effect.

Moreover, based on the traditional hypothesis theory, the carbon trading policy reduces economic performance. The company's participation in carbon trading in the short term will increase operating costs, production costs, labor costs, certification costs, and other transaction costs. This includes the carbon emissions market quota set for unreasonable reasons, the company's competitiveness in the market, and its value, which are negatively impacted by the carbon trading program. A model is constructed to elucidate the interconnection mechanism among China's CET, energy, and finance markets. The analysis reveals a negative dynamic correlation coefficient between China's CET market and the capital market. This might be attributed to the irrational introduction of quotas in the carbon emissions market (Ma et al., 2020). In the article by Liu et al. (2021), the authors revealed that implementing carbon emissions trading in China would lower the current capital market price while increasing the overall company gearing. Carbon emission rights in China's carbon trading pilot regions have a substantial positive effect on a company's financial performance but a notable negative effect on its long-term value (Jafarinejad &Jory, 2022). Using a sample of United Kingdom (UK) non-financial companies from 2009-2018, the study concluded

that the sample company's real carbon performance did not add to the company's financial or market performance (Adu et al., 2023). Carbon ETS has an average short-term negative impact on a company's value, with the external market response mechanism being the principal conduit via which ETS affects company value (He et al., 2022).

Based on Porter's hypothesis, there is also a view that carbon trading policy enhances economic performance. Carbon trading policy, which puts a cap on carbon emissions, allows companies with excess allowances to sell them for profit. The purchase of allowances in the carbon market by companies that exceed their allowances increases environmental costs and imposes penalties on companies that exceed their limits. Carbon emissions trading aims to reduce CO_2 emissions via market mechanisms and financial incentives (Zhou et al., 2022). The establishment of a carbon trading mechanism can highlight companies with lower carbon emissions in the carbon market. According to Hang and Chun (2019), the low-carbon economic transformation in China is closely connected to its carbon trading system, and there is a direct relationship between the two. Furthermore, they contended that China's implementation of a carbon trading pilot system has substantially influenced the shift towards a low-carbon economy, hence bolstering Porter's claim. At the same time, Wang et al. (2022) asserted that carbon trading policy has a substantial and enduring influence on promoting carbon neutrality in five areas: political, economic, cultural, social, and ecological civilization.

Ultimately, scientists have made significant advancements in their research on the correlation between environmental regulation and the financial worth of companies through the utilization of multidimensional analysis. The studies' conclusions differ significantly due to changes in study individuals, research samples, and research techniques, as indicated in Table 3.6.

Table 3.6
The Effect of Carbon Emission Trading on Economic Performance

View	Main Content
Non-significant	Carbon emission trading does not have a substantial effect economic performance
Negative impacts	Carbon emission trading reduces economic performance
Positive impacts	Carbon emission trading increases economic performance

The relationship between carbon trading policy and economic performance is

complex and multifaceted, and this study will further explore the economic impacts of carbon trading policy based on Porter's hypothesis theory.

b) Overview of Carbon Trading Policy and Sustainable Performance

Most studies have indicated that implementing a carbon trading policy can effectively contribute to carbon emission reduction and improve sustainable performance. Carbon trading policy have significantly contributed to reducing carbon emissions, and the impact of these policies in the pilot areas will extend to the surrounding non-carbon trading pilot areas (Guo et al., 2022). Guo et al. (2020) indicated that the trading profits of EU-ETS Phase I and Phase II participating companies contributed to the reduction of carbon emissions. Zhang et al. (2023) noted that carbon market trading significantly reduced carbon emissions of carbon trading pilot companies. This reduction was attributed to the external influence of environmental regulations. Jia (2023) utilized an energy-environment-economy research model and discovered that carbon trading programs possess substantial societal worth and foster job growth in energy-intensive, low-carbon sectors.

Only a few researchers have discovered a negative correlation between carbon trading policy and ESG performance. Shu and Tan (2023) selected the dataset of Chinese industrial listed companies from 2010 to 2019. The study demonstrated that carbon control policy risk and ESG performance are negatively correlated, and bank loan costs and financing constraints affect the relationship.

In conclusion, most studies proved the positive impact of carbon trading policy on sustainable performance. Carbon trading policy significantly promotes carbon emission reduction. Through the implementation of a carbon trading policy, the company can achieve better performance in ESG aspects and realize a win-win situation for the company and society.

3.4.2 Overview of Green Technology Innovation as a Moderator in the Relationship between Carbon Market Mechanisms and Company Performance

Due to the limited amount of research available on the tripartite relationship

between carbon market mechanisms, green technology innovation, and company performance, this section focuses on analyzing the two separate relationships: the relationship between carbon market mechanisms and green technology innovation and the relationship between green technology innovation and company performance. The evaluation of the bilateral relationship is anticipated to further explore the interconnection between carbon market mechanisms, green technology innovation, and company performance.

3.4.2.1 Overview of Green Technology Innovation as a Moderator in the Relationship between Carbon Finance and Company Performances

a) Overview of Carbon Finance, Green Technology Innovation and Economic Performance

Previous studies have demonstrated that GF promotes green technology innovation by alleviating financing constraints, and green innovation drives company value. Companies with robust green innovation skills generally command higher valuations in the marketplace (Pan, 2022). Green innovation enhances company value directly and profoundly impacts company value through financial flexibility, industry structure optimization, and other multi-dimensional channels (Xie et al., 2022). Chouaibi et al. (2022) conducted a study in the UK and Germany and discovered that green innovation connects a company's ESG practices and its financial performance. GF initiatives are believed to indirectly impact financial performance by encouraging the development of environmentally friendly innovations within the organization.

Collectively, the above references suggest that synergies between green technology innovation and carbon finance can improve financial performance and positively impact company performance.

b) Overview of Carbon Finance, Green Technology Innovation and Sustainable Performance

By providing financial support for ecologically friendly projects, GF alleviates

the financial burden on green companies and contributes to reducing greenhouse gas emissions. It also encourages the growth of green technology innovation, which effectively strengthens carbon emission reduction (Chen & Chen, 2021). Digital finance is essential in streamlining industry distribution and providing financial support for innovative green technologies. Moreover, it advocates for the extensive implementation of greener technologies, which are crucial in reducing carbon emissions (Cai & Song, 2022). The rapid growth of GF indirectly aids in reducing carbon emissions by enabling the implementation of green technology advancements. This highlights the significant correlation between finance and environmental conservation (Chen & Chen, 2021). The development of innovative green technologies is crucial for reducing carbon emissions and promoting sustainable growth. Digital finance is critical in supporting and facilitating this process (Hu et al., 2022).

Advancements in green technology are crucial for reducing carbon emissions. Green technology advancements contribute to reducing carbon emissions throughout the production process and enhance CTFP. It also promotes the development of economic systems in a more sustainable and environmentally friendly direction (Du & Li, 2019). Green innovation positively affects companies' ESG ratings and financial performance. It suggests that a company's green innovation practices enhance environmental performance and significantly improve ESG scores, enhancing overall company performance (Zheng et al., 2022).

Lee et al. (2023) determined that GF substantially enhances energy efficiency by fostering green technology innovation and optimizing energy structures. Habiba et al. (2022) asserted that green technology innovation and the adoption of renewable energy will be the primary determinants of future reductions in carbon emissions. Zhu et al. (2023) conducted a comprehensive analysis of the influence of GF on the low-carbon economy. The size effect, technological effect, and structural effect of GF significantly contribute to a low-carbon economy.

In conclusion, in promoting carbon emission reduction and environmentally friendly development, GF and technological innovation develop synergistically, and together, they enhance a company's ESG score and achieve sustainable and efficient development.

3.4.2.2 Overview of Green Technology Innovation as a Moderator in the Relationship between Carbon Price and Company Performances

a) Overview of Carbon Price, Green Technology Innovation and Economic Performance

Research in the literature has revealed that carbon price mechanisms, such as carbon taxes and carbon emissions trading systems, motivate companies to embrace green and clean technologies, thereby increasing company value and market competitiveness (Zhu et al., 2022). The carbon trading mechanism effectively incentivizes companies to reduce carbon emissions through clear carbon price signals and improve environmental performance through technological innovations. Against the backdrop of growing carbon price, companies face increased cost pressures. They are, therefore, more driven to transition to cleaner technologies, encouraging the development of advanced technology that promotes low-carbon solutions (Yang et al., 2022). In addition, implementing the carbon price mechanism provides a solid basis for market innovation, the promotion of GF options, and the optimal use of energy resources, thereby contributing to environmental sustainability (Anser, Abbas et al., 2021).

Overall, a higher carbon price would drive technological innovation and the company's adoption of cleaner technologies, which in turn would increase company value. This relationship emphasizes the significance of environmental policy, such as carbon price, in promoting sustainable innovation and improving the economic performance of the company.

b) Overview of Carbon Price, Green Technology Innovation and Sustainable Performance

According to Khurshid et al. (2023), the combination of innovation and environmental policy can effectively decrease carbon emissions in both the long and short run. Among other things, carbon price has proven its effectiveness as a short-term

strategy for achieving sustainable development goals. Pursuant to Dong et al. (2022), a strong association exists between a moderate to high carbon price and the development of green technical advancements, resulting in a substantial improvement in the efficiency of reducing emissions. In the article by Chen and Wang (2023), China's carbon price policy has pushed companies in heavily polluting industries to develop new energy sources using new emissions reduction technologies. It successfully achieves additional emissions reductions of more than 20%. The study revealed a positive correlation between higher levels of green technology innovation in organizations and their ability to effectively fulfill their social responsibilities. At the same time, it achieves a harmonic symbiosis and coordinated development of economic and environmental benefits (Xie, 2022). In accordance with research conducted by Cai et al. 2021, green technology innovation enhance energy efficiency through the use of carbon capture and storage technologies. Heavily polluting companies have significantly reduced their carbon emissions through various measures, including developing cleaner energy sources (Pang et al., 2023).

Essentially, a rational carbon price mechanism stimulates the advancement of environmentally friendly technical breakthroughs, leading to decreased carbon emissions. The collaboration between carbon price policy and the development of green technologies is essential for enhancing sustainable performance.

3.4.2.3 Overview of Green Technology Innovation as a Moderator in the Relationship between Carbon Trading Policy and Company Performances

a) Overview of Carbon Trading Policy, Green Technology Innovation and Economic Performance

The current research on carbon price and green technology innovation can be categorized into three distinct groups, as summarized in Table 3.7.

According to the traditional hypothesis, some argue that environmental regulation, such as a carbon ETS, hinders companies from investing in R&D and advancing green technology. Several scholars argue that the carbon market has failed

to incentivize investment in R&D or the development of green technologies. The implementation of the carbon trading pilot scheme led to a significant reduction of around 9.26% in the number of green patents (Chen et al., 2021). In carbon trading pilots, government-led innovation does not immediately improve energy efficiency in the short term. Meanwhile, company-led innovation negatively correlates with energy efficiency (Liu et al., 2020). CET mechanisms and green technology innovation negatively correlate but considerably reduce carbon emissions and intensity. In particular, the inhibition is more prominent in the East (Zhang et al., 2022).

An alternative viewpoint, grounded in Porter's hypothesis, posits that environmental regulation, such as the carbon ETS, stimulates investment in R&D and fosters innovation in green technologies. Experts assert that the carbon trading systems used by both the European Union and China have effectively increased investment in R&D, as well as the development of environmentally friendly technologies. According to Zhou and Wang (2022), there exists a direct correlation between the implementation of the carbon price pilot policy and the advancement of green technology innovation in the pilot cities of China. Nevertheless, there is notable geographical disparity, with minimal progress in the level of green technology innovation in the western region and areas with established industrial infrastructure. The carbon trading programmer has significantly stimulated the advancement of green technology innovation in companies in the eastern region of China. This strategy has significantly accelerated the advancement of companies' innovation in green technology (Li et al., 2022).

The carbon trading policy has greatly promoted green technology innovation among companies. For every 1 million yuan increase in carbon trading volume, the number of green invention patents authorized will increase by 119.4 (Weng et al., 2022). Carbon trading policy can significantly promote green technology innovation in pilot provinces. However, there is a lag effect, and carbon emissions trading policy can also indirectly affect green technology innovation by influencing investment (Liu et al., 2022). CET can significantly promote green technology innovation in pilot cities. Environmental regulation and development strategies can greatly enhance this positive effect, confirming the effectiveness of the CET policy (Zhou & Wang, 2022). CET pilots can significantly increase urban green technology innovation, and human capital investment and science and technology support have a significant and partially

mediating role in the policy effects of CET on green technology innovation (Zhen et al., 2023). Carbon emissions trading policies under different environmental strategies positively impact companies' technological innovation and are more likely to promote technological innovation than reactive environmental strategies (Tian et al., 2022).

Based on the uncertainty hypothesis, the carbon ETS, which represents environmental law, has a limited and diverse effect on a company's innovation in green technology. Hang et al. (2020) mentioned that the emissions trading mechanism does not significantly affect the development of green technology innovation in companies that aim to reduce emissions. Notably, carbon emission pricing mechanisms have a varied effect on low-carbon innovation, shaping technological development. In particular, Beijing and Shanghai are moving towards cleaner technological change, while Guangdong and Chongqing are moving towards grey (Wang et al., 2020).

Table 3.7
Impact of Carbon Emission Trading on Green Technology Innovation

View	Main Content
Negative impacts	Environmental regulations, such as the carbon ETS, discourage R&D investment and green technology innovation.
Positive impacts	Environmental regulations, such as the carbon ETS, have boosted company R&D investments and green technology innovation.
Non-significant and heterogeneity	ETS has a limited and inconsistent impact on green technology innovation in companies since trade policy allocation mechanisms, geographies, industries, and company characteristics differ.

In conclusion, carbon trading policy and green technology innovation present a complex relationship, and this study will further confirm the relationship between carbon trading policy, green technology innovation and economic performance based on the theory of Porter's hypothesis.

b) Overview of Carbon Trading Policy, Green Technology Innovation and Sustainable Performance

There are two views on whether green technology innovation increases the carbon trading policy's sustainable performance. One opinion holds that green technology innovation has a favorable moderating effect, while another claims that it does not contribute to gains in sustainable performance (Table 3.8).

Under Porter's theory, one viewpoint is that the carbon market mechanisms strongly stimulate green technology innovation in pilot companies, lowering carbon emissions and dramatically improving ESG performance. China's carbon trading policy has facilitated the improvement and modernization of industrial structure and the efficient allocation of resources through the innovation of environmentally friendly technologies. Additionally, it offers a platform for companies to accomplish the dual-carbon target (Lan et al., 2022). Green technology innovation is crucial in connecting economic growth with environmental conservation, facilitating a transition towards a green, low-carbon future and fostering sustainable development (Ye et al., 2023). The implementation of carbon market mechanisms has significantly stimulated the development of environmentally friendly technology among pilot companies. This results in a notable reduction in greenhouse gas emissions (Liu & Li, 2022).

Under the traditional hypothesis theory, another viewpoint is that green technology innovation has not led to increased sustainable performance. Liu et al. (2021) also maintained that technological innovation, renewable energy consumption, and foreign direct investment in China's provinces have not reduced carbon emissions. Shao et al. (2021) stated that breakthroughs in renewable energy and green technology do not contribute to CO_2 emission reductions. Meanwhile, Du et al. (2019) discovered a single threshold effect for the influence of green technology innovation on income levels. The abatement impact is most substantial in economies with incomes above the threshold but not in those below it.

Table 3.8
Impact of Carbon Trading, Green Technology Innovation on Sustainable Performance

View	Main content
Negative impacts	Green technology innovation has not contributed to carbon reduction.
Positive impacts	Carbon trading promotes innovation in green technology and, thus, carbon emission reduction.

The impact of carbon trading policy on sustainable performance is complex and multifaceted. Based on Porter's hypothesis, this study will further confirm the impact of carbon trading policy and green technology innovation on sustainable performance.

3.4.3 Literature Review Summary

Since the launch of the carbon trading policy in 2013, scholars' research on carbon market mechanisms has covered multiple dimensions such as GF, carbon price and carbon trading. The carbon market mechanisms have a wide range of economic, environmental, technological and social effects. Carbon finance belongs to a subset of GF, and scholars have extensively studied the impact of GF reform pilot zones, GF policy, and the issuance of green bonds on firm value and ESG performance (Li & Di, 2021; Zhang & Ke, 2022; Zhou & Cui, 2019). Moreover, carbon price is one of the core elements of the carbon trading market, and scholars have studied the relationship between carbon price and stock price and the impact of carbon price on carbon emission reduction (Krokida et al., 2020; Mo et al., 2023; Adamolekun, 2023). Research on carbon trading policy is extensive, covering the impacts of carbon trading policy on firm value, TFP, technological innovation, carbon emission reduction and social employment (Nie et al., 2021; Schneider, 2022; Song et al., 2020; Zhou & Li, 2019). Based on Porter's hypothesis theory and traditional theory, the study results are mixed and contradictory, with both positive and negative impacts. This reflects the complexity of market-based environmental regulation (carbon market mechanisms) and the controversial nature of Porter's hypothesis.

However, the following shortcomings are in the previous literature. Firstly, previous researchers and scholars have extensively examined the economic and environmental effects of GF at the macro level. There is also a lack of research investigating the economic and environmental effects of carbon finance at the micro-company level. Second, previous literature has mainly explored the correlation between carbon price and stock prices and the impact of carbon price on carbon emissions. However, there is limited empirical evidence on the impact of carbon price on company performance. Third, previous literature has mostly examined the single impact of carbon trading policy on economic efficiency or emission reduction effects, and there is a lack of comprehensive study. Fourth, previous literature has examined the direct impacts of carbon finance, carbon price, and carbon trading policy on technological innovation. Despite that, it has not examined the relationship between carbon market mechanisms, green technology innovation and company performance. Fifth, no

literature has investigated the opportunities and challenges as well as the problems and development countermeasures of China's carbon market in the field by means of interviews.

This study will provide a mixed research approach integrating multiple dimensions to fill these gaps and provide new insights into the interactions between environmental regulations and firm performance in the context of the Chinese carbon market. This study explores the following four aspects in depth. Firstly, in this study, a continuous DID model is used to construct carbon finance indicators at the micro-company level, compare the impacts of carbon finance on low-carbon economic development and carbon emission reduction between carbon trading pilots and non-carbon trading pilots, which, to the best of our knowledge, is the first of its kind. Second, this study uses a continuous DID model to compare the impacts of carbon price on company performance between carbon trading pilots and non-carbon trading pilots, which provides the latest empirical evidence on carbon price mechanisms. Third, this study comprehensively examines the dual impacts of carbon trading policy on economic performance and sustainable performance, perceiving market-based environmental regulation from multiple perspectives. Fourth, this study applies innovation theory to further investigate the moderating role of green technology innovation in enhancing or weakening the impact of carbon market mechanisms and examine the relationship between the three. Fifth, this study adopts the field survey method to summarize the real problems and development countermeasures in China's carbon market to better expand and supplement the quantitative research.

3.5 Hypothesis Development

This study presents testable hypotheses based on the underlying theoretical framework and prior literature. There are 12 hypotheses that need to be examined to determine the correlation between carbon market mechanisms, green technology innovation, and company performance, including six main hypotheses and six moderating hypotheses.

3.5.1 Hypotheses for Testing Carbon Market Mechanisms and Company Performance

3.5.1.1 Hypotheses for Testing Carbon Finance and Company Performance

a) Hypotheses for Testing Carbon Finance and Economic Performance

Porter's hypothesis proposes that effective environmental legislation will stimulate technological innovation, increasing company productivity and economic performance. Researchers generally agree that issuing green bonds and implementing green credit and GF pilot policy can contribute to an increased sense of Company's Social Responsibility (CSR), promoting financial performance and company value. There is a strong positive association between GF and sustainable green economic growth.

Zhou and Cui (2019) argued that green bonds in China might incentivize companies to engage in CSR, promote environmental well-being, attract investors, and enhance company valuation. According to Malini (2021), implementing GF in Bank Islam Indonesia promotes the bank's financial performance and company's value and promotes the bank's active social responsibility. Further research discovered that implementing GF can only achieve short-term profits and not long-term sustainability. Hu et al. (2021) reported that the Pilot GF policy has a substantial impact on the long-term value of environmentally friendly companies. This is achieved by stimulating stock exchange activity via capital market effects and enhancing profitability and operational efficiency through real impacts. Panibratov et al. (2022) provided evidence of the significant influence of carbon tax policy in Finland and China, both EU member states, on economic development. They recommended that the EU and other countries adopt comparable policies to optimize sustainable economic growth.

Carbon finance expands financing channels and reduces financing costs. The growth of the carbon finance industry has provided companies with new financing options, such as green bonds, green credits, and carbon bonds, amongst others (Zhou & Cui, 2019). These avenues not only help the company to raise funds but also reduce the cost of financing. Due to the inclination of investors to support environmentally

conscious companies and engage in environmentally sustainable practices, these companies will naturally be cheaper to finance.

Empirical evidence conclusively demonstrates that GF effectively reduces carbon emissions while simultaneously fostering economic growth. In the framework of the low-carbon transition, the advancement of carbon finance specifically fosters environmental sustainability, diminishes carbon emissions, and stimulates economic growth. Hence, it positively influences economic performance. The additional hypotheses are suggested in light of the previous discoveries.

H1a: There is a significant positive relationship between carbon finance and company economic performance.

b) Hypotheses for Testing Carbon Finance and Sustainable Performance

Under the theory of Porter's hypothesis, a considerable number of empirical studies have demonstrated that green financial policy, including green credit, green bonds, green financial reform, and innovation pilot zones, have significantly reduced companies' intensity and carbon emissions. It also enhances the sense of the company's responsibility and improves the level of ecological performance in the region, thereby contributing to the level of the company's ESG performance.

Empirical research has demonstrated a direct and beneficial relationship between GF and ESG performance. GF metrics align with the objectives of the Sustainable Development Goals (SDGs) (Xue et al., 2023). Li et al. (2019) examined the influence of carbon finance on carbon emissions by analyzing the carbon market and green credit effects of carbon finance. Their findings indicated that green credit has a mitigating effect on carbon emissions. Meanwhile, Chen et al. (2022) stated that China's GF Reform and Innovation Pilot Zone programmer encourages enhanced ESG systems, leading to greater ESG scores for companies, with social responsibility scores playing an increasingly important role in driving the scores. Dai et al. (2022) argued that in Bangladesh, CSR and GF significantly influence the environmental performance of emerging market banking institutions. They discovered that GF specifically contributes to the improvement of environmental performance. Wang et al. (2022) stated that GF policy improves company ESG performance by introducing various

forms of financial incentives, lowering financing constraints, reducing financing costs, and increasing managers' environmental awareness. This is in addition to the fact that GF can positively affect green innovation.

The analysis of China's GF policy reveals that it strongly stimulates improving a company's ESG levels, and the effect varies among different companies (Qian & Yu, 2023; Sun et al., 2023). According to Xu et al. (2023), the GF policy minimizes the company's carbon intensity while also promoting the improvement of industrial companies' ESG ratings and technological dissemination. Ran et al. (2023) discovered that GF has a beneficial impact on carbon emission efficiency and encourages its enhancement. According to Xu and Liu (2023), the study utilized the Partial Least Squares Regression (PLSR) model to examine the impact of carbon finance on the green transformation of China's marine industry between 2006 and 2020. The findings indicated that the comprehensive score of China's marine industry has been changing at higher levels. The company's ESG and eco-performance in various locations are greatly influenced by the local GF Policy (Xue et al., 2023; Ge et al., 2022).

The study indicates that carbon finance exerts a beneficial and substantial impact on the ESG performance of companies in the subsequent manners:

Environmental: carbon financial instruments, such as carbon trading and green bonds, Incentivize companies to invest in environmentally friendly technology and initiatives that cut carbon emissions while advancing a low-carbon transition and green economic development. In addition, carbon finance allows companies to better minimize the cost of carbon emissions while also stimulating the potential for emission reductions. Furthermore, formulating more detailed and scientific emission reduction plans to reduce pollution to the environment further.

Social: companies active in carbon finance demonstrate a strong sense of social responsibility. This enhances the company's brand image and social standing, hence attracting fresh stakeholders and investors (Xu et al., 2023).

Governance: carbon finance requires companies to disclose clearer carbon emissions data, explicit emission reduction targets, and reports on achievement. This helps the company to develop a more transparent governance structure and system of governance that enhances the trust of investors and stakeholders. Companies involved in carbon finance need to comply with relevant regulations and policies. This can help

to promote the establishment of a more standardized and sustainable company model and enhance the quality of the company's governance and compliance.

Overall, empirical research supports the favorable influence of carbon finance on a company's ESG, which promotes ESG practice, strengthens social responsibility, improves governance, and reduces the cost of financing. Therefore, the following hypothesis is proposed for further investigation.

H1b: There is a significant positive relationship between carbon finance and environmental score.

3.5.1.2 Hypotheses for Testing Carbon Price and Company Performance

a) Hypotheses for Testing Carbon Price and Economic Performance

Empirical research supports Porter's hypothesis, and the theory posits that there is a direct correlation between carbon price and company value. The implementation of this system has resulted in significant emission reductions. According to Bolton et al. (2023), the correlation between carbon price and stock price is primarily influenced by the proportion of emissions that are subject to carbon permits. For companies with severe carbon allowance deficits, an increase in the daily carbon price is strongly connected with a decline in stock price over the same time period. Carbon price rises on a daily basis are connected with better stock prices for companies with larger license coverage over time. Liozu and Hinterhuber (2013) noted that value-based carbon price strategies will drive company performance and that carbon price decisions will significantly affect company performance. Chen et al. (2017) mentioned that carbon price positively affects the operational efficiency and market competitiveness of companies. They also stated that the carbon price mechanism is a key factor in facilitating manufacturing companies to make optimal operational decisions and improve overall performance.

Researchers have argued that lower carbon price do not positively impact company value, competitiveness, and emissions reductions. By adopting the general equilibrium model, the analysis suggests that China's current carbon trading price is too low. It has minimal effect on emission reduction and makes it challenging for companies to actively participate in carbon trading (Lin & Jia, 2019). Venmans et al.

(2020) examined the effect of carbon price on competitiveness in the electrical and industrial sectors of G-20 and OECD countries, concluding that lower energy and carbon price had no meaningful influence on competitiveness. Flachsland et al. (2020) highlighted that The EU ETS establishes a minimum carbon price standard. This institutional innovation is vital for enhancing political and economic stability and ensuring price stability in the EU ETS. Song and Liu (2023) conducted a comprehensive analysis of the relationship between carbon trading price and stock price using a Vector Auto Regression (VAR) model. The study revealed that the proportion of carbon trading price accounted for the entirety of the contribution in the initial phase but gradually declined to a minimum of 98.27% in the eighth phase.

According to this study, an increase in the price of carbon will encourage companies to invest in technological innovation. To minimize production costs and comply with carbon emission limits, the company will invest more in R&D to develop more efficient emission reduction technologies and cleaner energy sources. These technological innovations reduce the company's long-term production costs and increase productivity, improving economic performance. The influence of carbon price on a company's economic success is complicated and multidimensional. Although implementing a carbon price may initially lead to higher costs and a decline in a company's economic performance, the overall influence on the company's economic performance is intricate and varied. Over time, increasing carbon costs will incentivize companies to invest in technological innovation, transformation, and upgrading in order to achieve sustainable development and enhance economic performance. Consequently, this study introduces the ideas outlined below.

H2a: Carbon price is positively related to the company's economic performance.

b) Hypotheses for Testing Carbon Price and Sustainable Performance

Multiple empirical studies have confirmed the crucial importance of the carbon trading price in motivating companies to implement carbon reduction initiatives. Carbon price incentivizes the shift towards a more diverse energy portfolio and the decrease of carbon emissions, fosters the growth of low-carbon initiatives, and advances the cause of sustainable development (Du & Chen, 2021). In the study by

Adamolekun (2023), the author discovered that, by analyzing data from 1,591 companies in 23 European countries, higher carbon price contributed to lower carbon emissions. Khurshid et al. (2023) considered that carbon price can mitigate carbon emissions in the region. Still, the carbon price is an effective short-term tool, and green technology innovation and stringent environmental policies are essential for achieving long-term sustainable development. Lin and Jia (2019) indicated that an increase in the price of CET has a significant effect on encouraging reductions in carbon emissions. This is with sectoral reductions and an increase in the rate of free allowances being the primary drivers of the increase. Bayer and Aklin (2020) highlighted that the EU ETS has effectively contributed to the reduction of carbon emissions by companies despite the relatively low market price. ICP can effectively reduce carbon intensity (Zhu, Ye et al., 2022).

Scientists posit a direct correlation between the cost of carbon trading and the degree to which carbon emissions are reduced. They argue that as the price of carbon trading increases, the impact of reducing carbon emissions becomes more apparent. Conversely, when the price of carbon trading is lower, its ability to enhance environmental performance is diminished. In the article by Lin and Jia (2019), the authors asserted that lower CET prices would impede the carbon market's capacity to mitigate emissions. China's carbon market is too small, and emissions reductions are inadequate. Green (2021) noted that the carbon price has a minimal mitigation effect, ranging from 0 to 2% annually.

Some academicians argue that high carbon price positively impact employment in low-carbon manufacturing and thermal power. For example, Fragkos and Fragkiadakis (2022) contended that the global decarburization process would have a small effect on overall employment. However, they emphasized that the low-carbon manufacturing and electricity sectors would experience a particularly significant influence on employment. According to Zhang and Cross (2020), employment in China's thermal power sector is expected to expand as power coal prices rise as a result of the carbon strategy. This study investigated the impact of the carbon price on ESG factors in the following domains.

Environment: carbon price is an essential economic instrument for lowering greenhouse gas emissions. As the price of carbon rises, companies will have more

incentives to embrace cleaner energy sources, enhance energy efficiency and develop low-carbon technology to reduce the financial impact of carbon emissions. This will assist in limiting global greenhouse gas emissions, thereby mitigating the effects of climate change.

Social: A rise in the price of carbon may increase the cost of production in certain energy-intensive industries (e.g., electricity, steel), which in turn would affect employment and social stability in those industries. However, over time, with the advancement of clean energy and low-carbon technologies, these industries will also gradually move in a more environmentally friendly and sustainable direction, thus creating more employment opportunities for society.

Governance: An increase in carbon price will prompt companies to emphasise environmental and social responsibility, thereby promoting the company's governance structures that are more transparent, fair, and sustainable. With the popularization of ESG investing concepts, an increasing number of investors will focus on a company's ESG performance, prompting companies to pay greater attention to ESG governance and strengthen the company's governance.

Overall, the impact of carbon price on ESG is far-reaching. It can drive green transformation in companies and reduce greenhouse gas emissions. Moreover, it may also serve as a catalyst for society to prioritize environmental conservation matters and strengthen the company's governance frameworks. Considering the previous data, this paper establishes the following ideas.

H2b: Carbon price is positively related to environmental score.

3.5.1.3 Hypotheses for Testing Carbon Trading Policy and Company Performance

a) Hypotheses for Testing Carbon Trading Policy and Economic Performance

Porter's hypothesis theorizes that there is a positive relationship between market-based environmental regulation (carbon trading policy) and company value. Carbon trading policy promotes technological innovation, incentivizes emission reductions, and promotes a carbon premium, increasing stock and company values. According to Wang et al. (2020), carbon emissions and the level of financial development contribute significantly to China's GDP. However, renewable energy use

and technical innovation negatively correlate with carbon emissions. The implementation of the ETS pilot had a significant positive impact on the company's financial performance, particularly due to the differential effects of the policy. The ETS pilot significantly impacted the financial performance of privately owned companies compared to state-owned companies (Yu et al., 2022).

Carbon credits can be traded as a commodity in the carbon market, making them a distinct financial asset (Schneider, 2022). At the outset of the Carbon Emission Trading Pilot (CETP), these companies obtained carbon property rights by participating in the CETP (most of the carbon permits in China's CETP are free). This is analogous to the act of raising the company's assets, and the remaining carbon allowances can be exchanged on the carbon market, generating more income and enhancing the company's value. In addition, the continuous growth of the carbon finance sector has led to the emergence of other carbon financial products, such as carbon options and carbon futures, and the continuous development and growth of these products will help increase the company's long-term value.

Since the official establishment of the national CET market in 2017, companies around the country have started to prioritize energy saving and the reduction of emissions. Numerous organizations actively engage in the CET sector, acquire emission reduction equipment, enhance procedures, and reduce production and operational expenses through green technology innovation and industrial chain upgrading to boost production efficiency and increase the company's value (Song et al., 2020; Zhou & Li, 2019). Simultaneously, within the framework of sustainability and reduced carbon emissions, the government will enact a series of advantageous laws for environmental companies, resulting in substantial benefits for the company's manufacturing and operations and its societal endeavors. This will allow the company to generate greater revenue, increase its cash flow, and boost its value. As a result, within the framework of low-carbon environmental conservation, the government and institutional investors will encourage companies to enter the carbon emission rights market. This results in an increase in the company's value. This study proposes the following hypothesis derived from previous research and views regarding the correlation between carbon trading policy and the company's value.

H3a: Carbon trading policy is positively associated with company economic

performance.

b) Hypotheses for Testing Carbon Trading Policy and Sustainable Performance

Porter's assumption states that numerous empirical studies have demonstrated the effectiveness of carbon trading regimes in reducing energy consumption and carbon emissions while simultaneously promoting employment in energy-intensive, low-carbon industries. Promote the optimization of the company's governance structures, build the notion of green and sustainable development, and significantly contribute to improving the company's ESG performance.

While there is less research on the impact of CET on a company's ESG performance, some studies have examined the correlation between carbon markets and specific ESG sub-indices. The carbon emissions trading mechanism serves as a significant market regulation and environmental management tool. It effectively reduces greenhouse gas emissions in a cost-effective and efficient manner, hence facilitating the achievement of society's overall green and low-carbon development goals (Li et al., 2020). Studies have proven that carbon emissions trading policies have made significant contributions to global greenhouse gas emissions reduction through environmental regulations to control CO_2 emissions based on the carbon market (Yuan et al., 2019). The carbon market trading mechanism actively promotes carbon emission reduction and reduces pollutant emissions from heavily polluting industries (Zhou, 2023). Niyommaneerat et al. (2023) noted that companies should consider the value of social responsibility (CSR) programs, such as obtaining carbon credits for reducing carbon emissions, in order to create economic value. Carbon trading policy promotes rational and optimal allocation of resources (Clarkson et al., 2015). Companies with effective company governance frameworks can respond favorably to the request for carbon trading policy and establish green and sustainable development values both internally and externally (Yu et al., 2022).

Some researchers suggest that the carbon trading policy creates job opportunities. The study discovered that the carbon trading regime greatly increased the scale of employment and decreased carbon emissions, i.e., there is a double dividend benefit of employment and emission reduction in the CETP policy (Yang et al., 2020).

The ETS has contributed significantly to the labor demand of regulated companies, with positive employment effects being seen as companies scale up production (Ren et al., 2020).

The carbon emissions trading market is an essential mechanism for motivating companies to decrease their CO_2 emissions (Yuan et al., 2022). The study concludes that the carbon trading mechanism improves company ESG performance. a) Capping carbon emissions. The carbon market mechanisms limit carbon emission allowances, putting pressure on companies to take proactive steps to decrease carbon emissions, such as using cleaner energy sources and increasing energy efficiency. This promotes the virtuous circle and sustainable development of the company. b) Introducing third-party verification, whereby the carbon market requires carbon trading pilot companies to submit carbon emission reports to the relevant authorities and have them verified by third-party organizations. This helps improve the company's governance structure and transparency and further improves ESG. c) Guiding investment: The carbon trading policy aims to guide investment through carbon trading to make more capital flow to low-carbon projects. Low-carbon companies have more funding sources and are thus better able to implement sustainable development strategies. Drawing on Porter's hypothesis theory and existing literature, this study puts up the subsequent hypotheses: H3b: Carbon trading policy is positively associated with environmental score.

3.5.2 Hypotheses for Testing the Moderating Effect of Green Technology Innovation on the Relationship between Carbon Market Mechanisms and Company Performance

3.5.2.1 Hypotheses for Testing the Moderating Effect of Green Technology Innovation between Carbon Finance and Company Performance

a) Hypotheses for Testing the Moderating Effect of Green Technology Innovation between Carbon Finance and Economic Performance

Based on Porter's premise and innovation theory, the empirical study indicates that globalization fosters a company's technical innovation, and there is a positive correlation between R&D expenditure, technological progress, and company performance. Green technology is important for the company's economic performance.

According to prior research conducted by Han et al., 2022 and Lu et al., 2022, experts deduce that China's pilot programmer on GF significantly contributes to fostering the company's innovation in green technology. Li and Yang (2022) mentioned that GF encourages a company's technological innovation, and CSR improves the association between GF and technical innovation. Huang et al. (2022) asserted that GF has a significant role in enhancing creativity in green technologies. However, its driving influence on green technology innovation has reduced as environmental regulations have increased. GF increases its investment in environmental preservation and R&D, which leads to a decrease in funding limitations and an enhancement in creative performance (Liu et al., 2023). Xu et al. (2023) also mentioned that GF policy promotes green process improvements, end-of-pipe treatment of pollutants, and increased innovation in green technologies. In the Innovation theory view, there is a positive correlation between investment in R&D, the creation of technology, and the performance of a company. Green technology enhances a company's financial performance and productivity, hence increasing competitiveness in the carbon market (Hung & Chou, 2013).

This study concludes that carbon finance provides a very good financing channel for green technology innovation projects, and such projects can obtain more capital tendency and cost preference in the carbon finance system. Companies are encouraged to innovate and promote technological progress through the ability to meet the financial requirements of technological progress.

Green technology innovation can help organizations improve their economic performance by upgrading and improving industrial technologies, optimizing production methods, increasing resource efficiency, and reducing energy losses. Cleaner production technologies in green technology innovation can change or prevent pollutants at the source with more appropriate material substitution, recycling processes, and management practices and gain cost leadership in market competition. Increasing the company's operating income, in consequence, enhances its economic performance. Green technology innovation can potentially enhance the industrial process, resulting in reduced production costs and environmental management expenses. The advantages of green technology innovation exceed the expenditure on R&D, which can increase the company's profits. For further research, the following hypotheses were formulated

for this study.

H4a: Green technology innovation moderates the relationship between carbon finance and company economic performance.

b) Hypotheses for Testing the Moderating Effect of Green Technology Innovation between Carbon Finance and Sustainable Performance

Empirical research grounded in innovation theory has demonstrated that the adoption of green technology innovation enhances sustainable performance. According to Cao et al. (2021), there is a positive correlation between digital finance, green technology innovation, and energy and environmental performance in China. Additionally, green technology innovation plays a role in enhancing energy and environmental performance. GF promotes improved environmental performance, and technological innovation positively affects a company's environmental performance (Awawdeh et al., 2022). During the 2019 coronavirus disease pandemic, the adoption of finch and green innovations in the banking sector positively impacted GF and environmental performance (Guang Wen & Siddik, 2023).

The sustainable effects of carbon finance can be realized through green technology innovation, which, supported by innovation theory, has emerged as a pivotal catalyst in the evolution and advancement of companies. Due to financial constraints, high-carbon industries must seek strategies to change their development routes. High-carbon companies address air pollution through technical advances such as carbon decomposition and carbon capture and the creation of cleaner industries through technological collaboration to meet carbon reduction targets.

Green technology innovation can improve resource efficiency, reduce company energy consumption, and lower energy-related costs. Green technology innovation might focus on either process technology or green goods. Green technology innovation is achieved by upgrading existing production processes or updating production equipment to reduce the emission of pollutants and hazardous substances, environmental pollution, and environmental performance. Green product innovation involves incorporating environmentally friendly principles across the whole life cycle of a product, covering the selection of raw materials, design, functional design,

packaging and recycling, and other aspects. Reduce negative environmental impacts at all product life cycle stages at the source. The innovation of green technology has the capacity to significantly diminish environmental pollution while simultaneously reducing the expenses associated with environmental compliance for companies. Building upon the previous discussion, this study puts forth the following hypothesis.
H4b: Green technology innovation moderates the relationship between carbon finance and environmental score.

3.5.2.2 Hypotheses for Testing the Moderating Effect of Green Technology Innovation between Carbon Price and Company Performances

a) Hypotheses for Testing the Moderating Effect of Green Technology Innovation between Carbon Price and Economic Performance

Empirical studies suggest that increased carbon price incentivize companies to invest in technological innovation, which boosts a company's value. According to the notion of innovation, this study argues that fluctuations in the cost of carbon emissions will incentivize companies to engage in innovation, optimize the allocation of resources, and ultimately improve company performance over an extended period of time. Under a carbon trading mechanism, companies with the advantage of reducing emissions will adopt low-carbon and green production technologies. Thus, by maintaining allowances, one can sell them at a profit when the price of carbon emissions increases. On the contrary, for those companies with high abatement costs, i.e., relatively outdated technologies and production methods, a high price on carbon emissions would put them under cost pressure. However, signals from carbon price can force these companies to make cleaner transitions, optimize resource use, and achieve emissions reductions at the lowest possible cost. According to Porter's hypothesis, these reforms would help the company better adapt to a high-carbon price environment. Still, they would also increase profits to offset compliance and innovation costs. The following hypotheses were formulated for this study based on the above analyses.
H5a: Green technology innovation moderates the relationship between carbon price and company economic performance.

b) Hypotheses for Testing the Moderating Effect of Green Technology Innovation between Carbon Price and Sustainable Performance

Under the guidance of innovation theory, empirical studies support the idea that carbon price promotes technological innovation and effectively reduces carbon emissions. Carbon price policy boosts the development of low-carbon technology, effectively contributing to reducing carbon emissions (Lundgren et al., 2015). Lv and Bai (2021) emphasized that greater carbon trading price and price volatility greatly push companies to innovate, proving the good effect of CET policy in motivating companies to innovate to minimize carbon emissions. Existing carbon price regimes have caused modest development in innovation despite lowering emissions (Lilliestam et al., 2022). The study demonstrated that green innovation has a twofold effect. Firstly, it enhances the financial performance of the company. Secondly, it enhances the quality of the company's carbon disclosure, improving its environmental performance (Peng et al., 2022).

This paper argues that carbon emission pricing, as a fundamental market-oriented environmental strategy, provides a reasonable price formation mechanism and a governmental regulatory system to motivate companies to develop green technology advances. The magnitude of the carbon price, whether high or low, significantly influences a company's ability to develop and implement environmentally friendly technological advancements. Implementing a carbon price might motivate companies to prioritise profit-maximizing actions by modifying the expenses associated with production, carbon emissions, and the adoption of green technologies. Carbon price are high enough to encourage companies with low marginal abatement costs to invest in green technologies and create surplus allowances to sell for a profit. Companies with high marginal abatement costs will experience financial pressure, necessitating them to modify, upgrade, and innovate environmentally-friendly solutions. Green technology innovation will continue to help the organization improve its ESG performance. As a result, this study suggests the hypotheses listed below.

H5b: Green technology innovation moderates the relationship between carbon price and environmental score.

3.5.2.3 Hypotheses for Testing the Moderating Effect of Green Technology Innovation between Carbon Trading Policy and Company Performance

a) Hypotheses for Testing the Moderating Effect of Green Technology Innovation between Carbon Trading Policy and Economic Performance

According to the theory of Porter's hypothesis, a large number of empirical studies have demonstrated the positive impact of carbon trading policy and green technology innovation on economic performance. Liu and Sun (2021) demonstrated a considerable positive association between China's carbon emissions pricing mechanism and low-carbon technological innovation. This positive correlation becomes stronger with time. Studies have indicated that carbon trading mechanisms have been effective in guiding companies towards a low-carbon development path while at the same time promoting the flourishing of green technology innovation (Cui et al., 2022). Hasan et al. (2021) noted that profits and carbon emission reductions are directly proportional to investment in green technologies under carbon regulation. Razzaq et al. (2021) examined the inherent connection between the advancement of green technology and the reduction of carbon emissions. They employ a comprehensive range of non-linear model techniques and evaluate monthly data from the BRICS countries spanning from 1990 to 2017. Their findings indicated that the invention of green technology contributes to the reduction of carbon emissions. Qi et al. (2021) investigated the influence of a pilot carbon trading policy on the low-carbon innovation of a company participating in the pilot. The findings reveal that the carbon trading policy effectively stimulates the low-carbon innovation of the company. Further analysis of various quota allocation systems demonstrates that benchmarking has a greater impact on the extent of low-carbon innovation. According to Qi et al. (2021), China's CET mechanism has a substantial impact on R&D investment and green technology innovation in the eastern area and among state-owned companies in relation to company size and ownership.

This study suggests that if a company's green technology innovation is effective, it can make up for the gap produced by increased expenses and make up for it. It is also feasible to use some of the conserved quotas to trade in the carbon market, increase the production capacity of the equivalent quota, or sell the patented technology to the outside world, all of which can boost the company's profits. This would encourage companies to increase their R&D investment in green technology innovation, and the first companies to complete green technology innovation will be able to reap market returns in a timely manner. The market share of the company is a major source of revenue. On this premise, the study puts up the following hypotheses.

H6a: Green technology innovation moderates the relationship between carbon trading policy and company economic performance.

b) Hypotheses for Testing the Moderating Effect of Green Technology Innovation between Carbon Trading Policy and Sustainable Performance

Research in the literature has demonstrated that implementing a carbon emissions trading policy has a significant impact on fostering the advancement of environmentally friendly technological innovation. This is achieved through reducing production costs, optimizing industrial structure, and lowering capital costs (Li et al., 2022). According to Zhang et al. (2023), CET programmers improve ESG performance by strengthening internal controls and increasing R&D expenditure. Yao et al. (2023) suggested that ETS improves green governance in pilot companies by increasing government regulatory pressure and encouraging companies to innovate cleanly. Huang and Tian (2023) emphasized that increased innovation in green technology contributes to greater reductions in carbon emissions from environmental regulations. green technology innovation is considered a powerful tool for achieving both economic growth and environmental conservation simultaneously (Jiang et al., 2022).

According to this study, the carbon trading mechanism helps to internalize the cost of carbon emissions, serves as a cost constraint, and stimulates companies to undertake green technology innovation. The carbon market mechanisms control total greenhouse gas emissions. To meet the limit, companies that continue to use their original production technologies have two options. One possibility is to buy carbon

credits on the carbon market while keeping the same output level. The alternative is to reduce the company's production to keep carbon emissions within quotas. Either approach would raise pollutant control expenses, lowering profitability and market competitiveness. Companies having surplus allowances on the carbon market can generate additional funding. When companies do not have enough carbon permits, the government urges them to invest more in R&D, technological advancement, and industrial transformation.

Implementing a carbon trading programmer supports the company's investment in R&D and promotes scientific and technological innovation (Ni et al., 2022). Companies are compelled to increase their investment in R&D in order to enhance innovation and ESG performance due to financial limitations. Companies that invest heavily in R&D have excellent information-gathering skills, optimized internal processes, and patent applications that grow in tandem with R&D investment, increasing the magnitude of innovation even more. Consistent innovation will increase the company's worth, making institutional investors more inclined to invest in companies with superior ESG performance, thus establishing a positive feedback loop. In this study, the hypotheses were formulated based on the findings of the literature review and prior analyses.

H6b: Green technology innovation moderates the relationship between carbon trading policy and environmental score.

Table 3.9 presents all the hypotheses developed for the study.

Table 3.9

List of Hypotheses to Address RQ

Research Questions	Hypothesis	Relationship
RQ1: What are the different impacts of the carbon market mechanisms (i.e., carbon finance, carbon price and carbon trading policy) on the company performance (economic and sustainability) of heavily polluting industries before and after the implementation of carbon trading policy among the pilot and non-carbon trading pilot companies?	H1a	There is a significant positive relationship between carbon finance and company economic performance.
	H1b	There is a significant positive relationship between carbon finance and environmental score.
	H2a	Carbon price is positively related to the company's economic performance.
	H2b	Carbon price is positively related to environmental score.
	H3a	Carbon trading policy is positively associated with the company's economic performance.
	H3b	Carbon trading policy is positively associated

		with environmental score.
RQ2: What are the different impacts of green technology innovation on the relationship between carbon market mechanisms (carbon finance, carbon price and carbon trading policy) and company performance (economic and sustainability) of heavily polluting industries before and after the implementation of the carbon trading policy between pilot and non-carbon trading pilot companies?	H4a	Green technology innovation moderates the relationship between carbon finance and company economic performance.
	H4b	Green technology innovation moderates the relationship between carbon finance and environmental score.
	H5a	Green technology innovation moderates the relationship between the carbon price and the company's economic performance.
	H5b	Green technology innovation moderates the relationship between carbon price and environmental score.
	H6a	Green technology innovation moderates the relationship between carbon trading policy and a company's economic performance.
	H6b	Green technology innovation moderates the relationship between carbon trading policy and environmental score.

3.6 Key Factors Influencing Carbon Trading Pilot and Non-Carbon Trading Pilot

This section delineates the principal determining elements for carbon trading pilots and non-carbon trading pilots, respectively.

3.6.1 Key Factors Influencing Carbon Trading Pilot

Carbon trading pilots are crucial for attaining carbon reduction objectives, and their efficacy is affected by numerous factors. The following sections elaborate on the principal elements influencing carbon trading pilots.

3.6.1.1 Carbon Finance

Carbon finance offers a variety of financing mechanisms for carbon trading initiatives, including carbon quota pledge financing and carbon asset repurchase financing, which assist companies in optimizing their carbon assets, mitigating financial burdens, and fostering the investment and advancement of low-carbon projects (Li & Liu, 2011). The advancement of carbon finance has facilitated the innovation of carbon trading instruments, including carbon futures, carbon options, and

other financial derivatives, thereby enhancing the product diversity of the carbon trading market and augmenting its activity and liquidity (Han et al., 2023). Carbon finance has drawn increased participation from investors and financial institutions in carbon trading by offering varied financing avenues and risk management instruments, thereby augmenting the market's vibrancy and appeal (Lo, 2016). The advancement of carbon finance has facilitated the profound integration of the carbon market with the financial market, transforming carbon trading from mere emissions trading to a close association with financial capital and the financial market, establishing a more intricate and efficient carbon financial system (Zhou & Li, 2019).

3.6.1.2 Carbon Price

The carbon price serves as a crucial indicator in the carbon trading market, representing the market's supply and demand dynamics. When the supply of carbon emission allowances surpasses the demand, the carbon price will increase, and conversely. This pricing system directs companies to decrease carbon emissions and enhance the efficacy of emission reduction efforts (Zhu et al., 2019). An appropriate carbon price can serve as a compelling economic signal for companies, motivating them to implement strategies to decrease carbon emissions. Simultaneously, variations in carbon price will influence the costs and advantages of emission reduction for companies, motivating them to engage more actively in carbon trading (Lin & Jia, 2019).

Fluctuations in carbon price influence market anticipations for future carbon credits. An increase in carbon price prompts the market to anticipate a scarcity of carbon credits, resulting in heightened engagement in carbon trading. Conversely, this may also cause a decline in market involvement (Edenhofer et al., 2021). A consistent carbon price fosters the stable evolution of the carbon market. Volatile carbon price may cause market disruptions and influence companies' decisions about emission reductions and investment strategies. Consequently, the government and pertinent bodies must uphold the stability of carbon price by policy regulation (Mo et al., 2023).

3.6.1.3 Carbon Policy and Regulation

Carbon policy and regulation are critical determinants influencing the operational efficacy of carbon trading initiatives. The government has established a carbon trading policy that delineates the overall goal amount, coverage, quota allocation methodology, trading regulations, and other fundamental elements of the carbon trading market. This ensures a policy framework for the market's effective operation (Qi et al., 2021).

The distribution of carbon emission allowances and the structure of most operational pathways in the carbon trading market are predominantly directed by the government, exhibiting a clear policy bias (Peng et al., 2021). The government directs companies to diminish carbon emissions and encourage low-carbon development by establishing emission reduction objectives, distributing carbon emission allowances, and formulating trading regulations (Springer et al., 2019).

The sustained functionality of the carbon trading system necessitates enduring and consistent policy backing. Frequent regulatory alterations will heighten market uncertainty and influence the company's investment decisions and involvement in carbon trading (Chen et al., 2024).

A robust regulatory framework is essential for guaranteeing the equitable and transparent functioning of the carbon trading market. Robust regulation can mitigate market manipulation and fraudulent activities while bolstering the confidence of market participants (Cheng, 2022).

3.6.1.4 Allocation of Carbon Allowances

The allotment of carbon quotas is a significant aspect influencing the operational efficiency of the carbon trading experiment. The method of allocating carbon allowances directly influences the availability of carbon emission rights in the market, thereby impacting the price and trading activity within the carbon trading market.

Three primary modalities exist for distributing carbon allowances: free allocation, reimbursable allocation, and mixed modalities (Du et al., 2020). Free

allocation typically relies on factors such as a company's historical emissions, annual carbon intensity, or industry energy efficiency benchmarks. At the same time, compensated allocation distributes allowances via auctions or priced sales. Meanwhile, the hybrid model initially emphasizes free allocation before progressively shifting to compensate allocation. Diverse allocation techniques influence the cost of emission reduction and the efficacy of the carbon trading market (Jiang et al., 2024).

The determination of the overall quota amount must consider the national emission reduction objective, the degree of economic development, and the specific features of the industry (Li et al., 2020). Quota allocation directly influences the supply and demand dynamics in the carbon trading market. Excessive quota allocation will result in a decline in carbon price, diminishing companies' motivation to lower emissions; conversely, insufficient quota allocation will cause an increase in carbon price, elevating the costs associated with emission reduction (Zhou & Wang, 2016). Consequently, an equitable distribution of quotas is essential for the effective functioning of the carbon trading market.

As technology progresses and emission reduction objectives are modified, the total quantity of allowances and allocation methods must be periodically evaluated and revised to guarantee the efficacy and equity of the carbon trading market (Peng et al., 2021).

3.6.1.5 Carbon Cost

Carbon costs are a crucial consideration for companies engaging in carbon trading experiments. Carbon costs encompass the expenses associated with acquiring carbon emission allowances, the investment in R&D of emission reduction technology, and the expenditures related to carbon asset management.

The carbon price directly influences the expense of acquiring carbon emission allowances. As the carbon price escalates, the expense of acquiring allowances grows, resulting in heightened abatement costs for the company. Conversely, a decline in the carbon price reduces the cost of allowances, facilitating a decrease in the company's abatement expenses (Le & Azhgaliyeva, 2023).

To mitigate carbon emissions, the Company must invest in the research,

development, and implementation of emission reduction technology. The expenses related to research, development, and implementation of emission reduction technology are critical considerations for the company's involvement in carbon trading policy (Rode et al., 2021). For compliance assurance, the company must implement a carbon asset management system to monitor, report, and verify carbon emissions. This endeavor requires substantial people, material, and financial resources, elevating the company's carbon asset management expenses (Naranjo Tuesta et al., 2021).

3.6.1.6 Carbon Management Capacity

The carbon management capability of a company is a crucial determinant in the efficacy of its involvement in carbon trading initiatives. The company must implement a thorough carbon emission monitoring system, track and document emissions in real-time, and report and verify them in compliance with applicable legislation (Tang & Luo, 2014). These activities necessitate that companies possess expert technical and personnel assistance to guarantee data accuracy and compliance.

The company must form a specialized carbon asset management team tasked with the acquisition, disposition, and oversight of carbon permits to enhance carbon asset distribution and minimize carbon expenses (Zhang et al., 2018). The carbon trading market experiences price volatility, regulatory alterations, and various hazards. Thus, the company must implement a robust carbon risk management framework utilizing hedging strategies, carbon financial instruments, and other risk mitigation methods (Zhou et al., 2020).

3.6.1.7 Green Investments

The magnitude of green investment directly influences a company's capacity to mitigate emissions and its involvement in carbon trading. Extensive green investment can markedly diminish a company's carbon intensity and dependence on carbon permits (Ren et al., 2022). The scope of green investment encompasses clean energy, energy-efficient technologies, carbon capture, and sequestration. Diverse investment avenues yield varying impacts on emission reduction and economic advantages. Hence,

companies must select suitable investment paths based on their unique attributes (Tan & Solangi, 2023). Green investments entail an extended return period, necessitating that companies evaluate both immediate economic advantages and enduring environmental benefits. Government policy assistance and market incentives, such as carbon price, can augment the return on green investments and improve a company's propensity to invest (Tran et al., 2020).

Green investment incentivizes companies to diminish carbon emissions and fosters the advancement of associated industries, generating employment possibilities and economic advantages (Li et al., 2022). Consequently, governments and companies must augment their support for green investments to foster the advancement of a low-carbon economy.

3.6.1.8 Green Technology Innovation

Innovations in green technology are crucial for low-carbon advancement and addressing climate change. Green technology innovation encompasses advancements in clean energy technologies, energy efficiency and emission reduction technologies, and carbon collection and utilization technologies.

Advancements in clean energy technology can lower manufacturing costs and enhance market competitiveness, hence facilitating the extensive adoption of clean energy (Jayabal, 2024). Moreover, advancements in energy conservation and emission mitigation technology can enhance the company's energy utilization efficiency and diminish carbon emission intensity. These technologies encompass high-efficiency energy-saving apparatus, industrial waste heat recovery systems, smart grids, and others (Chu et al., 2024). In particular, advancements in carbon capture and utilization technologies facilitate the collection, utilization, and sequestration of Carbon Dioxide (CO_2), thereby diminishing carbon emissions. These technologies encompass chemical absorption, membrane separation, and biological techniques (Saxena et al., 2024).

Green technology innovation necessitates collaborative efforts among governments, companies, and research institutes (Guo et al., 2021). Hence, governments ought to augment their support for green technology innovation by allocating research funding and establishing preferential policies. In contrast,

companies should engage proactively in green technology innovation while enhancing research, development, and application. Moreover, scientific research institutions should intensify their investigation and exploration of green technology innovation, facilitating the transformation and application of innovative technological outcomes (Li et al., 2024).

3.6.1.9 Carbon Disclosure

Carbon disclosure is a crucial mechanism for companies to communicate their carbon emissions and mitigation efforts to external stakeholders, influencing the transparency and credibility of the carbon trading experiment (Zhang & Liu, 2020). Companies must consistently report information, including carbon emissions data, reduction targets and progress, and carbon trading status. Notably, transparent information disclosure can bolster the confidence of market participants and augment the liquidity of the carbon trading market (Yan et al., 2020).

Standardized carbon disclosure protocols are essential for guaranteeing the comparability and reliability of data. Governments and international bodies must establish and enhance carbon disclosure requirements and compel companies to comply with these standards (Jeevesh & Suhasini, 2021). Governments can promote corporate carbon disclosures through policy incentives (e.g., tax benefits, subsidies) and market incentives (e.g., carbon price). Transparent carbon disclosure can improve a company's social reputation and market competitiveness while also augmenting its incentive to engage in carbon trading (Downar et al., 2021).

Numerous factors influence carbon trading pilots, such as carbon policy and regulation, carbon quota allocation, carbon costs, carbon management capacity, green investment, green technology innovation, and carbon disclosure. These elements interrelate and collectively influence the efficacy of carbon trading pilots. To attain carbon emission reduction targets, governments and companies must thoroughly evaluate these issues and develop scientifically sound and rational policies and strategies to facilitate the effective execution of carbon trading pilots.

3.6.2 Key Factors Influencing Non-Carbon Trading Pilot

In the context of global climate change and the emergence of carbon markets, pilot companies in non-carbon trading encounter many problems and opportunities. The contributing elements, such as conceptual awareness, policy and regulations, financial restrictions, technical advancement, carbon management, and market competitiveness, can be examined thoroughly.

3.6.2.1 Perception and Awareness

The primary challenge for non-carbon trading pilot companies at the awareness stage is the perception of carbon emissions and carbon markets. Due to their exclusion from the carbon trading system, these companies may lack precise awareness and oversight of carbon emissions, making it more challenging to comprehend the potential value and hazards associated with the carbon market. Consequently, these companies must enhance their environmental awareness and deepen their comprehension of carbon emissions and the carbon market to establish a foundation for future carbon management (Tao & Xu, 2019).

The initiative and accountability of non-carbon trading pilot companies will directly influence their future performance in the evolving carbon market. These companies must proactively monitor the dynamics of the carbon market and policy alterations, engage in carbon emission reduction initiatives, and fulfil their social duties (Herr et al., 2017). Companies can progressively cultivate a constructive carbon management culture by enhancing internal training and awareness initiatives and fostering employee engagement in environmental conservation.

As the carbon market evolves, pilot companies in non-carbon trading must progressively acclimatize to this emerging market landscape. This encompasses comprehending the trading regulations of the carbon market, techniques for monitoring and reporting carbon emissions, and tactics for engaging in carbon market transactions (Zhou & Li, 2019). Through active engagement in carbon market training and communication initiatives, companies can progressively enhance their market adaptability and ready themselves for forthcoming carbon trading (Munnings et al.,

2016).

3.6.2.2 Legislation and Policy

Companies participating in non-carbon trading pilots must remain cognizant of regulatory and policy modifications pertaining to carbon emissions and carbon markets. These legislation and policies may pertain to restrictions on carbon emissions, carbon market regulations, and environmental standards (Yao et al., 2023). Companies must closely monitor these policy changes to ensure compliance with relevant legislation and mitigate legal risks associated with non-compliance (Qi et al., 2021).

The government may use a range of incentives and support measures to motivate companies to engage in carbon emission reduction and carbon market trading (Shi et al., 2022). Companies participating in non-carbon trading pilots can actively obtain support from these policies, including incentives such as carbon emission quotas, tax benefits, or cash subsidies. These legislative incentives will diminish the company's carbon emission reduction expenses and enhance its incentive to engage in the carbon market (Ma et al., 2021).

As the carbon market evolves, additional non-carbon trading pilot companies may be integrated into the carbon market in the future. These companies must focus on the access conditions to the carbon market, including carbon emission thresholds, monitoring, and reporting obligations (Lo, 2016). By understanding these factors beforehand, companies can strategise their forthcoming involvement in the carbon market.

3.6.2.3 Financing Constraints

Companies participating in non-carbon trading pilots may encounter the following financial limitations:

Financial institutions may exhibit a greater propensity to extend credit to companies with consistent earnings and commendable environmental performance. Companies participating in non-carbon trading pilots may struggle to secure adequate financing support due to the unpredictability of their environmental performance (Zhou

& Li, 2019).

Financial institutions may impose elevated interest rates or more stringent security requirements when evaluating loan applications from companies not participating in carbon trading pilots (Ma et al., 2023).

Companies participating in non-carbon trading pilots may encounter restricted access to financing while pursuing funding. Certain investors or financial institutions may have a greater propensity to invest in companies engaged in carbon trading and possessing explicit environmental goals and strategies (Li et al., 2021).

3.6.2.4 Technology Upgrade

Companies participating in non-carbon trading pilots must concentrate on advancing and implementing energy-efficient and emissions-reducing technology at a technological level. These technologies can assist companies in diminishing carbon emissions and enhancing energy efficiency (Liu et al., 2018). Accordingly, by implementing and advancing sophisticated energy-efficient and emission-reducing technology, companies can meet their carbon reduction objectives without incurring extra expenses or even at a lower cost (Chu et al., 2024).

As the carbon market continues to develop, accurate monitoring and reporting of carbon emissions will become an important task for pilot companies in non-carbon trading. These companies must concentrate on advancing and implementing carbon monitoring and reporting systems to guarantee the precision and dependability of their carbon emissions data (Deng et al., 2018). Through the implementation of sophisticated monitoring apparatus and data analytical methodologies, companies can enhance the precision and clarity of their carbon emissions data (Christiansen, 2024).

Despite non-carbon trading pilot companies not being directly engaged in carbon market transactions, they must remain attentive to the evolution and implementation of carbon trading technologies (Song et al., 2020). These tools assist companies in comprehending carbon market trading regulations, price fluctuations, and trading methodologies. By acquiring and using these technologies, companies can position themselves for future engagement in the carbon market (Yadav et al., 2023).

3.6.2.5 Carbon Management

Construction of a carbon management system. Companies participating in non-carbon trading pilots must implement an efficient carbon management system to address the difficulties and opportunities the carbon market presents (Feng et al., 2024). This system must incorporate procedures for the monitoring, reporting, and verification of carbon emissions, the establishment of carbon reduction objectives and implementation plans, and the formulation and execution of carbon trading schemes (Joseph & Mustaffa, 2023). By implementing an effective carbon management system, companies may enhance their oversight of carbon emissions and augment the value of their carbon assets.

Despite non-carbon trading pilot companies not being directly engaged in carbon market transactions, they must prioritise carbon asset management. These companies may diminish their carbon emissions and enhance the value of their carbon assets through strategies such as energy efficiency and carbon asset management t systems to address the difficulties and opportunities presented by the carbon market (Feng et al., 2024). Simultaneously, companies must observe carbon market trends and regulatory alterations to engage in carbon market transactions opportunely and capitalize on the advantages (Zhang et al., 2018).

Companies participating in non-carbon trading pilots must establish explicit carbon reduction objectives and strategies to direct their forthcoming carbon mitigation efforts (Chang & Lo, 2022). The targets and plans must match the company's growth strategy and environmental goals while considering the company's current conditions and resource limitations. By establishing explicit carbon reduction objectives and strategies, companies can more effectively regulate their carbon emissions and enhance the worth of their carbon assets.

3.6.2.6 Market Competitiveness

Companies participating in non-carbon trading pilots must prioritise their environmental image and branding to enhance market competitiveness (Ma et al., 2023). As customers grow more apprehensive about environmental preservation and

sustainability, these companies must bolster their environmental initiatives and carbon reduction efforts to improve their ecological reputation and brand equity (Gavsi, 2023). Through active engagement in carbon reduction initiatives and carbon market trading, companies can exhibit their environmental accountability and sustainability to customers, thus garnering a more extensive consumer base and increasing market share.

In a carbon market context, pilot companies in non-carbon trading must prioritize integrating and optimising their supply chains. By streamlining supply chain management and minimizing carbon emissions, companies may decrease operational costs and enhance market competitiveness (Hou et al., 2020). Simultaneously, the company may cultivate deeper relationships with its suppliers and consumers, collaborating to further environmental protection and carbon emission reduction objectives (Amore et al., 2021).

In summary, pilot companies in non-carbon trading should bolster internal training, elevate environmental consciousness, monitor policy shifts, enhance capital risk management, and adopt advanced technology. This includes developing a comprehensive carbon management system and reinforcing brand development in response to the challenges and opportunities the carbon market presents. These companies can more effectively navigate the constraints the carbon market poses and capitalize on possibilities for sustainable development.

Table 3.10 summarizes the key factors affecting carbon trading pilots and non-carbon trading pilots.

Table 3.10

The Key Factors Affecting Carbon Trading Pilots and Non-Carbon Trading Pilots.

Carbon Trading Pilot		**Non-Carbon Trading Pilot**	
1. Carbon price	Carbon financial instruments Carbon financial products Enhancing market dynamics Promoting the integration of carbon and financial markets	1.Perception and awareness	Cognition and perception Initiative & responsibility Market adaptability
2. Carbon finance	Carbon price signaling Carbon price incentives Carbon price have an impact on Keeping the carbon price stable	2. Legislation and policy	Regulations & supervision Policy incentives and support Carbon market access conditions
3. Carbon policy and regulation	Policy orientation role Policy stability Regulatory strength	3. Financing constraints	Limited credit resources Rising financing costs Restricted financing channels
4. Allocation of carbon allowances	Quota allocation method Total amount of quota Quota adjustment	4. Technology upgrade	Energy saving and emission reduction technologies Carbon monitoring and reporting technology Carbon trading technology
5. Carbon cost	Carbon Price Impact Costs of emission reduction technologies Carbon asset management costs	5. Carbon management	Carbon management system construction Carbon asset management Carbon emission reduction target and plan
6. Carbon management capacity	Monitoring, reporting and verification capacity Carbon asset management Carbon risk management	6. Market competitiveness	Environmental image and branding Supply chain integration and optimization
7. Green investments	Investment scale Investment direction Investment return		
8. Green technology innovation	Clean energy technology innovation		

	Energy saving and emission reduction technology innovation Carbon capture and utilization technology innovation	
9. Carbon disclosure	Information disclosure Disclosure standards Disclosure incentives	

3.7 Research Framework

The study is a mixed study, with the first phase being quantitative (data analysis) and the second phase being qualitative (semi-structured interviews). The first stage of the study was quantitative data analysis, which yielded preliminary results on the relationship between carbon market mechanisms, green technology innovation and company performance. The first phase of the study answered RQ1 and RQ2.The second phase of the study used the preliminary results of the first phase to explore in-depth the opportunities, challenges and problematic countermeasures faced by carbon trading pilots and non-carbon trading pilots using a semi-structured interview methodology. The second phase of the study answered RQ3. Each phase of the study aims to provide reliable and comprehensive results on the relationship between carbon market mechanisms, green technology innovation and company performance.

Figure 3.4 depicts the study's framework, which is based on the strong Porter's hypothesis and the innovation theory. Porter's hypothesis highlights the positive impact of market-based environmental regulation. It suggests that stricter and well-designed environmental laws, especially those based on market mechanisms like carbon trading and pollution permits, can stimulate innovation and help companies offset the costs of complying with environmental regulations. This can offer companies a competitive edge in the market and improve their overall performance (Porter & van der Linde, 1995). The robust Porter's hypothesis theory provides a theoretical framework for examining the correlation between carbon market mechanisms, green technology innovation and a company's performance. The theory of green innovation is an extension of innovation theory that specifically emphasizes the consideration of eco-environmental benefits (Kemp & Foxon, 2007). Green technology advancements serve as a connection between carbon market mechanisms and company performance. The notion of green technology innovation highlights the importance of green technology innovation in enabling carbon market mechanisms and enhancing company performance. Conversely, innovation theory offers significant theoretical backing for elucidating the role of green technology innovation in mediating the connection between carbon market mechanisms and a company's prosperity.

In the first phase, carbon market mechanisms (carbon finance, carbon price, and

carbon trading policy) are used as Independent Variable (IV), and company performance, which reflects the company's value creation capacity and sustainability, is used as the Dependent Variable (DV). Company performance is categorized into economic performance and sustainable performance. In particular, EVA measures economic performance, and sustainable performance is measured by ESG scores and green technology innovation as a Moderator Variable (MV). To eliminate influence from other factors, this study's Control Variable (CV) are listed below: asset-liability ratio, company growth, asset turnover, current ratio, equity concentration, management power, nature of the company and age of the company in the market.

There is a potential interaction between independent variable and dependent variable. The impact of carbon finance on economic performance is derived in H1a, and the impact of carbon finance on sustainable performance is derived in H1b. The effect of a carbon price on economic performance is derived in H2a. The effect of a carbon price on sustainable performance is derived in H2b. The effect of carbon trading policy on economic performance is derived in H3a. The effect of carbon trading policy on sustainable performance is derived in H3b.

The moderating effect of green technology innovation on the relationship between carbon finance and economic performance is derived in H4a. The moderating role of green technology innovation on the relationship between carbon finance and sustainable performance is derived in H4b. The moderating effect of green technology innovation on the relationship between carbon price and economic performance is derived in H5a. The moderating effect of green technology innovation on the relationship between carbon price and sustainable performance is derived in H5b. The moderating effect of green technology innovation on the relationship between carbon trading policy and economic performance is derived in H6a. The moderating role of green technology innovation on the relationship between carbon trading policy and sustainable performance is derived in H6b.

In the second phase, based on the results of the quantitative analysis, a qualitative research semi-structured interview method was used to investigate the impacts of carbon market mechanisms (carbon finance, carbon price, and carbon trading policy) on company performance, comparing the opportunities and challenges faced by carbon trading pilots and non-carbon trading pilots, as well as the problems

and countermeasures. Finally, based on the mixed research results, countermeasure suggestions are proposed at the government, company, and society levels to promote low-carbon transition and achieve sustainable economic and environmental development. The quantitative study is based on objective data for verification, and the qualitative study relies on in-depth interviews for interpretation. The two corroborate each other to make the research results more convincing.

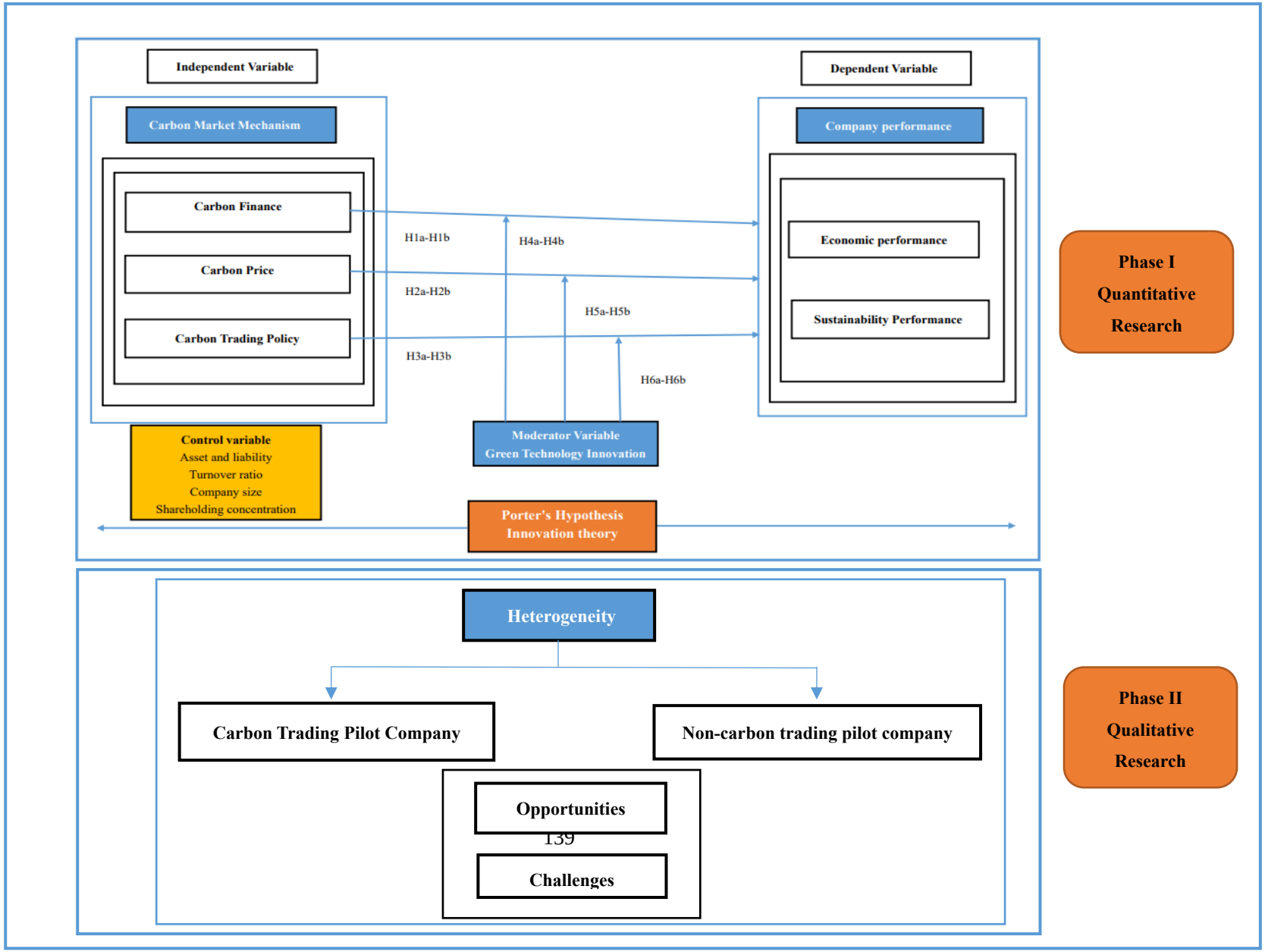


Figure 3.4 Research Framework

3.8 Chapter Summary

This chapter examines the theoretical foundations of the study, the conceptual framework, an overview of carbon market mechanisms and company performance, key factors affecting carbon trading pilots and non-carbon trading pilots, hypothesis development, and the research framework. The next chapter outlines the research methodology.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 Introduction

This chapter details the research methodology. This study used mixed research methods to measure and test the research hypotheses. This chapter is divided into six sections: Section 4.2 describes the stages of the study, which is divided into three stages, and Section 4.3 describes the research methodology used in this study. Section 4.4 describes the research design, including a quantitative and a qualitative research design. The quantitative research methodology includes an introduction to the Difference-in-Differences (DID) model, sample selection, data collection methods, variable definition and measurement, and multiple regression equations. The qualitative research methodology includes sample selection and qualitative analysis steps. Section 4.5 presents the treatment of ethical issues in this study. Section 4.6 summarizes the chapter.

4.2 Research Phases of This Study

This study adopts a mixed research method, taking the carbon market mechanisms as the axis and the development of a low carbon economy as the logical starting point, and follows the logical line of analysis of the current situation - literature review - research framework - quantitative research/qualitative research - conclusions and insights. The specific research ideas are as follows: firstly, construct the conceptual framework, theoretical framework and research framework of this study, then quantitative research design, construct regression equation model, empirically test the data using STATA econometric software, followed by qualitative research design and thematic analysis of interview results. Finally, the mixed research results are analyzed in depth and rationally summarized to form the final research conclusions of this paper and put forward suggestions and countermeasures. The specific research stages are displayed in Figure 4.1.

Phase 1

In this study, Chapters 1 to 3 provide an overview of the background, research issue, aims, and contributions of the study. Chapter 1 specifically focuses on these aspects. Chapter 2 provides an account of the development of China's carbon market mechanisms, while Chapter 3 addresses the theoretical foundation, evaluation of existing literature, conceptual framework, and formulation of hypotheses. This section presents the theoretical basis for the economic and long-term consequences of the carbon market mechanisms. It summarises institutional policy, fundamental theories, and a literature evaluation.

Phase 2

Chapters 4, 5, and 6 of this study pertain to the phase of research design and analysis. Chapter four delineates the research design, DID model, data sources, sample selection, measurement of variables, and multiple regression equation. In Chapter 5, the quantitative analysis stage involved analyzing the sample data using the STATA measurement software. This analysis included descriptive statistical analysis, parallel trend test, and correlation test. The data was empirically tested via placebo testing and multiple regression analysis. In Chapter 6, the qualitative analysis step involved thematically analyzing the audio data through the use of semi-structured interviews, resulting in the production of an analysis report.

Phase 3

Chapter 7 of this study provides conclusions, policy recommendations, and suggestions for further research. This section provides a comprehensive and logical summary of the empirical test results and interview findings from Chapters 5 and 6. It also summarizes the theoretical and practical insights and presents the final research conclusions of this study. The purpose is to formulate policy recommendations and guide future research endeavors. Figure 4.1 illustrates the research phases of this study.

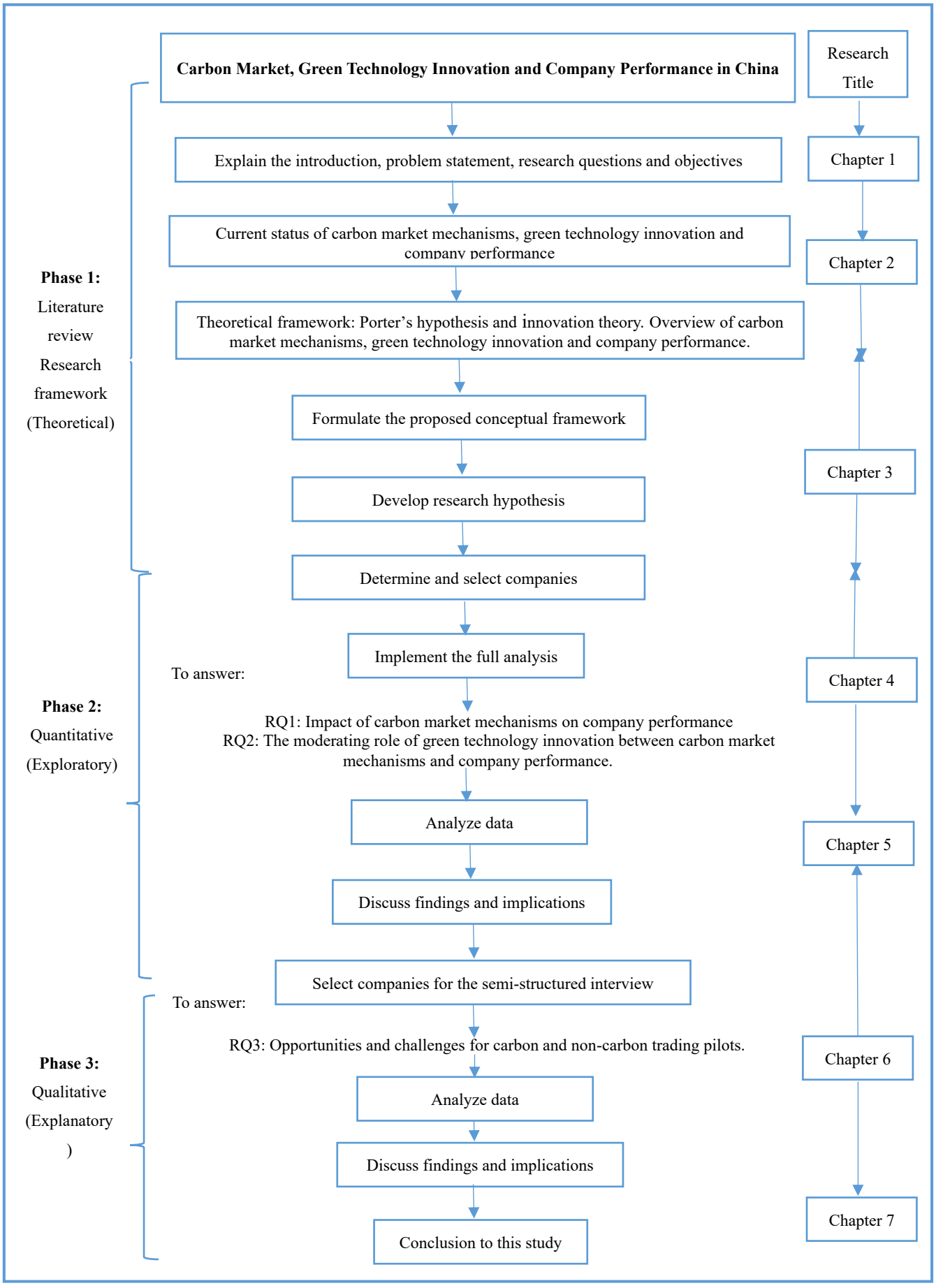


Figure 4.1 Research Phases of This Study

Table 4.1 demonstrates the study's constructs, analytical factors, components, and methods used.

Table 4.1
Constructs, Analytical Factors, Components, and Methods Used

Construct	Analytical Factor	Components	Method
1. The relationship between carbon market mechanisms and company performance	RQ1: What are the different impacts of the carbon market mechanisms (i.e., carbon finance, carbon price and carbon trading policy) on the company performance (economic and sustainability) of heavily polluting industries before and after the implementation of carbon trading policy among the pilot and non-carbon trading pilot companies?	Carbon market mechanisms and company performance	Quantitative research
2. The relationship between carbon market mechanisms, green technology innovation and company performance	RQ2: What are the different impacts of green technology innovation on the relationship between carbon market mechanisms (carbon finance, carbon price and carbon trading policy) and company performance (economic and sustainability) of heavily polluting industries before and after the implementation of the carbon trading policy between pilot and non-carbon trading pilot companies?	Carbon market mechanisms, green technology innovation and company performance	
3. Opportunities and challenges for carbon and non-carbon trading pilots	RQ3: How does implementing carbon market policy affect the company performance of high-polluting industries - pilot and non-carbon trading pilot companies?	Key challenges and opportunities	Qualitative research

4.3 Research Method: Mixed Methods

This section describes the rationale for mixed-method designs and the sequential interpretation of mixed-method designs.

4.3.1 Reasons for Mixed-Method Design

Mixed research methods aim to tackle challenges that arise in intricate social environments (McKim, 2017). Doyle et al. (2009) posited that mixed research methodologies offer more substantial opportunities to address the research questions. This results in reliable findings and the ability to conclude the research questions. A synthesis of quantitative and qualitative research methods is necessary to avoid the exclusive use of either approach. In order to address the research inquiries, researchers employ either a singular data-collecting technique (known as a single-method design) or many data-gathering strategies (known as a multi-method design), both of which adhere to suitable analytical procedures.

Multi-approaches encompass both multi-methods and mixed-methods, with multi-methods referring to the technical integration of quantitative and qualitative methods for data-gathering procedures and analysis (Timans et al., 2019). Hybrid techniques can refer to either a hybrid method or a hybrid model. Notably, mixed methods study design incorporates both qualitative and quantitative elements in its design, data gathering, and data analysis (Wheeldon, 2010). Moreover, a mixed model design distinguishes between two types of variables in a statistical model: between-subjects variables and within-subjects variables. This study employed a mixed research methodology to address the research issues using diverse approaches. This investigation ensured that the research design was pertinent to the research inquiries. The rationale for utilizing mixed approaches in this investigation is presented in Table 4.2.

Table 4.2

Specific Justifications for Mixed Methods Design Applied in This Research

Reason	Applied in This Study
Facilitation	This study initially investigates the correlation between carbon market mechanisms and company performance through a quantitative analysis. Subsequently, it selects specific companies for a qualitative investigation.
Complementarity	Mixed approaches enhance quantitative research by providing additional insights, while qualitative research aids in comprehending the effects of carbon market mechanisms on both carbon trading pilot and non-carbon trading pilot companies.
Generality	Finding the root causes of the impact of carbon market mechanisms on company performance.
Assist in interpreting	Assistance in interpreting specific quantitative results.
Examine various facets	The study uses quantitative methods to analyse the correlation between carbon market mechanisms and company performance using empirical data. Additionally, qualitative research is conducted to elaborate and elucidate the

	findings of the quantitative study.
Figure out a puzzle	Combining quantitative and qualitative research to provide a comprehensive explanation of carbon market mechanisms.

Source: Adopted from Wheeldon (2010).

This study is centered on the utilization of mixed research methods. This study employed a quantitative research approach for Research Question 1 (RQ1) and RQ2 and a qualitative research method for RQ3. A mixed research method was designed to fill the gap in previous research on the relationship between carbon market mechanisms and company performance, as indicated in Table 4.3.

Table 4.3
Quantitative and Qualitative Designs

	Quantitative	**Qualitative**
RQ addressed in this paper	RQ1-RQ2 DID model and multiple regression analysis	RQ3 Semi-structured interview method Thematic analysis

RQ1 and RQ2 employed the quantitative method of DID model and multiple regression analysis. The procedure consists of the following steps: Begin by gathering and arranging data pertaining to carbon finance, carbon price, economic performance and sustainable performance. Simultaneously, the experimental group and control group data will be created based on the list of emission-control companies in the carbon trading market, following the DID principle. Then, the variables for the model will be selected by combining previous research findings with the characteristics of the listed companies in the carbon market. Secondly, in accordance with the traditional framework of empirical investigation, regression models are constructed to examine the impacts of carbon finance, carbon price, and carbon trading policy on companies' economic and sustainable performance. Finally, this work aims to establish Moderating Variables for green technology innovation in order to analyse its role in the carbon market mechanisms and company performance.

RQ3 employed the qualitative method of semi-structured interviews. The procedure consists of the following steps: firstly, the initial steps involve formulating the interview process and constructing the interview questions. Additionally, it entails selecting the sample companies to be surveyed and determining the participants who will be questioned. Subsequently, telephone or in-person interviews were conducted,

and the interviews were then thematically analyzed using the NVivo program, leading to a conclusive report on the analysis of the interviews.

4.3.2 Mixed Methods Design Type: Sequential Explanatory Design

This study employed a sequential explanatory design, which is a sort of mixed-methods design (Ivankova et al., 2006). Interpretive design refers to gathering quantitative data first and then using qualitative data to explain the underlying reasons or mechanisms behind the first quantitative findings. This design aimed to offer a thorough and cohesive explanation of the study outcomes. In this typology, relying solely on quantitative data is insufficient to fully elucidate the existing findings. Hence, a mixed research methodology, incorporating both quantitative and qualitative approaches, was selected for this study. In this study, an additional set of qualitative data was gathered to illustrate the early impact. The purpose of exploring qualitative questions is to reveal the perspectives of individuals, groups, or diverse groups on the topic of the study. The data collected during the qualitative phase helps to explain and elaborate on the results of the quantitative phase in more detail. Figure 4.2 depicts the step-by-step explanatory design approach and the corresponding research inquiries.

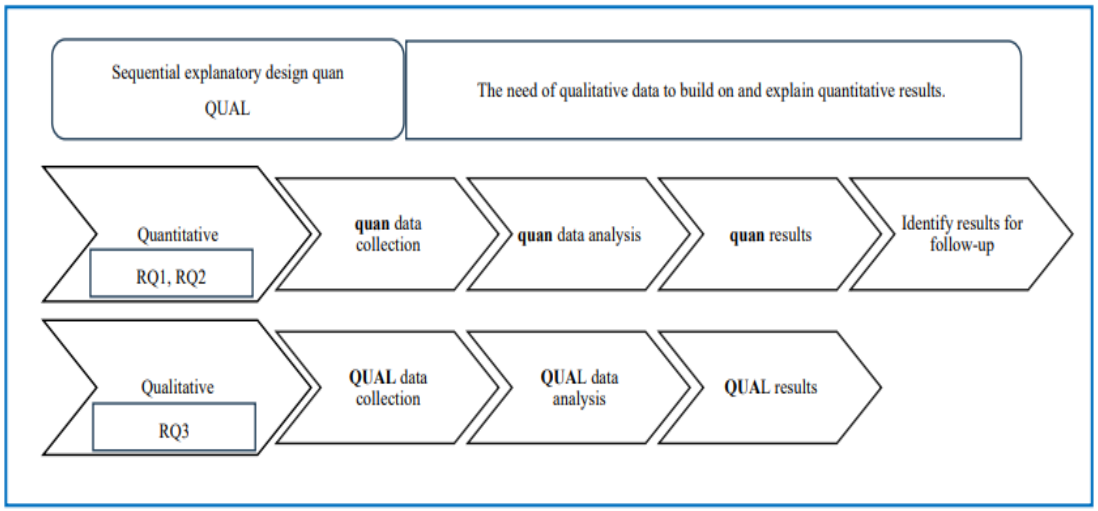


Figure 4.2 Sequential Explanatory Design Flow Process

Source: Adopted from Timans et al. (2019)

4.4 Research Design

A mixed research method was used in this study. Research designs are classified into two main categories: quantitative and qualitative. The quantitative and qualitative research designs are described separately below.

4.4.1 Quantitative Research

This study employed quantitative research methodologies to address research questions RQ1 and RQ2. This study examines the economic and sustainability impacts of carbon market mechanisms, such as carbon finance, carbon price, and carbon trading policy. Additionally, it aims to investigate the role of green technology innovation in moderating these effects. This study utilizes the commonly employed DID model of research design to conduct a thorough empirical analysis.

4.4.1.1 The DID Model

a) Research Review of the DID Model

The current research approaches investigating the connection between carbon market mechanisms and company performance mostly rely on quantitative methods. The introduction of Carbon Emission Trading Pilots (CETP) can be viewed as a quasi-natural experiment in policy. Scientists have mostly used the DID approach, Propensity Score Matching-Difference-in-Difference method (PSM-DID), and Difference-in-Difference-in-Difference method (DDD) to analyse policy effects in recent years. Carbon trading pilot markets are not selected at random. They are directly tied to provincial carbon emissions, industrial structure, and level of economic growth. While different provinces, cities, and industries in China are more heterogeneous, it is challenging to meet the criterion of consistent time impacts (Chu et al., 2023).

This study investigates the economic and long-term implications of carbon market mechanisms (carbon finance, carbon price, and carbon trading policy) as a foundation for assessing the carbon market's success. Initially, it is necessary to conduct comparative research between the experimental and control groups to observe the changes in company performance before and after the policy adoption. Second, changes

in company performance before and after policy implementation should be monitored to observe whether the carbon market mechanisms impact company performance. In the field of quasi-natural experiments, on the other hand, the DID model can better regulate the effects of unobservable and indigeneity explanatory variables on regression outcomes (Fallis, 2013).

The analysis involved the categorization of samples into experimental and control groups. A DID model was employed to establish multiple regression equations using data from carbon trading pilot-listed companies spanning from 2010 to 2022. To examine the impact of carbon market mechanisms on a company's performance and accurately assess the effectiveness of the CETP policy.

This paper examines the literature on the use of DID models to evaluate carbon market mechanisms in China. Researchers have extensively employed the DID model to assess the effects of carbon price regimes on company value and technical innovation. Nie et al. (2021) utilized dynamic panel data models and the PSM-DID technique to ascertain no nonlinear correlation between environmental regulation and the regional Porter's effect. Liu et al. (2021) utilized the DID approach and discovered that adopting Carbon Emission Trading (CET) reduces the value of the current capital market. However, it effectively increases the company's total gearing and does not lead to an increase in Research and Development (R&D) spending. Wang and Liu (2021) utilized the PSM-DID approach to investigate the impact of carbon price policy on both company financial performance and green technology innovation. The relationship between carbon trading legislation and a company's financial success exhibited a U-shaped pattern, posing challenges to the long-term support of a company's green technology innovation.

Niu et al. (2022) employed DID and DDD panel regression models and stated that CET could significantly increase the company's market value, indicating that CET supports Porter's hypothesis. He et al. (2022) also employed the PSM-DID approach and reported evidence of a detrimental immediate association between CET and company performance. Zha et al. (2022) used the Propensity Score Matching (PSM) model to demonstrate that participating in CET companies increases future financial performance. Tang et al. (2022) employed the DID methodology to ascertain that the CET regulation has the potential to enhance the market worth of publicly traded companies by exerting an influence on the carbon price, innovative endeavors, and

carbon transparency. Chen et al. (2022) utilized PSM-DID analysis methods and revealed that CET had a significant and beneficial impact on reducing carbon emissions. Additionally, they observed that technological innovation has a substantial and positive moderating effect. Sun et al. (2022a) highlighted the considerable correlation between carbon emissions trading systems and the performance of energy-intensive companies, utilizing the PSM-DID approach and the DID model to establish that the Emission Trading System (ETS) pilot had a favorable effect on company profitability and value, enhanced Total Factor Productivity (TFP), and resulted in a decrease in company operational costs.

Researchers commonly employ the DID model to study the correlation between carbon trading policy and Environmental, Social, and Governance (ESG) performance. The study utilized the PSM model to evaluate the correlation between the risk of carbon control policy and a company's ESG performance. The findings revealed a significant negative relationship between the two factors (Shu & Tan, 2023). The study employed the DID model to examine the impact of carbon emissions trading regulations on companies' ESG performance. The findings revealed a significant positive correlation between the two factors (Zhang et al., 2023). The PSM-DID approach was employed to evaluate the impact of the carbon emissions trading mechanism on the green governance of pilot companies engaged in carbon trading, revealing a favorable correlation between the two (Yao et al., 2023).

Researchers have commonly employed the DID model to examine the impact of a carbon price on the decrease of carbon emissions and productivity. Dong et al. (2021) discovered that higher carbon price have a beneficial impact on the financial performance of regulated companies. Additionally, they observed a favorable correlation between China's carbon trading pilot system and the company's financial performance. However, the more volatile the carbon price is, the more negatively it affects performance, and the research methodology is the PSM-DID model. Wu (2022) used a continuous DID model and asserted that carbon price increases and increased trade volume have been suggested to have a long-term and considerable influence on CO_2 emission reduction. A study using the DID model noted that China's carbon price stabilization mechanism significantly increases TFP (Mo et al., 2023; Wu & Wang, 2022).

This study stands out from other DID models due to its incorporation of green

technology innovation as a moderating element in the DID model. The cumulative effect of implementing carbon trading policy has been the subject of traditional DID approaches. However, few have included green technology innovation within the same model to test in depth the impact of green technology innovation enhancing or weakening the effectiveness of carbon market mechanisms on company performance. Therefore, incorporating green technology innovation in the DID model provides a new perspective for validating environmental economics theories and assessing the effectiveness of policy implementation.

b) DID Model

The DID approach (also known as the double-difference technique) is a method for evaluating new policies. It is now the leading method for analyzing policy effectiveness. Heckman (1999) introduced it to investigate the impacts of public policy. This method has the advantage of specifically addressing the indigeneity of the sample (Fallis, 2013). This method evaluates the effects of policy implementation by analyzing the disparities between experimental and control groups before and following the policy intervention (Abadie, 2005). Since its inception in the 1980s, the DID model has been extensively utilized across various domains. The main principle of this model is to minimize the number of control variables to prevent the introduction of factors that could cause indigeneity and other complications (Nie et al., 2021). This divides the study population into a control group and an experimental group, introducing two dummy variables: policy trend and time trend. After twofold differencing, it was observed whether there was a substantial change in one of the economic indicators of the participants in the experimental group following the adoption of the programmer to assess the effects of policy implementation (He et al., 2022; Dong et al., 2020).

The use of the DID model presupposes that the sample selection for the experimental group meets the requirement of statistically significant randomness, i.e., the model was first used to study randomized experiments. The release of the national policy usually has a large scope of influence and generally from point to point to gradually promote the implementation of the whole country. Hence, the policy event should be introduced only to meet the conditions of the quasi-experimental (Athey &

Imbens, 2018). The DID model can be infinitely close to random in the selection of experimental group samples and does not require that the exalted characteristics of the two groups of samples are identical. In line with this, the DID model has gradually been widely used in the field of quasi-natural experiments (Chen et al., 2022).

The DID approach has the following advantages over the general ordinary least squares method: first, the effects of external policy on variables are external shocks, avoiding indigeneity and reverse causation to some extent; second, the methodology examines the dynamics of the main variables over a period of time. This enables a more precise assessment of the impacts of policy implementation (Sun et al., 2022).

The DID approach differentiates panel data horizontally and vertically in terms of the cross-sectional and temporal dimensions, thus eliminating the influence of non-temporal and temporal factors on the outcome of the dependent variable, and is a common tool for identifying causal effects (Goodman-Bacon, 2021). The primary premise of the DID approach is the common trend assumption, which posits that the experimental and control groups would have exhibited a similar pattern of change in the absence of policy intervention (Callaway & Sant'Anna, 2021), which is illustrated in Figure 4.

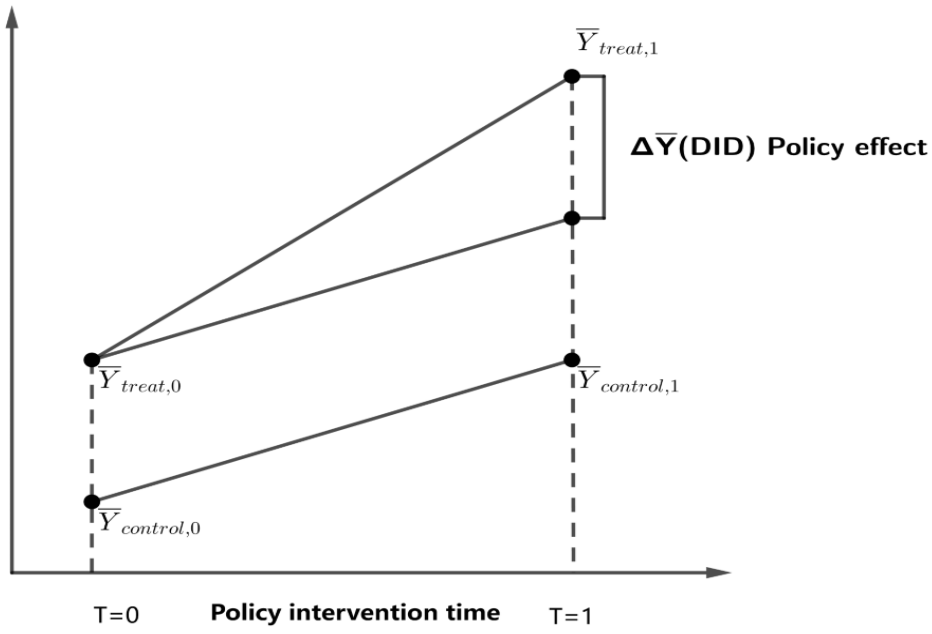


Figure 4.3 DID Principle

Source: Boffelli & Urga (2016)

The figure above represents the time before the policy is implemented as 0 and after the policy is implemented as T = 1. $\bar{Y}_{treat,0}$ and $\bar{Y}_{treat,1}$ indicate the observations of the experimental group prior to and following the implementation of the policy, accordingly. Meanwhile, $\bar{Y}_{control,0}$ and $\bar{Y}_{control,1}$ are the observations for the control group prior to and following the implementation of the policy. $\bar{Y}_{treat,0}$ is the mean objective value of all participants in the experimental group before the implementation of a policy and $\bar{Y}_{treat,1}$ refers to the average value of the goals achieved by all individuals in the experimental group after implementing a programmer. $\bar{Y}_{control,0}$ represents the mean value of the desired outcome for all individuals in the control group at the beginning of the trial and $\bar{Y}_{control,1}$is the mean target value of all participants in the control group at the end of the experiment. $\Delta\bar{Y}_{treat}$ represents the difference in average goal values among all individuals in the experimental group before and after a policy is implemented. $\Delta\bar{Y}_{control}$ represents the average difference in goal values across all participants in the control group before and after the experiment when no policy was implemented. The double difference estimator $\Delta\bar{Y}$(DID) is the difference in mean target values between experimental and control groups.

$$\Delta\bar{Y}_{treat}=\bar{Y}_{treat,1}-\bar{Y}_{treat,0}, \tag{4.1}$$

$$\Delta\bar{Y}_{control}=\bar{Y}_{control,1}-\bar{Y}_{control,0}, \tag{4.2}$$

$$\Delta\bar{Y}(\text{DID})=\Delta\bar{Y}_{treat}-\Delta\bar{Y}_{control}=(\bar{Y}_{treat,1}-\bar{Y}_{treat,0})-(\bar{Y}_{control,1}-\bar{Y}_{control,0}). \tag{4.3}$$

The same trend presupposes that in the absence of policy interventions, development trends in the experimental and control groups will remain consistent. However, due to other internal factors, such as policy, the experimental group does not follow the trend of the dotted line. Thus, in assessing the effects of policy implementation, changes in common trends need to be subtracted, and the remainder is the policy effect. The DID model largely circumvents macroeconomic, temporal and indigeneity issues. It can also correct the individual and time effects in panel data, minimize group gaps, boost the data's goodness of fit, and improve the accuracy of empirical results.

This study used a DID model to investigate the impact of introducing a pilot CET legislation on company performance. This study categorizes company performance into economic performance and sustainable performance. The heart of company performance is the ability of a company to survive and continue to be profitable on an ongoing basis. Companies with insufficient profitability and viability will find it difficult to sustainably attract investors and lack sufficient profits to support the company's technological development and asset renewal. Therefore, in this paper, company value and sustainable performance are selected as proxy variables for company performance by combining the consideration of various factors to measure the profitability and sustainability of a company. On this basis, the DID model is utilized to examine the influence of policy events on company performance. This paper uses the following DID model for regression. According to Callaway and Sant'Anna, 2021, the DID model is as follows:

$$Y^{PSM} = a_0 + a_1 post + a_2 treat + a_3 post * treat + \gamma X_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}. \quad (4.4)$$

In the formulation, Y^{PSM} is the explanatory variable of this paper, i.e., company performance. According to Sun et al. 2022, He et al. 2022, and Ma and Xue 2022, the method requires the definition of two dummy variables, policy dummies for the experimental and control groups treat = {0,1}, assign a value of 1 to pilot areas and a value of 0 to non-carbon trading pilot companies in other pilot areas. At the same time, defining time dummy variables time = {0,1}, the value of time = 1 represents the period after the implementation of the CET, while the value of time = 0 represents the period prior to the installation of the CET pilot system. The interaction term between the two is the main explanatory variable of the paper, DID, illustrating the impact of the carbon pilot policy on the company's performance, and it is a good measure of the net effect of the policy. This study uses unbalanced panel data for related companies from 2010-2022. It reduces differences between time and individuals by controlling for both individual and time-fixed effects. Among these, $X_{i,t}$ is control variable, set δ_i control individual fixed effects, μ_i control time fixed effects. Table 4.4 interpretation of the coefficients of the DID model.

$$\boldsymbol{Treat_i}=\begin{cases} 1, & i \in experimental\ group \\ 0, & i \in control\ group \end{cases},$$

$$\boldsymbol{Post_t}=\begin{cases} 1, & t \in experimental\ period\ (2013-2022) \\ 0, & t \in non-experimental\ period\ (2010-2012) \end{cases},$$

$$\boldsymbol{Treat_i * Post_t} = \begin{cases} 1, & i \in experimental\ group, t \in experimental\ period \\ 0, & other \end{cases}.$$

Table 4.4

Interpretation of the Coefficients of the DID Model

	Before Policy Implementation (post = 0) $(2010-2012)$	**After Policy Implementation (post = 1)** $(2013-2022)$	**Difference**
Experimental group (treat = 1)	$a_0 + a_1$	$a_0 + a_1 + a_2 + a_3$	$a_2 + a_3$
Control group (treat = 0)	a_0	$a_0 + a_2$	a_2
Difference	a_1	$a_1 + a_3$	DID=a_3

The value of $a_2 + a_3$ in Table 4.4 represents the change in the impact of the experimental group before and after the implementation of the policy. It is a combination of the policy effect and the time effect, a_2 represents the disparity in the impact of the control group prior to and following the implementation of the policy in response to a time effect. This reflects the divergence between the two, a_3 (DID), reflects a net effect of policy implementation. Thus, in studying the impact of a policy or event, the primary concern when applying the DID approach is the net effect. If a_3 is statistically negatively significant, the policy or event has a negative effect on the observer. Conversely, if a_3 is statistically positively significant, it implies that the policy or event has a favorable impact on the observed subjects (Abadie, 2005).

This study examines the effects of implementing the carbon emission price pilot programmer on a company's performance, specifically focusing on two distinct areas where differences in impact are observed. There are discernible distinctions between companies that have implemented policy and those that have not, as well as between the CET system after and before its implementation. Consequently, the DID approach may accurately evaluate the efficacy of CET regimes.

China has established a carbon emission market mechanism in seven pilot

provinces and localities since 2013, with the launch timing varying between the test locations. In June 2013, Shenzhen was the first to introduce CET. Subsequently, Shanghai, Beijing, Guangdong, and Tianjin followed. In particular, Hubei and Chongqing implemented their carbon markets in the first six months of 2014, whereas Fujian initiated its Carbon Emission Trading Pilot (CETP) programmer in late 2016. Consequently, this study employs a DID model to evaluate the overall effectiveness of the carbon market mechanisms and to scrutinize the dependability of the findings. The research spans from 2010 to 2022. If the time is 2013 or any year after that, it is assigned a value of 1. Otherwise, it is assigned a value of 0.

The continuity double difference method is a method evolved on the basis of the double difference method, and the basic ideas and principles of the two methods are similar. The double-difference method can only explore the average treatment effect of a policy by assigning 0 and 1 to the treatment and control groups before and after the implementation of the policy. However, it is not able to quantify the effect of the policy when the indicators in the study are continuous variables. Thus, continuous double-differencing can be used as a complementary form of double-differencing to further quantify the policy effects of the object of study. This study uses the continuous double difference method to assess the impact of carbon finance and carbon price on company performance.

4.4.1.2 Sample and Sample Size

a) Sampling Context

The Chinese context was preferred for this study. China has started a CETP since 2013. This study selects the pilot-listed companies in the seven regions (Hubei, Guangdong, Beijing, Shanghai, Tianjin, Chongqing, and Shenzhen municipalities) conducting CETPs since 2013 as the research subjects. Policy development in the seven pilot regions took place at different times, focused on 2013-2014. Sichuan also began experimental work on carbon trading at the end of 2016. However, Sichuan belongs to the market without quota trading. Hence, it is excluded from the sample. Meanwhile, Fujian Province announced its admission to the CET in 2016, and the policy has only been in force for a short time. In order to ensure the accuracy of the findings, this study

excludes pertinent samples from the provinces of Sichuan and Fujian. Although the national carbon trading market in China was officially initiated in July 2021, its influence on the paper's findings is negligible. China's CET strategy largely focuses on regulating eight industries with high levels of carbon emissions. This article selects companies from eight industries, including petrochemicals, chemicals, building materials, iron and steel, non-ferrous metals, paper, electricity, and aviation, as the research sample (China's Blueprint for the Country's Economic and Social Progress in 2011; carbon trading network, 2015).

This study chose seven pilot A-share listed companies from Shanghai and Shenzhen stock exchanges between 2010 and 2022 as the research sample (A-share refers to Renminbi ordinary shares, and A-share listed companies are companies registered in China whose shares are publicly traded on mainland China stock exchanges, such as the Shanghai Stock Exchange or the Shenzhen Stock Exchange), based on the available data. The experimental group consists of listed companies on the pilot list, whereas the control group consists of non-Carbon Dioxide (CO_2) regulated listed companies in non-carbon trading pilot locations.

b) Choice of Timing of Policy Shocks

The policy shock in this analysis is defined as the specific day when carbon emission exchanges were established in each site. The pilot provinces and municipalities mentioned in this article refer to the initial set of locations authorized by the State Council to establish CET platforms. More precisely, the seven administrative divisions are Beijing, Shanghai, Tianjin, Chongqing, Guangdong, Shenzhen, and Hubei. For this study, the year 2013 has been selected as the specific time period to examine the impact of policy changes in seven provinces and cities (Wu, 2022).

The choice of 2013 as the point of policy shock was based on two main considerations. Carbon trading only had a considerable policy impact on the company after these two times in time. Nevertheless, as far back as 2011, the National Development and Reform Commission (NDRC) issued the notice on CETP Work, granting permission to seven provinces and localities to conduct carbon trading pilot projects. However, dating back to 2011, The NDRC released the notice on CETP Work,

authorizing seven provinces and localities to conduct carbon trading pilot initiatives. Therefore, this study determines that the policy notification implemented in 2011 had a negligible effect on the company. Secondly, following the progressive construction of carbon emissions exchanges worldwide, carbon trading has become customary for companies engaged in manufacturing and economic activities. It has caused a sustained and substantial policy shock to the company's operation and production. Hence, this study finally chooses the actual establishment of carbon emission exchanges around the world as the policy shock point.

c) Sample of the Experimental Group

The experimental group in this study comprised listed companies in the pilot zone that had control over their CO_2 emissions. Annually, the Development and Reform Commission of the pilot region compiles a roster of companies involved in carbon emission pricing. Subsequently, a fresh list of companies is generated each year following the implementation. Accordingly, companies from the original list are added or removed. Based on data availability and consistency, this study uses unbalanced panel data. The data collection process from carbon trading pilot companies was divided into three major parts. Initially, this research gathers and organizes the roster of companies participating in the carbon trading pilot programmer by utilizing the official government websites of each pilot province and city and the official websites of the Development and Reform Commission and the Department of Ecology and Environment. Secondly, all listed companies on the pilot list were manually screened using company information search methods such as the National Company Credit Information Publication System and Company Search to obtain ticker symbols. A total of 248 pilot-listed companies have been queried in this step. Ultimately, this study aligns the data of the listed companies from the China Stock Market & Accounting Research (CSMAR) database by utilizing the company's stock code as a distinctive identifier.

To assure the quality of the data, improve the study design, and increase the reliability of the empirical analysis, this study additionally screens the raw data as follows: a) Companies in the financial industry that are listed are not included; b)

Companies that have been delisted, have ST or *ST status are not included. In the Chinese stock market, ST and *ST are special identifiers in the name of a stock. ST stocks, or specially treated equities, are primarily for publicly traded companies that exhibit anomalous financial or other situations. *ST stock, i.e., special treatment warning of the danger of termination of listing or delisting risk warning, applies to companies with the risk of termination of stock listings (Zhihu, 2023). d) Excluding companies with missing data, this step of matching yields sample data for a total of 230 pilot-listed companies.

d) Sample for the Control Group

Twofold differencing is necessary when the sample's progress reveals a parallel trend, indicating that the experimental and control groups had comparable development paths before the policy was implemented. According to some studies, the elements influencing a company's CET include its location, industry, size, profitability, and other indicators (e.g., Liu et al., 2015; Sun et al., 2022). Thus, for this study, this study opt for listed companies in non-carbon trading pilot locations with emissions not regulated by CO_2 control as the control group. In essence, the researchers collected data from 951 companies for this control group.

The pilot and non-carbon trading pilot companies consisted of 1,181 listed companies, and a total of 5,889 observations were recorded. This study additionally considered the impact of extreme values by narrowing down the continuous variables to the 1% and 99% quartiles. In order to reflect the technical specifications of the study, statistics on the sampling process and the sample selection process of the pilot companies are presented in this study, as provided in Tables 4.5 and 4.6.

Table 4.5

Sampling Process for Pilot Companies

Process	Shenzhen	Shanghai	Beijing	Guangdong	Tianjin	Hubei	Chongqing
Year of implementation of CET	2013.6	2013.11	2013.11	2013.12	2013.12	2014.4	2014.6
Number of pilot companies	6390	2040	5674	1745	1023	2088	350
Number of listed companies	80	35	79	7	3	32	9
ST and *ST companies were excluded	71	33	69	6	3	24	9
Financial companies were stripped out	71	31	59	23	13	24	9
Total number of carbon trading pilot-listed companies				230			

Table 4.6
Sample Selection Process

Selection Process	Number
Carbon Trading Pilot Listed Companies	230
Plus A-share listed non-carbon trading pilot companies	5653
Excluding financial sector, ST*ST companies	5424
Indentation and elimination of missing lines	1181
Number of observations	5889

4.4.1.3 Source of Data

This study answers the research questions through the use of secondary data. The empirical studies in this work utilize pertinent data from three main areas, as summarized in Table 4.7.

a) Company conducting a pilot programmer for CET. The compilation of carbon emission pilots is predominantly sourced from the official website of the NDRC, as well as the official websites of the Development and Reform Commissions of each pilot province and city, along with the CET Centre. These lists contain listed companies and a large number of unlisted companies. Listed companies were manually collected from these lists, and duplicates were eliminated (e.g., Chen et al., 2022; He et al., 2020a; Wang & Liu, 2021; Zha et al., 2022).

b) Carbon price, CO_2 emissions and ESG data. Carbon price comes from the official CET website, CSMAR database, and China Carbon Accounting Database (CCADs), and CO_2 emissions data were calculated and obtained. The company's ESG scores are sourced from the Bloomberg database, which has the advantage of a rich data volume and an extended data window (Chen & Xie, 2022).

c) Financial data on non-carbon trading pilot listed company's data and green patents data. The empirical research relied on several primary sources for the company's financial data, including the China Statistical Yearbook, the CSMAR database, the National Bureau of Statistics of China, and the official websites of each company (e.g., He et al., 2020a; Liu et al., 2021; Wang et al., 2019). The Green Patent Research Database (GPRD) provided by the China Research Data Service Platform (CNRDS) serves as the primary source of green patent information for listed companies. The World Intellectual Property Office's Green Patent Classification Number standard, consisting of seven key classes, and China's patent data were combined to create the

professional database known as GPRD (e.g., Cai & Song, 2022; Geng et al., 2023).

Table 4.7

Description of Data Source

Variable Symbol	Data Name	Data Source	Year	Industries Covered (eight)
DID	Carbon trading pilot companies	The official website of the NDRC, the official website of the Development and Reform Commission of each pilot province and city, and the official website of carbon emissions trading (He et al., 2022; Yu et al., 2022)	2010-2022	A shares in Shenzhen and Shanghai, electric power, petrochemicals, chemicals, building materials, iron and steel, non-ferrous metals, paper, domestic civil aviation, eight industries
CP CO_2	Carbon price CO_2 emissions	Carbon emissions trading official website and CSMAR database, China carbon accounting database (CEADs) (Wu, 2022; Li et al., 2022)	2010-2022	
ESG	ESG data	Bloomberg database (Zhang et al., 2023;Yao et al., 2023)	2010-2022	
GTI	Green technological innovation (sum of green invention patents and green utility patent applications)	GPRD of China Research Data Service Platform (CNRDS) (Tian et al., 2022; Zhao et al., 2022)	2010-2022	
FA	Non-carbon trading pilot companies Financial data	CSMAR database (Tang et al., 2022b)	2010-2022	

4.4.1.4 Variables and Measurement

This section describes in detail the variables employed in this investigation and their units of measurement. Establishing units of measurement for variables is an integral part of any study and research design, as it will enable the thesis to assess hypotheses and subsequently answer the research questions.

a) Dependent Variables

i) Economic Performance

The ultimate goal of a company's operations is to maximize its value, but the connotations of company value are complex. This study employs Economic Value Added (EVA) to assess economic performance. The formula is:

Economic value added = Net operating profit after tax - Capital cost = Net operating profit after tax - Average capital employed × Weighted average cost of capital. (4.5)

In this scenario, the profitability of the company's operations is indicated by its net operating profit after tax. The average capital utilized is indicative of the company's consistent investment in a variety of debt and equity capital. The average cost rate of the company's numerous types of capital is represented by the Weighted Average Cost of Capital (WACC) (Sharma & Kumar, 2010; Jakub et al., 2015).

When the EVA is positive, it indicates that the operator is adding value to the company; when it is negative, it suggests that the operator is reducing the company's value. EVA is determined by considering the expenses associated with all forms of capital, such as stock and debt. As such, it provides companies with better criteria for evaluating their performance and enables managers to make more informed decisions (Artikis & Alexopoulos, 2016; Zhang & Wang, 2021).

ii) Sustainable Performance

Quantitative measures of sustainable performance do not yet exist in research in a uniform way. For reasons of data availability, completeness, and accuracy, the paper draws on the study by Zhang et al. 2023 and Yao et al. 2023. The Bloomberg database's environmental performance score was used to directly quantify the company's level of sustainable performance. A higher environmental score indicates a better level of sustainable performance. Environment, society and governance are the three pillars of Bloomberg's ESG score, each weighing approximately 33%. There are seven subjects in the environmental pillar, six in the social pillar, and eight in the governance pillar. Table 4.8 provides detailed parameters for the Bloomberg ESG score. The score is based on publicly released social responsibility reports and financial reporting information from Chinese-listed companies. This reflects the company's environmental performance in a more comprehensive and objective way and has been increasingly applied in relevant domestic studies in recent years.

Table 4.8

Elements and Constituents of the Bloomberg ESG Ratings

Column (Mass)	Topic (Mass)
Environmental (33.32%)	Impacts on Biodiversity and the Environment (4.79%)
	Chain of Supply (4.79%)
	Water (4.79%)
	Air Purity (4.78%)
	Waste and Resources (4.74%)
	Vitality (4.73%)
	Climate Variations (4.70%)
Social (33.30%)	Safety and Health (5.58%)
	Morality and Adherence (5.57%)
	Human Resources (5.59%)
	Chain of Supply (5.54%)
	Customers and the Community (5.53%)
	Variety (5.49%)
Governance (33.38%)	Self-reliance (4.18%)
	Governance and Nominations Supervision (4.18%)
	Governance of Sustainability (4.18%)
	Tenure (4.18%)
	Risk and Oversight in Auditing (4.17%)
	Variety (4.17%)
	Board Make-Up (4.16%)
	Restitution (4.16%)

b) Independent Variables

This study's explanatory factors include the carbon market mechanisms, including carbon finance, carbon price, and carbon trading policy, which are described separately next. These three variables are essential components of the carbon market mechanisms and important independent variables. They collectively contribute to the healthy development of the carbon market.

i) Carbon Finance

The evolution of financial institutions' involvement in carbon finance is exemplified by financial decarburization, which quantifies the level of entry into decarburization through carbon lending intensity. It refers to the comprehensive carbon finance evaluation indicator system (Jiang et al., 2023). Company finance decarburization is expressed in terms of carbon loan intensity. The Carbon Emission Loan Intensity is the carbon emissions per unit of loan balance of financial institutions at the end of the year for each company, and it represents financial institutions' support

for carbon emissions. i.e.

$$\text{Carbon finance} = \text{Carbon emission loan intensity} = \text{Carbon emissions/loan balances.} \quad (4.6)$$

Financial decarburization means that financial development has resulted in fewer and fewer carbon emissions per unit of total finance, indicating that the financial system is moving towards decarburization. To evaluate the financial system's sustainability, carbon lending intensity calculates the correlation between a nation's or region's financial development and carbon emissions. Financial carbon content is the ratio of carbon emissions to loan balances. The lower the carbon emissions per unit of loan financing, i.e., the smaller the indicator's value, the lower the carbon lending intensity, and vice versa. The smaller the financial decarburization indicator is, the higher the level of carbon financial development it represents. For example, this indicator is an inverse indicator, which is negatively correlated with the level of carbon financial development. Therefore, before applying the empirical analysis to this indicator, the researcher first conducts the forwarding treatment to ensure that the significance expressed by each carbon finance indicator is the same in order to eliminate the difference in the results caused by the different dimensions. For instance, transforming the relevant inverse indicator into a positive indicator (Lee & Lee, 2022). The specific transformation is achieved by taking the inverse of the inverse indicator and thus reversing the positive, which is expressed by the formula:

$$X^* = 1 / X. \quad (4.7)$$

X denotes the original value of the negatively correlated indicator, i.e., the initial value of the financial decarburization indicator. X* is the value after positive normalization, which can be used for empirical analysis.

$$CF^*Post = \text{Carbon Finance} \times \text{Post}. \quad (4.8)$$

CF*Post denotes the cross-multiplier term of the carbon finance and time

dummy variable, comparing the effect of carbon finance on company performance before and after the implementation of the carbon trading policy (2013). Since carbon finance is not a policy and there is no distinction between experimental and control groups, only the time dummy variable is multiplied.

The following describes the methodology for estimating CO_2 emissions. Carbon accounting serves as the foundation for doing research pertaining to carbon emissions. The International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC), both international research agencies, have produced statistics and techniques for accounting for carbon emissions. However, China does not yet have an official organization releasing authoritative carbon emission data. Three main carbon emission accounting methods are commonly used: measured methods, mass balance methods, and emission factor methods.

The actual measurement approach is collecting released gases, measuring their concentration, flow rate, and other indicators based on professional testing equipment, and then calculating the relevant carbon emission data. Although this method has accurate results and few intermediate steps, the cost is high, and it is not extensively used in China, mainly for environmental monitoring stations (Von Caemmerer, 2013). The mass balance method, also known as material accountancy, is based on the principle that the mass of input materials must be equal to the sum of the mass of output and lost materials in the same production system. This method saves material and human resources, the cost is relatively small, and the method is able to differentiate between the differences in carbon emissions produced by various types of facilities. However, the prerequisite for using this method is that it requires knowledge of the company's detailed production process, raw material consumption and management level, and there are certain limitations in its application (Stabile et al., 2021). The IPCC initially recommended the adoption of the emission factor technique in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, and it remains one of the most extensively utilized approaches in practice. Based on a provided list of carbon emission inventories, the method multiplies each type of energy consumption with an emission factor. It sums it up as an estimate of total carbon emissions.

Taking the above analyses together, the emission factor approach is simple to operate and easier to promote and communicate globally than the other two approaches. Hence, this article aims to measure the carbon emissions of every sector in China by

employing the methodology provided by the IPCC (2006).

Since there is no direct access to the company's energy consumption or carbon emissions, according to Sun et al. 2023 and Xu et al. 2023, the company used a cost-sharing methodology to assess its carbon emissions by considering the industry's carbon emissions and the operating costs. The 2006 IPCC Guidelines for National Greenhouse Gases, released by the IPCC in 2006, include instructions for calculating the overall amount of CO_2 emissions (IPCC, 2006), determining the aggregate CO_2 emissions generated by the entire industry sector from all fossil fuel sources, including coal, crude oil, petrol, coke, paraffin, fuel oil, diesel and natural gas. Sectoral carbon emissions are calculated by combining the total energy consumption by sector, as reported in the China Energy Statistical Yearbook, with the reference coefficients of carbon emissions from different energy sources provided by the CET Network (Yan et al., 2020). The formula for determining total industry CO_2 emissions is the following (IPCC, 2006):

$$CO_2 = \sum_{i=1}^{8} E_i \cdot C_i = \sum_{i=1}^{8} E_i \cdot CF_i \cdot CC_i \cdot COF_i \cdot 44 \,/\, 12, \tag{4.9}$$

where E_i indicates the kind of energy consumption, C_i is the energy source's CO_2 emission coefficient, and i is the energy source's consumption, including coal, crude oil, gasoline, petrol, coke, paraffin, diesel oil, fuel oil and natural gas. Moreover, CF_i represents the mean heating value at a low level, CC_i represents the amount of carbon per unit of calorific value, COF_i represents the rate at which carbon is oxidized, and $CF_i \cdot CC_i \cdot COF_i$ represents the factor that determines carbon emissions. The molecular weights of C and CO_2 are 12 and 44, respectively, and $44/12$ is the percentage of C in CO_2, which is the conversion factor between carbon and CO_2. $CF_i \cdot CC_i \cdot COF_i \cdot 44 \,/\, 12$ is known as the CO_2 emission factor. Table 4.9 provides the CO_2 emission factors for various energy sources.

The formula demonstrates the use of each energy source in tonnes of standard coal, which must be converted to tonnes of standard coal by first obtaining raw data in tonnes, billion kilowatt hours, and billion cubic meters. The energy consumption of each category is multiplied by the reference coefficients for converting standard coal for each energy category, derived from the China Energy Statistics Yearbook 2020. The

data on the primary operating expenses of the industry are sourced from the China Industrial Economic Statistics Yearbook. Data on the utilization of different energy sources, standard coal coefficients, and the average low-level calorific value were extracted from previous editions of the China Energy Statistical Yearbook. The carbon content and oxidation rate per unit of calorific value is determined according to the guidelines provided by the NDRC in their document titled "Guidelines for the Preparation of Provincial Greenhouse Gas Inventories" (2011).

According to IPCC (2006), the equation can be simplified as follows:

$$CO_2 = \sum_{i=1}^{8} E_i \cdot e_i \cdot p_i \cdot 44/12, \quad (4.10)$$

Where E_i represents energy consumption, e_i is the normal coal discount factor, and p_i is the carbon emission factor.

According to Sun et al. 2023 and Xu et al. 2023, the company's CO_2 emissions were approximated based on industry CO_2 emissions, and the calculation formula is provided below:

Company CO_2 emissions = (Company operating costs/Industry main operating costs) × Industry CO_2 emissions. (4.11)

Table 4.9
Carbon Emission Reference Factors for Various Energy Sources

Energy Name	Average low level Heat Generation (KJ/Kg)	Discount Factor for Standard Coal	Carbon Content Per Unit Calorific Value (Tons of Carbon/TJ)	Carbon Oxidation Rate	CO_2 Emission Factor ($kgCO_2/kg$)
Coal	20934	0.7143 kgce/kg	26.37	0.94	1.9027
Coke	28470	0.9714 kgce/kg	29.5	0.93	2.8639
Crude Oil	41868	1.4286 kgce/kg	20.1	0.98	3.024
Gasoline	43124	1.4714 kgce/kg	18.9	0.98	2.9287
Paraffin	43124	1.4714 kgce/kg	19.6	0.98	3.0372
Diesel oil	42705	1.4571 kgce/kg	20.2	0.98	3.0998
Fuel Oil	41816	1.4286 kgce/kg	21.1	0.98	3.1705
Natural Gas	38979	1.3300 kgce/kg	15.3	0.99	2.1649

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

ii) Carbon Price

Limited to data availability, this paper is unable to obtain the specific price at which each company trades carbon. However, the information sheet of the CSMAR database regarding CET reveals the daily price of carbon exchanged in each region. This article utilizes the provided data to calculate the annual average carbon trading price for each region. It then applies this average price to every company inside the respective region.

$$\text{Carbon Price} = \text{Annual average of carbon trading price.} \tag{4.12}$$

$$\text{CP*Treat== Carbon Price× DID = Carbon Price× Post× Treat.} \tag{4.13}$$

CP*Treat denotes the cross-multiplier term of the carbon price and DID variables. Comparing before and after implementing the carbon trading policy (2013), the impact of carbon price on company performance for carbon trading pilot and non-carbon trading pilot.

iii) Carbon Trading Policy

Carbon trading policy measures comprise the time of implementation (post), whether a company is included in carbon trading (treat), and its interaction term (DID = post *treat), with dummy variables for both time of implementation and inclusion in carbon trading.

1. Carbon emission trading policy implemented or not (post)

Pilot time is a dummy variable that distinguishes the order in which the carbon emissions trading pilot policy occurred. According to Sun et al. 2022, He et al. 2022, Nie et al. 2021, and Ma and Xue 2022, this study designates the year 2013 as the reference point for the policy shock. If a company is impacted by the carbon trading policy in 2013 or later, it is denoted as post = 1, indicating that the policy has been implemented. Conversely, post = 0 signifies that the carbon trading policy has not yet been enacted prior to 2013.

2. Whether the company participating in CET as a pilot company (treat)

According to Sun et al. 2022a, Chen et al. 2022, Tang et al. 2022, and Ma and Xue 2022, pilot companies are dummy variables. In this study, the emission control companies in pilot provinces participating in carbon trading are defined as the experimental group, then treat = 1. Meanwhile, non-emission control companies not participating in carbon trading in pilot provinces of non-carbon trading are categorized as the control group, i.e., treat = 0.

3. Interaction term DID (DID = post *treat)

According to Sun et al. 2022a, Chen et al. 2022, Tang et al. 2022, and Ma and Xue 2022, companies in the experimental group are affected by the carbon emissions trading policy after 2013 treat × post = 1. In contrast, if they are not affected by the carbon emissions trading policy, treat × post = 0. The values of the DID variables in the control group are all 0.

c) Moderate Variables

The study's Moderate Variables is the innovation of green technologies. The current patent system in China was founded in 1985 and encompasses three types of patents: innovation patents, utility model patents, and design patents, as defined by Chinese patent legislation (Wu et al., 2023; Zhang et al., 2019). Patents for inventions and utility models cover innovative technical solutions. A design patent is a novel design that enhances the appearance and color of a product. Green invention and utility model patents exhibit higher levels of innovation than design patents. The quantity of patents granted is a more reliable indicator of a company's promptness in inventing compared to the number of applications submitted (He et al., 2022; Rubashkina et al., 2015; Ma & Xue, 2022). This paper focuses on the green technology innovation capability of companies under pressure from the carbon emissions trading policy. Due to the lag in patent granting, the number of patent applications is a more timely reflection of the green technology innovation level of companies than the number of patents granted. Therefore, using Tian et al.'s (2024) method, the sum of green invention patents and green utility model patent applications is selected to measure the company's green technology innovation level.

According to Chen, Zhang et al. 2021, and Zhu et al. 2019, this paper uses the number of green patent applications to measure a company's green technology

innovation (4.14).

Green technology innovation = the sum of green invention patents and green utility patent applications filed independently and jointly by listed companies in the year. (4.14)

d) Control Variables

In order to more accurately assess the effect of the independent variable s on the dependent variables, controlling for other variables that may impact company performance is essential. According to Sun et al. 2022, Jeevesh and Suhasini 2021, Fu and Shen 2020, and Chen et al. 2022, this study will select control variables from three aspects. The first aspect involves the company's own financial and operational factors, such as gearing (lev), company growth (growth), asset turnover (turnover), and current ratio (current). The second aspect includes the company's shareholding structure characteristics, the concentration of shareholding (cocen) and management power (topm). Thirdly, other factors, such as the nature of the company (state) and the age of the company's listing (age).

i) Financial and Operational Status

Assets and liabilities (LEV). This paper uses the gearing ratio to measure the financial leverage of the company. Financial leverage is the leveraging effect of changes in profits due to the presence of debt. While financial leverage brings additional benefits to the company, it also raises financial risk (Busch & Hoffmann, 2011). According to Wu et al. (2023), the financial leverage of a company is indicative of its level of risk. In the capital structure of publicly listed companies, a larger debt ratio increases the financial risk undertaken by the company. The company's performance is influenced by its capital structure, and the gearing ratio is used as a control variable to measure this impact.

Current Ratio (CURRENT). The current ratio measures the relationship between a company's current assets and current liabilities. It is utilized to evaluate the company's ability to convert its current assets into cash in order to meet its obligations

to creditors before short-term debt becomes due. Typically, a higher ratio indicates that the company has more liquid assets and is more financially stable in the short term. The opposite is also true. There is a general consensus that the present ratio should exceed 2:1. A current ratio of 2:1 indicates that the value of current assets is double the value of current liabilities, guaranteeing the repayment of all current liabilities even if only half of the current assets are realized in the near future (Liu et al., 2021b). The higher the current ratio, the greater the operating capacity and this variable is believed to improve the company's performance. Hence, it is employed as a control variable.

Asset Turnover (TURNOVER). The asset turnover ratio is used to measure the efficiency of the use of company assets, defined as the ratio of net operating income to total assets, which reflects the efficiency of a company's asset operations and is indicative of the extent to which a company utilizes its assets and the level of its operational management. Differences in asset turnover will lead to differences in company performance. If this variable is not controlled, the changes in performance caused by it may be confused with the impact of the carbon market mechanisms, interfering with the accurate judgement of the relationship between the carbon market mechanisms and company performance.

Company Growth (GROWTH). The growth of a company is different from short-term profitability indicators. It is more a reflection of the long-term profitability of a company and its ability to add value to its assets continually. This is a measure of a company's ability to grow in the future. The better the growth, the more likely a company is to be favored by investors and the more likely it is to be noticed by stakeholders. This amplifies the impact of the company's behavior on its value (Wu et al., 2023). This study utilizes the growth rate of operational income as a control variable to assess the company's performance and quantify its growth.

ii) Shareholding Structure Characteristics

Shareholding Concentration (COCEN). Shareholding concentration is an indicator of whether a company's shareholding is concentrated or dispersed through the percentage of shares held by some of its largest shareholders (Qi et al., 2021). The level of shareholding concentration can have a greater impact on company decision-making

(Huergo & Jaumandreu, 2004). Differences in shareholding concentration can also lead to differences in the position of shareholders within a company. High ownership concentration poses the risk of major shareholders infringing upon the interests of minority shareholders (Bai et al., 2019). Therefore, when analyzing the impact of the independent variable on the dependent variable, this study must consider the concentration of equity. In this study, the ratio of the first largest shareholder's shareholding is used to measure the company's equity concentration.

Management Power (TOPM). Management rights represent the rights of management, defined as the percentage of management's shareholding and the power of management to influence the company's decisions and operations. It can either enhance company performance through efficient decision-making and strong strategy execution or lead to a decline in performance due to poor decision-making and misappropriation of benefits. Therefore, management rights are used as a control variable.

iii) Other Factors

Nature of the Company (STATE). The inherent characteristics of a company have a significant impact on its environmental conduct. Typically, government-owned companies are more inclined to uphold their environmental obligations vigorously. Stakeholders want state-owned companies to actively and assertively comply with national policy. On the other hand, state-owned companies are better able to meet their environmental duties due to their political background, larger size, and profitability. In comparison, non-state-owned companies are more concerned with the survival and development of the company, and their attitudes towards environmental pollution may differ from those of state-owned companies (Earnhart & Lizal, 2006). Therefore, the nature of the company will have some impact on the company's operations and its value. This study categorizes the type of company using a binary variable, where a value of 1 denotes state-owned companies and a value of 0 reflects non-state-owned companies (Liu et al., 2022). The nature of the company is used as a control variable.

Age of Listing of Companies (AGE). For a-share listed companies, company performance is also affected by the listing length. Chen et al. (2021) asserted that the longer a company has been listed, the more experienced it will be in capital operations,

internal governance and secondary market participation, the more standardized the disclosure of relevant public information, and the more adept it will be at used public information to improve its performance. Tang et al. (2021) noted that the length of a company's listing reflects the company's experience in trading activities on the capital market, the degree of sophistication of the disclosure mechanism, and the efficiency of the company's own financing. The longer a company has been listed, the more expertise it has in capital operations and company governance, which will directly or indirectly impact company performance (Gao et al., 2020). The age at which a company goes public is expected to affect company performance and is therefore used as a control variable.

d) Overview of Essential Definitions and Measurement Methods for the Variables

Table 4.10 summarizes the key definitions of all the variables used in this study, the units of measure for each variable, and the data sources.

Table 4.10

Table of Variable Definition

Variable Type	Variable Name	Variable Symbol	Indicator Type	Definition	Data Source	References
Dependent variable	Economic value added	EVA	Economic performance	Economic value added = Ln (net operating profit after tax - capital cost) = Ln (net operating profit after tax - average capital occupation × weighted average capital cost)	Secondary data from the CSMAR database	Horváthová (2010); Liu et al. (2021); Adu et al. (2023); Lu & Taylor (2018)
	ESG score	ESG	Sustainable performance	ESG score	Bloomberg database	Chen et al. (2022); Qian & Yu (2024)
Independent variable	Carbon Finance	CF CF*Post	Carbon loan intensity	CO_2 emissions/loan balance Interaction of company carbon finance levels with policy dummy variables	Secondary data from the CSMAR database	Jiang et al. (2023)
	Carbon price	CP CP*Treat	Carbon market price	Average annual carbon trading price Cross-multiplier of carbon trading price and DID variables	Secondary data from the CSMAR database	Mo et al. (2023); Wu & Wang (2022); Wu (2022); Feng et al. (2024)
	Whether the carbon emissions trading policy is implemented (pilot year)	POST	Time variable	Dummy variable, post = 0, before 2013, before the implementation of the carbon emissions trading post = 1, after 2013, after the implementation of the CET	Secondary data from official ETS websites	Sun et al. (2022a); He et al. (2022); Nie et al. (2021); Ma & Xue (2022)
	Whether the company is included in carbon emissions	TREAT	Policy variable	Dummy variable, treat = 1, included in carbon emissions trading pilot companies treat = 0, not included in the carbon	Secondary data from official ETS websites	Sun et al. (2022a); He et al. (2022); Nie et al. (2021); Ma & Xue (2022)

	trading (pilot company)			emissions trading pilot companies		
	The pilot of the CET policy	POST * TREAT (DID)	Cross-multipliers of policy and time dummy variables	If the city where the company is located has launched a pilot carbon trading policy in *t*, DID = 1; otherwise, DID = 0	Secondary data from official ETS websites	Sun et al. (2022a); He et al. (2022); Nie et al. (2021); Ma & Xue (2022)
Moderate variable	Green technology innovation	GTI	Green technology innovation	The sum of the number of green invention patents and green utility patent applications filed independently and jointly by listed companies in the year	Secondary data from the CSMAR database	Chen et al. (2021); Zhu et al. (2019); Dechezleprêtre et al. (2013); Carrión-Flores & Innes (2010)
Control variable	Assets and liabilities	LEV	Financial operating conditions	Total liabilities/total assets	Secondary data from the CSMAR database	Sun et al. (2022b); Jeevesh & Suhasini (2021); Fu and Shen (2020)
	Current ratio	CURRENT	Financial operating conditions	Current assets/current liabilities	Secondary data from the CSMAR database	Liu et al. (2021); Wang & Liu (2021)
	Company growth	GROWTH	Financial operating conditions	(Main business income for the current period - Main business income for the previous period)/Main business income for the previous period × 100%	Secondary data from the CSMAR database	Chen et al. (2022)
	Asset turnover ratio	TURNOVER	Financial operating conditions	Net operating income/total assets	Secondary data from the CSMAR database	Liu et al. (2021); Wang & Liu (2021)
	Ownership concentration	COCEN	Company governance	The proportion of shares held by the largest shareholder to the total share capital	Secondary data from the CSMAR database	Wang et al. (2022b); Sun et al. (2022); Liu et al. (2021b)
	Management rights	TOPM	Company governance	Management shareholding ratio	Secondary data from the CSMAR database	Wang et al. (2022b); Sun et al. (2022); Liu et al. (2021b)
	Company Type	STATE	Company characteristics	It is 1 if state-owned holding, 0 otherwise	Secondary data from the CSMAR database	He et al. (2021); Shen et al. (2020)

	Company listing age	Ln AGE	Company characteristics	Ln (2022 - year of listing + 1)	Secondary data from the CSMAR database	Luo & Tang (2016); Ma & Xue (2022); Zhang et al. (2020)

4.4.1.5 Multiple Regression Equations

In order to empirically test the relationship between the variables in this study, the following four regression equations were established. The 1st to 2nd regression equations test the direct relationship between carbon market mechanisms and company performance. The 3rd to 4th regression equations test the moderating role of green technology innovation between carbon market mechanisms and company performance. The regression analysis will be used to understand the correlation between the dependent variables, independent variable s and control variable s. Chapter 5 will summarize the results of the regression analysis.

This study examines the immediate impact of the carbon market mechanisms on company performance, categorizing it into two distinct areas: economic performance and sustainability performance. Economic performance is indicated by indicators such as company value, while sustainable performance is indicated by ESG scores. Carbon market mechanisms are measured in three ways: carbon finance, carbon price, and carbon trading policy.

a) Carbon market mechanisms and Company Performance

This section examines the impact of carbon market mechanisms on company performance. The dependent variable s in this study include economic performance and sustainable performance (ESG). The independent variable s include carbon finance, carbon price, and carbon trading policy (DID). In this study, a basic double-difference model is constructed to test the effect of carbon trading policy on company performance, and a continuous double-difference model is constructed to evaluate the effect of carbon finance and carbon price on company performance. Models 4.15 and 4.16 were constructed to assess hypotheses H1a-H1b, H2a-H2b, and H3a-H3b.

In this study, model 4.15 is constructed to test hypotheses H1a-H2a-H3a.

$$EVA_{i,t} = a_0 + a_1 DID_{i,t}(CF_Post_{i,t})(CP_Treat_{i,t}) + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}, \qquad (4.15)$$

Where the dependent variable is $EVA_{i,t}$, $CF_Post_{i,t}$ is carbon finance,

$CP_Treat_{i,t}$ is carbon price, $DID_{i,t}$ is the carbon trading policy, $DID_{i,t}$ is a binary indicator that decides whether carbon trading should be initiated. If the region where company i is located begins the carbon trading pilot in year t, $DID_{i,t}$ will have a value of 1 in year t and all following years and a value of 0 otherwise. a_0 is the intercept term, $\gamma Control_{i,t}$ refers to a set of control variables that have the potential to modify the relationship between the carbon market mechanisms and EVA, the variable μ_i represents the industry fixed effect, δ_i represents the time-fixed effect, and ε_i represents the residual. Within this framework, $DID_{i,t}(CF_Post_{i,t})(CP_Treat_{i,t})$ is crucial. Its coefficient $a_1$quantifies the influence of carbon finance, carbon price, and the impact of carbon trading policy on a company's value in the carbon trading pilots is of utmost concern. When the hypothesis is correct, the coefficient a_1 is expected to be stable, positive, and significant, indicating that carbon finance, raising carbon price, and establishing a carbon trading strategy will result in improved economic performance with a considerable economic impact.

According to Zhang et al. 2023, Shu and Tan 2023, Zhang et al. 2021, Wu and Wang 2022, Sun et al. 2022, and Krokida et al. 2020, this study introduces a set of company-level control variables into the econometric model to reduce potential factors that may interfere with the results and eliminate bias in the assessment. The control variables are as follows:

a) Add Assets and liabilities to exclude the effect of the company's capital structure on company performance (lev).

b) The size of the current ratio affects the company's performance, so control for the current ratio (current).

c) The speed of asset turnover will affect the company's performance, so control the asset turnover (turnover).

d) Add the growth rate of revenue to control the effect of growth on company performance (growth).

e) The nature of the company affects the performance of the company. Hence, add the state control variable (state).

f) The natural logarithm of the age of the company's listing is used to control the effect of the life cycle on the company's performance (age).

g) Relevant studies have proven that stock options granted to executives have a

very positive impact on company performance (Bai et al., 2019). Therefore, in order to exclude irrelevant variables, equity concentration is controlled (cocen).

h) The level of management power affects company performance. Thus, the control variable for management power is added (topm).

In this study, model 4.16 is constructed to test hypotheses H1b-H2b-H3b.

$$ESG_{i,t} = a_0 + a_1 DID_{i,t}(CF_Post_{i,t})(CP_Treat_{i,t}) + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}, \quad (4.16)$$

Where the dependent variable is $ESG_{i,t}, CF_Post_{i,t}$ is carbon finance, $CP_Preat_{i,t}$ is carbon price, $DID_{i,t}$ is the carbon trading policy, $DID_{i,t}$ is a binary indicator that decides whether carbon trading should be initiated. If the region where company i is located begins the carbon trading pilot in year t, $DID_{i,t}$ will have a value of 1 in year t and all following years and a value of 0 otherwise. a_0 is the intercept term, $\gamma Control_{i,t}$ refers to a set of control variables that have the potential to modify the relationship between the carbon market mechanisms and ESG, the variable μ_i represents the industry fixed effect, δ_i represents the time-fixed effect, and ε_i represents the residual. Within this framework, $DID_{i,t}(CF_Post_{i,t})(CP_Treat_{i,t})$s is significant. Its coefficient a_1, quantifies the influence of carbon finance, carbon price, and the impact of carbon trading policy on ESG in the carbon trading pilots, which is of utmost concern. When the hypothesis is correct, the coefficient $a_1$is expected to be stable, positive, and significant, indicating that carbon finance, raising carbon price, and establishing a carbon trading strategy will result in improved ESG with a considerable sustainable impact. Model 4.16 control variables are the same as in model 4.15.

b) Moderating Effect—Green Technology Innovation

This section examines how green technology innovation affects the carbon market mechanisms and company performance. In this study, carbon finance, carbon price and carbon trading policy (DID) are used as explanatory variables, and green technology innovation is used as a moderator variable, company value (EVA) and environmental score (ESG) as dependent variables. Models 4.17 and 4.18 were

constructed to evaluate hypotheses H4a-H4b, H5a-H5b, and H6a-H6b.

In this study, model 4.17 is constructed to assess hypotheses H4a-H4c.

$$EVA_{i,t} = a_0 + a_1 DID_{i,t}(\ CF_Post_{i,t}\ )(CP_Treat_{i,t}) + a_2 GTI_{i,t} + a_3 DID_{i,t}(\ CF_Post_{i,t}\ )(CP_Treat_{i,t}) * GTI_{i,t} + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t} \quad (4.17)$$

Where the dependent variable is $EVA_{i,t}$, CF$_Post_{i,t}$ is carbon finance, $CP_Treat_{i,t}$ is carbon price, $DID_{i,t}$ is the carbon trading policy, $DID_{i,t}$ is a binary indicator that decides whether carbon trading should be initiated. If the region where company i is located begins the carbon trading pilot in year t, $DID_{i,t}$ will have a value of 1 in year t and all following years and a value of 0 otherwise. a_0 is the intercept term, $\gamma Control_{i,t}$ refers to a set of control variables that have the potential to modify the relationship between the carbon market mechanisms and EVA. The variable μ_i represents the individual fixed effect, δ_i represents the time-fixed effect, and ε_i represents the residual. In this paper, the regression analysis utilizes the interaction term $DID_{i,t}(CF_Post_{i,t})(CP_Treat_{i,t}) * GTI_{i,t}$ to examine how green technology innovation affects the relationship between the carbon market mechanisms and EVA. When the hypothesis is correct, the coefficient a_3 is projected to remain stably positive and substantial, suggesting that the advancement of green technology enhances the effectiveness of the carbon market mechanisms in increasing EVA. The control variables for model 4.17 are the same as for model 4.15.

In this study, model 4.18 is constructed to assess hypotheses H6a-H6c.

$$ESG_{i,t} = a_0 + a_1 DID_{i,t}(CF_Post_{i,t})(CP_Treat_{i,t}) + a_2 GTI_{i,t} + a_3 DID_{i,t}(CF_Post_{i,t})(CP_Treat_{i,t}) * GTI_{i,t} + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}, \quad (4.18)$$

Where the dependent variable is $ESG_{i,t}$, $CF_Post_{i,t}$ is carbon finance, $CP_Preat_{i,t}$ *is* carbon price, $DID_{i,t}$ is the carbon trading policy, $DID_{i,t}$ is a binary indicator that decides whether carbon trading should be initiated. If the region where

company i is located begins the carbon trading pilot in year t, $DID_{i,t}$ will have a value of 1 in year t and all following years and a value of 0 otherwise. a_0 is the intercept term, $\gamma Control_{i,t}$ refers to a set of control variables that have the potential to modify the relationship between the carbon market mechanisms and ESG. Meanwhile, the variable μ_i represents the industry fixed effect, δ_i represents the time-fixed effect, and ε_i represents the residual. In this paper, the regression analysis utilizes the interaction term $DID_{i,t}(CF_Pot_{i,t})(CP_Treat_{i,t}) * GTI_{i,t}$ to examine how green technology innovation affects the relationship between the carbon market mechanisms and ESG. When the hypothesis is correct, the coefficient a_3 is projected to remain stably positive and substantial, suggesting that the advancement of green technology enhances the effectiveness of the carbon market mechanisms in increasing ESG scores. The control variables for model 4.18 are the same as for model 4.15.

Table 4.11 presents the research objectives, corresponding hypotheses and empirical models.

Table 4.11
Research Objectives, Hypotheses and Empirical Models

Research Objectives	**Hypothesis**	**Empirical Model**
RO1: To examine the economic effects and sustainable effects of the carbon market mechanisms.	H1a-H1b H2a-H2b H3a-Hbb	$EVA_{i,t} = a_0 + a_1 DID_{i,t}(CF_Post_{i,t})(CP_\mathrm{Treat_{i,t}}) + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}$
		$ESG_{i,t} = a_0 + a_1 DID_{i,t}(CF_Post_{i,t})(CP_Treat_{i,t}) + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}$
RO2: To analyze the moderating effect of green technology innovation on the relationship between carbon market mechanisms and company performance.	H4a-H4b H5a-H5b H6a-H6b	$EVA_{i,t} = a_0 + a_1 DID_{i,t}(CF_Post_{i,t})(CP_Treat_{i,t}) + a_2 DID_{i,t}(CF_Post_{i,t})(CP_Treat_{i,t}) * GTI_{i,t} + a_3 GTI_{i,t} + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}$
		$ESG_{i,t} = a_0 + a_1 DID_{i,t}(CF_Post_{i,t})(CP_Treat_{i,t}) + a_2 DID_{i,t}(CF_Post_{i,t})(CP_Treat_{i,t}) * GTI_{i,t} + a_3 GTI_{i,t} + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}$

4.4.1.6 Data Analysis

a) Tool Used for Analysis

This study analyzed data using STATA17, a robust and efficient statistical

analysis software developed by the Computer Resource Centre (CRC) of the United States (US). It is both powerful and small, making it highly helpful for analyzing and managing data. In addition, it possesses the functionalities of data management software, statistical analysis software, graphing software, matrix computing software, and a programming language, rendering it distinctive in numerous aspects. STATA performs the features of Statistical Package for Social Sciences (SPSS) and Econometric Views (EVIEWS), and its operation is flexible, straightforward, and easy to understand and apply (Kirchkamp & Niggemann, 2017).

b) Data Analysis Techniques

This section describes the statistical techniques used in empirical analyses. In this study, data were analyzed using the econometric analysis software STATA version 17. There are six main stages in the data analysis process, which are fully described in the next chapter. The six stages are listed and explained below.

i) Descriptive statistical analyses
ii) Statistical analysis of correlation
iii) Parallel trend test
iv) Multiple regression analysis
v) Placebo test
vi) Robustness test

i) Descriptive Statistical Analysis

Descriptive statistical analysis is the first knowledge of the data source, which includes data frequency analysis, trend analysis, and discrete degree analysis, after understanding these to do further analysis. At this stage, the continuous independent variable s are summarized to enable this study to observe concentrated trends and variability in the data. In concentrated trends, a number is usually determined to summarize the distribution of the variable. For example, the mean is reported here. However, in terms of variability, they include determining maximum, minimum, and standard deviation values (Nicoletti, 2019).

ii) Statistical Analysis of Correlation

The Pearson correlation coefficient test for the main research variables of this thesis analyzes the correlation between the study variables to observe whether there is a significant problem of covariance between the variables (Abidin & Ngah, 2022).

iii) Parallel Trend Test

The DID methodology is commonly employed to analyse the effects of a policy or intervention on a certain demographic. This method relies on the following fundamental assumptions. In the absence of the policy or intervention, the trends in the experimental group (the group affected by the policy) and the control group (the group unaffected by the policy) should be similar and aligned (Heinrich et al., 2010).

Parallel trends are essential for the use of the DID model, which requires that the experimental and control groups maintain a similar pattern of development prior to the implementation of the policy. The fact that this same trend began to change after the pilot policy was introduced would indicate that the pilot policy was implemented rather than being interfered with by other factors (Randolph & Falbe, 2014).

The parallel trend hypothesis test ensures that the experimental and control groups exhibited identical trends before the policy was implemented, enabling an accurate evaluation of the overall effect on the experimental group (Callaway & Sant'Anna, 2021). Suppose there are substantial disparities between the experimental and control groups prior to implementing the policy. In that case, these discrepancies may influence the outcomes of the DID approach, perhaps resulting in an incorrect assessment of the policy's impact (Lechner, 2002).

Two methods for evaluating the parallel trend hypothesis are visually representing the time trend through graphs and employing statistical tools. The time-trend plotting method entails displaying the average outcomes (such as averages and proportions) of both the experimental and control groups prior to and following the implementation of a strategy in a trend plot (Riveros & Gavilanes, 2023). Examine the trend lines of the experimental and control groups to determine if they exhibit a parallel pattern. The validity of the parallel trend hypothesis is contingent upon the trend lines of both groups demonstrating a parallel relationship prior to the implementation of the

policy (Kane et al., 2020).

Statistical methods involve incorporating dummy variables or time-trend factors (such as year or quarter) into the regression model for both the experimental and control groups (Lunt, 2015). The significance of the interaction term between the dummy variable representing the experimental group and the temporal trend term was further analyzed. If the data do not exhibit statistical significance, it can be assumed that the parallel trend hypothesis is valid (Heckman & Todd, 1998).

iv) Multivariate Regression Analysis

This study employs multiple regression analysis to assess pre-established hypotheses and ascertain the level of correlation between the dependent and independent variables. Multiple regression analysis was employed to ascertain the variables that significantly impact company performance (Rahim, 2019). Regression modelling also examined the relationship between carbon finance, carbon price, carbon trading policy and company performance.

v) Placebo Testing

The placebo test is a frequent procedure for causal inference methods such as double difference. The primary objective is to eliminate the impact of extraneous factors, such as non-policy aspects, on the study's results and, ultimately, to establish the dependability of the study's subject's causal effect (Goodman-Bacon, 2021).

The central idea of the placebo test is to observe whether a spurious policy produces similar effects to the actual policy by constructing a non-real policy or an experimental group. Suppose false policy or experimental groups can also produce significant effects in such non-realistic contexts. In that case, this then implies that the effect of the actual policy is caused by other unobserved or contingent factors rather than the real policy itself. Thus, using placebo tests can help researchers be more convinced of the veracity of policy or treatment effects (Athey & Imbens, 2022).

In the DID model, substituting variables and samples, changing the time of occurrence of the policy, and randomly generating experimental groups are the more common methods of placebo testing (Hagemann, 2019). In this scenario, the approach

to modifying the timing of the policy's implementation was to either accelerate or delay it. Thereafter, it assesses if the outcome difference between the experimental and control groups remained statistically significant before and after the policy's implementation (Xiao et al., 2021). Randomized experimental groups were formed by randomly allocating participants into experimental and control groups. The aim was to assess if the policy impacts remained statistically significant following the random assignment. On the other hand, placebo tests with replacement samples and placebo tests with replacement variables examine the stability of policy effects by replacing samples or variables (Abadie, 2005).

vi) Robustness Check

Adjusting for explanatory factors in the underlying regression study to improve the reliability of the empirical findings (Nicoletti, 2019). In order to make the empirical findings of this paper more robust, this paper is designed to conduct robustness tests by adding control variables, industry cluster analysis, lagging the independent variable by one period, reducing fixed effects and placebo tests

Table 4.12 lists the purposes of the parallel trend test, the DID model and the placebo test.

Table 4.12
Parallel Trend Test, DID Model and Placebo Test

Testing	Purposes
Parallel trend test	The purpose of the parallel trend test was to ensure that the treatment and control groups were trending similarly prior to the implementation of the policy in order to measure the effect of the policy accurately and to avoid other factors interfering with causal inferences.
DID Model	The DID model test aims to accurately identify the true causal effect of carbon trading policy shocks on company performance by comparing the treatment and control groups and stripping away the interference of other factors.
Placebo test	Placebo tests are used to test the robustness of empirical results by fictionalizing the observed results of treatment variables and determining whether the resulting conclusions are true effects or pseudo-results arising from the interference of unobserved factors.

Figure 4.4 illustrates the first stage of quantitative analysis steps. The first step is data collection and cleaning. The second step is diagnostic tests, including descriptive,

correlation, heteroscedasticity, autocorrelation and Hausman. The third step is the parallel trend test for carbon trading policy, the fourth step is the DID test, the fifth is the robustness and placebo test, and the sixth is the results and discussion.

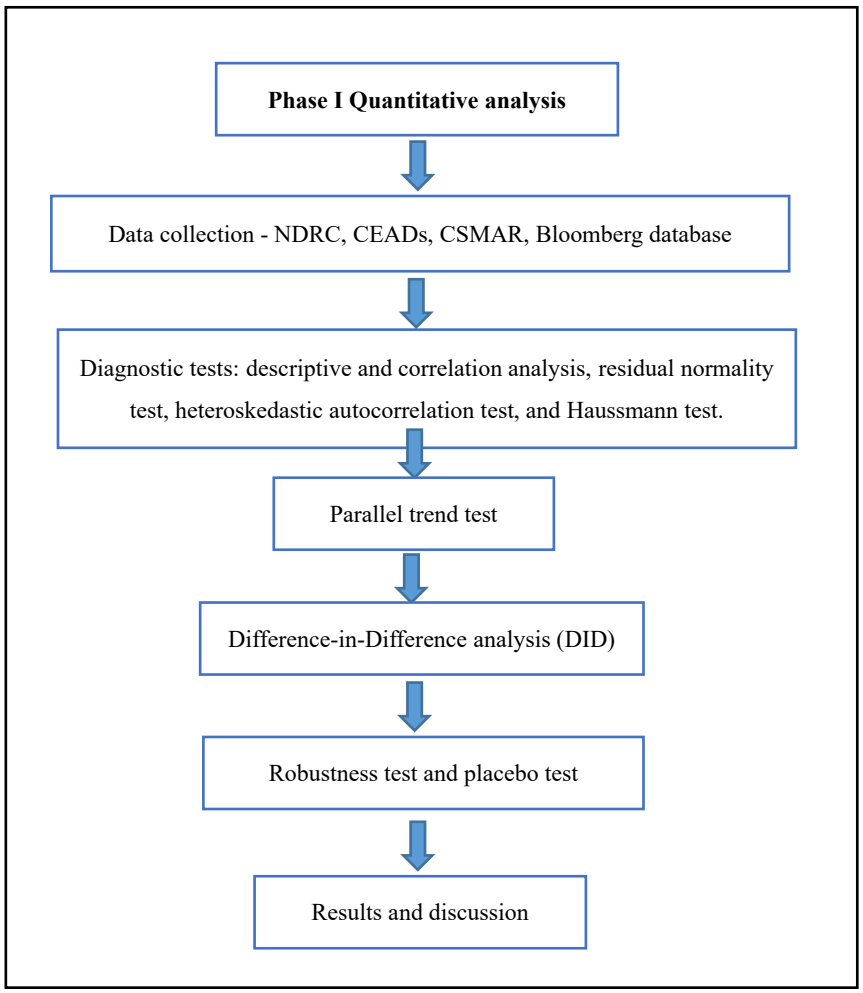


Figure 4.4 Phase I – Quantitative Approach Process

4.4.2 Qualitative Research

RQ3 compares the opportunities and challenges faced by carbon trading pilot and non-carbon trading pilot companies in implementing carbon trading policy. For RQ3, qualitative research methods were used. Qualitative research methods complement and further explain quantitative research methods.

4.4.2.1 Source of Data

Currently, the researcher plans to determine the research locations and representatives of the personnel from the chosen sample companies. The interview style facilitated comprehension of the intricacies of the carbon market mechanisms and the respondents' perspectives on the company's current situation, its issues, and the challenges it confronts. During this study phase, the data was initially audio format and subsequently converted into text for qualitative analysis (Lester et al., 2020). There are numerous techniques for qualitative analysis, and in this study, the primary selection is the thematic analysis method.

4.4.2.2 Sampling

The researchers sent emails to the general managers of both participating and non-participating pilot carbon trading companies, inviting 45 companies from significantly polluting industries to participate in the study. After a week, the researcher contacted them by telephone to arrange a specific time and location for the interview.

Accordingly, 30 people agreed to be interviewed: 15 from carbon trading pilot companies and another 15 from non-carbon trading pilot companies, of which 15 were executives and another 15 were finance managers. Another 15 companies declined the invitation due to time constraints and tight schedules. The interviews were performed for a duration of six months, spanning from September 2024 to February 2025. Each interview lasted around 40 to 60 minutes and was conducted individually. An expert transcribed the audio-recorded interviews into textual form, preserving the exact wording. The researcher was neutral during the interview process and asked for clarification of any unclear data in the sources via email or phone.

The process of selecting participants was as follows. The selection of participants for this study was paramount, and pragmatism was employed as the theoretical paradigm. The study questions were investigated by selecting appropriate participants through opportunity sampling. For this study, a sample size of 30 participants from various companies was deemed adequate. The data collection procedure is illustrated in Table 4.13

Table 4.13

Qualitative Data Collection Methods

Method of Collecting Data	**Date/Period**	**Companies Involved**
Email invitation	September 2024 - January 2025 (5 months)	Contacted 45 companies within the sampling unit.
Telephone conversation invitation (subsequent to sending an email)	Mid-September 2024-January 2025 (4.5 months)	Conducting follow-up calls to arrange interviews.
Acceptance of interview invitation	Interviewee Interview Date. November 2024-February 2025(4 months)	30 companies were involved in the study, while 15 others abstained due to their busy schedules at the time.

Prior to conducting the interviews, the study's purpose, interview protocol (refer to Appendix A), and interview questions were submitted to the company. Ensuring that the interviewers were well-informed created a calm atmosphere for open communication, putting them at ease. Furthermore, the interviewees were requested to grant consent to record the interview proceedings. The interviews commenced with fundamental inquiries on participant information, serving to alleviate anxiety and establish a connection with the participants.

The interview process is centered on simplifying the questions presented in formal academic language into the everyday conversational talk. Interview questions are designed to obtain insight into participants' perspectives, whereas research questions are based on the researcher's understanding of the subject matter (Lisle & Bourne, 2019). The objective of the interviews conducted in this study was to obtain a comprehensive understanding of the opportunities, challenges, and issues encountered by both carbon trading pilot companies and non-carbon trading pilot companies. Furthermore, the interviews were meant to gather novel insights on aspects not addressed within the research framework.

To gather a substantial amount of information, a set of initial interview questions was designed for this study. Nevertheless, a proactive approach is employed to consistently enhance and create new inquiries throughout the interview process, such as utilizing questions, prompts, probes, remarks, and other interventions (Newlin-Canzone et al., 2011). Subsequently, they were inquired about the prospects and difficulties encountered by their companies in engaging or abstaining from carbon

trading, along with the alterations in company performance before and subsequent to participating in carbon trading. An interview protocol matrix was also created to guarantee comprehensive coverage of all research questions in the interview protocol. The researcher scrutinizes the structure and detects any potential deficiencies that may be there. Accordingly, researchers have the ability to address any missing information by incorporating pertinent inquiries into the procedure, along with their research objectives.

The interview protocol was designed for two groups: individuals from the carbon trading pilot company and personnel from the non-carbon trading pilot company. The protocol consisted of four sections: understanding, retrieval, judgment, and reaction (Ashok et al., 2022; Hannan et al., 2020). Part A comprehends the notion of carbon market mechanisms from the standpoint of individuals and companies. The objective was to examine the participants' comprehension of essential terminology. Meanwhile, Part B focuses on retrieving information regarding carbon market mechanisms practices, aiming to assess participants' ability to obtain information on the present state of carbon market mechanisms and company performance. Moreover, Section C evaluates the correlation between carbon market mechanisms and company performance, specifically examining the strategies employed by participants to determine the impact of carbon market mechanisms on company performance. Furthermore, component D (i) specifically focuses on the participants' responses to the observed phenomenon. A survey was conducted to investigate participants' responses to the provided answer options. Respondents responded to inquiries pertaining to carbon market mechanisms and company performance. Part D (i) addresses the primary obstacles encountered by companies engaged in carbon trading and those not engaged, as well as the way forward. Part D (ii) examines the benefits and drawbacks, as well as the consequences, of a company's involvement or lack thereof in carbon trading.

This paper aims to confirm the efficiency of the negotiated market mechanism by concentrating on the changes in company performance both before and after the company's involvement in carbon trading and non-participation. Tables 4.14 and 4.15 provide a concise summary of the RQ3.

Table 4.14

Development of Interview Questions (IQ) for Addressing Research Questions (RQ) in the Carbon Trading Pilot Company

The Manner in Which the RQs were Addressed	RQ
Section C IQ: 1. What is your opinion on the impact of carbon market mechanisms on company performance?	RQ3: How does implementing carbon market policy affect the company performance of high-polluting industries - pilot and non-carbon trading pilot companies?
Section D (i) IQ: 1. Prior to engaging in carbon trading, what was the efficacy of your company? 2. What has been the status of your company's performance following your involvement in carbon trading? 3. What are the financial obstacles that your company encounters while engaging in carbon trading? 4. What are the challenges associated with your company's involvement in carbon trading? 5. How can your company more effectively address the possibilities and challenges of transitioning to a low-carbon economy in order to achieve carbon neutrality?	
Section D (ii) IQ: 1. What are the benefits and drawbacks of companies engaging in carbon trading? 2. What are the consequences of a company's involvement in carbon trading?	

Table 4.15

Development of Interview Questions (IQ) for Addressing Research Questions (RQ) in the Non-Carbon Trading Pilot Companies

The Manner in Which the RQs were Addressed	RQ
Section C IQ: 1. Will the carbon market mechanisms have an impact on company performance when the company engages in carbon trading?	RQ3: How does implementing carbon market policy affect the company performance of high-polluting industries - pilot and non-carbon trading pilot companies?
Section D (i) IQ: 1. What are the present fiscal obstacles confronting your company? 2. What challenges are present in your company's move towards a low-carbon model? 3. How can your company effectively address the opportunities and challenges of transitioning to a low-carbon economy within the framework of carbon neutrality?	
Section D (ii) IQ: 1. What are the benefits and drawbacks of a company choosing not to engage in carbon trading? 2. What are the consequences of a company abstaining from carbon trading?	

4.4.2.3 Qualitative Research Process

The process of qualitative content analysis consists of six steps: becoming acquainted with the data, creating initial codes, identifying themes, reviewing themes, defining and labeling themes, and producing reports. The initial phase is acquainting

oneself with the data, wherein the information contained in the audio file is transcribed or transformed into textual format (Lester et al., 2020). The researcher's choice of method for documenting the interview data is a crucial and pivotal stage (Hashimov, 2015). For instance, one can record all the questions posed during an interview or only focus on the important ones. Additionally, one can decide whether to record the dialogue word-for-word or create summaries. It is also possible to consider non-verbatim components such as voices, hesitations, and other audible behaviors. For this study, the researchers decided to transcribe all remarks, including questions and answers that were part of the interviews. This transcription would be highly valuable for the analysis.

The second step is to generate the initial code. This process entails developing preliminary codes pertinent to the study subject (Lester et al., 2020). The researcher impartially coded the data, identifying as many probable themes/patterns as feasible. The researchers utilized NVivo 14 to track the code and employed comments or memoranda to comprehend the significance of the data.

The third step is to search for themes. Themes are comprised of code units that symbolize the manifestation of concepts. Subsequently, potential themes were gathered, and all pertinent data corresponding to each potential theme was compiled to establish a category (Akinyode & Khan, 2018). The data analysis approach involved iteratively reviewing the interview data, condensing it, and then including additional categories or themes using NVivo 14 software. Hence, to extract additional relevant insights from the interview data, our study employed the thematic analysis of the identical six phases suggested by Lester et al. (2020) and implemented using NVivo (Table 4.16).

Table 4.16

Integrating Thematic Analysis with the NVivo Application

Analysis of Qualitative Data	***Used in NVivo 14**
Step 1: Familiarity with data. Transcribe the data, repeatedly review it, and record initial ideas.	
Step 2: Generate initial codes that methodically encode data characteristics throughout the dataset and gather the data linked to each code.	Generate several codes via open coding techniques.
Step 3: Conduct a search for underlying patterns, categorize the codes into potential themes, and gather all the data associated with each potential theme.	Refine the consolidation of codes or categorization.
Step 4: Evaluate the themes and ensure they are applicable to the coded excerpts and the entire dataset, creating a thematic map.	
Step 5: Involves the process of defining and naming themes,	

conducting analysis, refining the details of each topic, and the overall story conveyed by the analysis. It also includes generating unambiguous definitions and names for each theme.	
Step 6: Perform the analysis. Choose instances of vivid and captivating extracts, then merge the analysis with the research questions to produce the ultimate research report.	Create a schematic representation of the coding system from a network perspective. Create a quotation count report form from the Code Manager window, which may be saved as either a document file or an Excel file.

Source: Adapted from Lester et al. (2020) and Akinyode & Khan (2018).

The fourth step involves evaluating the themes, ensuring their relevance to the coded extracts and the overall dataset, and creating theme maps (Akinyode & Khan, 2018). Coherent classification focuses on identifying suitable matches until a satisfactory coding consistency or saturation level is reached.

The fifth step involves identifying and labelling themes, which is the most arduous aspect of the analysis procedure. During this phase, the researcher examines the explanations in relation to theoretical concepts, improving and creating precise definitions and labels for each subject (Lester et al., 2020). Furthermore, to account for potential changes in categories and codes, the accuracy and validity of the codes were reassessed and confirmed, and conclusions were derived from the coded data (Newcomer, 2004).

The sixth step involves generating the report, which serves as the ultimate analysis. The progression of the overarching narrative facilitates the connection between the themes, while the presentation of the findings and methods is tailored accordingly (Lester et al., 2020). Furthermore, the researcher presents the study's findings in NVivo 14, encompassing theoretical data saturation and the final network view data display.

Figure 4.5 describes the process of qualitative analysis, starting with qualitative data collection-30 participant interviews, followed by interview theme analysis and PESTLE analysis, and finally, report writing and refinement.

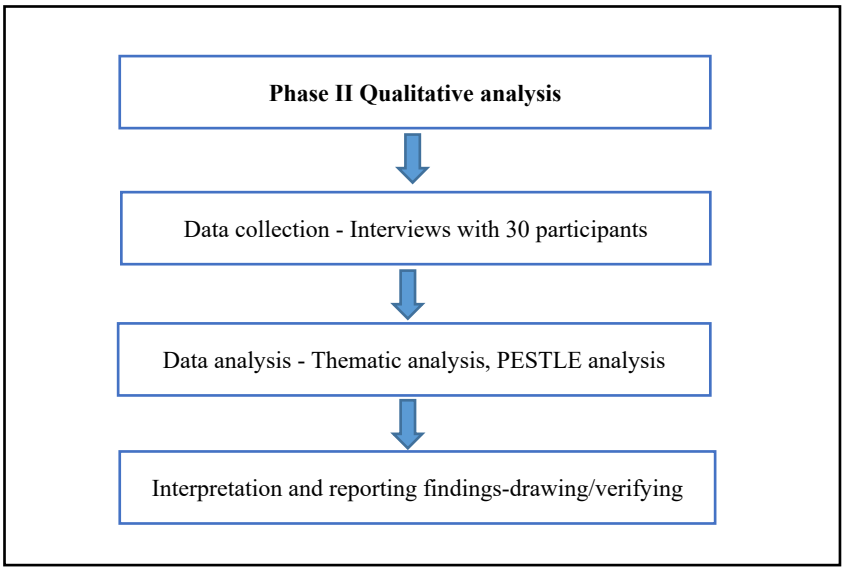


Figure 4.5 Phase II – Qualitative Approach Process

4.4.2.4 Qualitative Data Analysis (QDA)

The researcher utilized Microsoft Office Word to convert the audio data into written form, and the transcripts were generated based on the actual sequence of the interview rather than the order of the interview questions. However, the researcher subsequently reorganized the data based on the sequence of the interview questions and gained an alternative perspective on the responses. Prior to conducting Qualitative Data Analysis (QDA), researchers need to have a comprehensive understanding of each case and issue.

The meaning and comprehension in QDA are fully included in codifying and subsequently analyzing the data content for each code (Chowdhury, 2015). Lewis and Maas (2007) proposed that QDA comprises three primary processes: data reduction, data display, and conclusion. Researchers employ meticulous analytical methods and impartial judgment during data analysis. Notably, QDA approaches are employed to comprehend themes, specifically focusing on conducting micro-level content analysis to detect patterns in frequency counts.

Thematic analysis is a widely used approach involving qualitative analysis through open coding, categorization, and finalization of themes. There are two coding approaches: inductive and deductive. The inductive approach involves identifying

coding categories directly from the raw data. This approach is commonly employed in grounded theory research. The deductive technique is the second method used for direct qualitative analysis. It also involves initial coding that is guided by Porter's hypothesis theory and innovation theory. This strategy aims to validate or expand the conceptual model, framework, or theory (Beñalet, 2024). The researchers employed the second strategy in this investigation.

Researchers can choose to conduct QDA either manually or by utilizing Computer-Assisted Qualitative Data Analysis Software (CAQDAS). Software packages are pertinent to social science disciplines, as they save time and facilitate efficient project management. Therefore, the collaboration between human expertise and computer data processing plays a significant role for researchers. Additional CAQDAS options, such as ATLAS.ti, are available in the market. Nevertheless, researchers have a preference for NVivo. The interview data was subsequently imported into the software, enabling the researcher to organize and manage the abundance of data effectively. Furthermore, the NVivo program effectively managed the intricacy of the data by providing a centralized storage system for interview data and other documents. Consequently, the analytical process got more structured, and the code development grew more thorough.

4.4.2.5 Reliability and Validity Issues in Qualitative Research

Reliability refers to the consistency, stability and dependability of a measurement (Golafshani, 2003). In semi-structured interviews, reliability is assessed by the consistency of the interviewer, the stability of the interview process and the reliability of the interview data (Ibiamke & Ajekwe, 2017). In this study, the researchers selected carbon trading pilots and non-carbon trading pilots, listed companies as samples, selected 30 interviewees, and set up the interview outline in advance. The interview framework, the main questions, and the way of guiding remain unchanged during the interview process, and the interview information is real and reliable. Hence, the credibility of the interview can be guaranteed.

Validity refers to the degree to which a measurement tool or instrument can accurately measure the correct item. In semi-structured interviews, validity includes content, structural and criterion validity (Bashir et al., 2008). In this study, the

interviews comprehensively and accurately covered the research topic and the required measurements. They were able to reasonably and effectively guide the interviewees in answering the questions in depth and comprehensively.

To ensure the accuracy of the data collected from the interviews, the researcher conducted member checks and submitted the interview transcripts to the interviewers for feedback. Of all 30 participants who participated in the interviews, all 30 responded to the request to verify the interview transcripts. Comments and feedback from the interviewees were necessary to examine the accuracy of the interpretations made by the researcher.

4.5 Ethical Issues Addressed in This Study

Ethical considerations are crucial at every stage of the research process. The identities of the organizations participating in this study and the individuals interviewed were kept confidential, ensuring their privacy was upheld. Although participation was optional, participants were provided with prior information regarding the objectives and methods of this study. Table 4.17 presents the ethical concerns that were dealt with at various stages of this investigation, as derived from Saunders et al. (2009).

Table 4.17
Ethical Issues Addressed in this Study

Research Phase	Stage-Specific Ethical Concerns
Research subject development and clarification (Chapters 1 to 3)	The Graduate Office grants approval for the continuation of research projects.
Research design (Chapter 4)	Participants' right to information and privacy.
Collection of data (Chapter 4)	The researcher has the right to be free from compulsion and to have security. The participant has the right to be informed, to give consent, and to withdraw from the study. Both the researcher and the participant have the right to secrecy. Additionally, the participant has the right to be misled if necessary. The organization doing the research also has the right to confidentiality and anonymity.
Data processing and data storage (Chapter 4)	Participants own the entitlement to handle and retain their personal data in their individual capacity.
Statistical analysis and the creation of reports (Chapters 5 and 6)	The participants have the right to confidentiality, as do the organizations involved, which have the right to confidentiality and anonymity.

Source: Saunders et al. (2009, p. 191)

4.6 Chapter Summary

The chapter begins with an elucidation of the research technique and phases employed in this study, followed by the quantitative research design. This encompasses the process of determining the appropriate sample size, selecting data collection methods and empirical models, defining and measuring independent, dependent, moderating, and control variables, and ultimately determining regression equations and data processing procedures. The participant selection for the qualitative study, the thematic analysis process and the QDA methods are described in detail next. Chapter 5 will conduct descriptive statistical analysis, parallel trend test, correlation statistical analysis, multiple regression analysis, and placebo test, and finally, the study will be concluded.

CHAPTER 5

QUANTITATIVE DATA ANALYSIS AND FINDINGS

5.1 Introduction

This chapter comprises ten sections presenting the outcomes of the quantitative analysis. Section 5.2 delineates the diagnostic assessments, encompassing the descriptive statistical analysis, the correlation test, and the multicollinearity test, the histogram of residual normality, the heteroscedasticity autocorrelation test, and Haussmann's test. Section 5.3 examines the assessment of parallel trends in carbon trading policy. Section 5.4 delineates the findings of the baseline regression analysis. Section 5.5 delineates the examination of the regulatory process. Section 5.6 delineates the robustness test, Section 5.7 encompasses the results and discussion, Section 5.8 concentrates on the qualitative analysis discourse, and ultimately, the conclusion is provided.

5.2 Diagnostic Test

The diagnostic tests in this study included descriptive statistical analysis, correlation statistical analysis, multiple covariance test, residual normality test, heteroskedastic autocorrelation test, and Haussmann test.

5.2.1 Descriptive Statistics

Before the empirical study, the sample was initially examined using descriptive statistics to assist the researcher in assessing the distribution and skewness of the sample. Table 5.1 presents the descriptive statistics for the dependent variables economic performance, ESG), independent variables (CF_Post, CP_Treat, DID), and control variables. This includes detailing the number of observations, mean, standard deviation, minimum, and maximum values for each variable, as elaborated below.

The initial step is the descriptive statistical analysis of the explanatory variables, encompassing a total of 5,889 observations. The economic performance variable (lnEVA) has a mean of 19.46, a standard deviation of 1.456, and a range from 14.177 to 22.688, suggesting substantial variability in suggesting substantial variability in lnEVA among the sample companies. The sustainability performance variable (ESG) exhibits a mean of 28.988 and a standard deviation of 9.499, with a minimum of 6.198 and a high of 71.18. The elevated standard deviation indicates a substantial disparity in ESG performance among companies, with certain companies excelling while others may underperform.

The subsequent section presents the descriptive statistical analysis of the explanatory variables. The carbon finance (CF_Post) variable comprises 4,678 observations, with a mean of 0.02, a standard deviation of 0.082, a minimum value of 0, and a maximum value of 0.59. It signifies substantial disparities in carbon finance between companies, with certain companies exhibiting markedly greater carbon finance impacts than others. The carbon price variable (CP_Treat) comprises 1961 observations, with a mean of 4.851 and a standard deviation of 14.186, spanning a range from 0 to 92.326. This indicates significant volatility in the carbon trading market price from 2013 to 2022, potentially influenced by policy, market supply and demand, and other factors. The dummy variable for carbon emissions trading strategy (DID) has 5,889 data, with a mean of 0.05, a standard deviation of 0.217, and a range from 0 to 1. This signifies that a limited number of companies engaged in the carbon emissions trading pilot, and the overall sample was not predominantly incorporated in the pilot. Post is a binary variable that differentiates between pre- and post-carbon trading policy, with values ranging from 0 to 1. Treat is a binary variable used to differentiate between the experimental and control groups, with a mean value of 0.056, signifying that about 230 company-year samples participated in the pilot carbon emissions trading within the sample range of 0 to 1.

The descriptive statistical analysis of the control variables encompasses a total of 5,889 observations. The mean value of lev is 0.434, with a standard deviation of 0.183 and a range from 0.05 to 0.902, indicating variability in financial risk among the sample companies. The current ratio has a mean of 2.113, a standard deviation of 1.751, and a range from 0.322 to 17.491, indicating significant variability across companies in their short-term solvency. The turnover exhibits a mean of 0.679 and a standard

deviation of 0.387, with a low of 0.077 and a maximum of 2.438, indicating considerable variation in asset utilization efficiency among companies.

The mean growth is 0.468, and the standard deviation is 2.474, with values spanning from -19.468 to 27.703. This substantial standard deviation signifies considerable variability in companies' growth, with some seeing tremendous expansion while others face decline. The variable 'state' is a binary variable with a mean of 0.438 and a standard deviation of 0.496, taking values of 0 or 1, which suggests that the distribution of state-controlled and non-state-held companies is almost equal in the sample. Lnage possesses a mean of 2.373 and a standard deviation of 0.696, with values spanning from 0.693 to 3.367, indicative of the varying maturity levels of companies within the market.

The cocen variable in company governance has a mean of 37.151 and a standard deviation of 15.007, with values ranging from 8.48 to 74.09, indicating substantial disparities in ownership concentration among various companies. The mean of topm is 9.229, with a standard deviation of 16.516 and a range from 0 to 68.926. This indicates significant variability in the proportion of shares held by management across various companies. In addition, certain companies' exhibit elevated managerial shareholding and concentrated rights, whereas others display a more distributed structure.

The moderator variable green technology innovation comprises 5,889 observations, with a mean of 1.635 and a standard deviation of 7.293, exhibiting a range from 0 to 182, indicating substantial disparities among companies regarding their green technology innovation activities. Certain companies possess a substantial volume of patent applications in green innovation, whereas others exhibit less engagement in green technology innovation, signifying that the capacity for technological innovation differs among companies.

The descriptive statistics reveal notable disparities among the sample companies regarding suggesting substantial variability in economic performance among the sample companies. Sustainability performance, carbon finance, carbon price, and company governance, which may influence their performance under the carbon emission policy. The descriptive statistical analyses furnish the foundational data for the ensuing regression analyses, elucidate the fundamental distributional attributes of the variables, and facilitate a comprehensive discourse on the effects of carbon finance, carbon price, and carbon trading policy on company performance.

Table 5.1

Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
(Independent variables)					
lnEVA	5889	19.46	1.456	14.177	22.688
ESG	5889	28.988	9.499	6.198	71.18
(Dependent variables)					
CF_Post	4678	.02	.082	0	.59
CP_Treat	1961	4.851	14.186	0	92.326
DID	5889	.05	.217	0	1
post	5889	.05	.217	0	1
treat	5889	.056	.23	0	1
(Control Variables)					
lev	5889	.434	.183	.05	.902
current	5889	2.113	1.751	.322	17.491
turnover	5889	.679	.387	.077	2.438
growth	5889	.468	2.474	-19.468	27.703
state	5889	.438	.496	0	1
lnage	5889	2.373	.696	.693	3.367
cocen	5889	37.151	15.007	8.48	74.09
topm	5889	9.229	16.516	0	68.926
gti	5889	1.635	7.293	0	182

5.2.2 Correlation Test

This study performs correlation tests on the dependent, independent, and control variables, utilizing the Pearson correlation matrix with two-tailed settings and Spearman correlation coefficients based on the results of the descriptive analyses. The correlation statistic is commonly employed to assess the degree of relationship between linearly related variables. Table 5.2 illustrates the outcomes of the statistical correlation analysis between independent and dependent variables, specifically highlighting the correlation between dependent variables, such as economic performance(EVA) and sustainable development performance (ESG), and Independent variables, including carbon finance (CF_Post), carbon price (CP_Treat), and carbon trading policy (DID). The correlation analysis can initially indicate the direction and significance of the link between the variables, serving as a foundational reference for subsequent empirical research.

The relationship between carbon financing (CF_Post) and lnEVA is insignificant; nevertheless, there exists a significant positive link with ESG, indicated by a correlation coefficient of 0.051 ($p < 0.01$). This indicates that carbon finance may

be more predisposed to improve the company's sustainability while exerting a lesser direct impact on economic success.

The carbon price (CP_Treat) variable exhibits a correlation coefficient of 0.058 with both lnEVA and ESG, signifying a positive impact of carbon price on the company's economic and sustainability performance.

Subsequent analyses of the carbon trading policy dummy variable (DID) reveal a significant positive correlation with both lnEVA (correlation coefficient of 0.022) and ESG (correlation coefficient of 0.069), indicating that the enactment of the carbon emissions trading policy is crucial for enhancing overall company performance. The strong association between DID and ESG illustrates the influence of policy implementation on company performance in terms of environmental, social responsibility, and governance.

Ultimately, green technology innovation serves as a Moderating Variable that exhibits a significant positive correlation with both lnEVA (correlation coefficient of 0.095) and ESG (correlation coefficient of 0.122), reinforcing the beneficial impact of green technology innovation on company performance. This indicates that companies' investments in green technology Research and Development (R&D) bolster economic performance and enhance ESG performance by increasing resource utilization efficiency.

The correlation analyses indicate that the significant relationships between the Independent variables and dependent variables corroborate the theoretical predictions regarding carbon finance, carbon price, and carbon trading policy in improving company performance. These findings offer initial evidence for further empirical research and indicate that adopting carbon price legislation and deploying green technical advances are crucial for advancing sustainable company development.

Table 5.2

Correlation Statistics

Variables	lnEVA	ESG	CF_Post	CP_Treat	DID	lev	current	turnover	growth	state	lnage	cocen	topm	gti
lnEVA	1.000													
ESG	0.349***	1.000												
CF_Post	0.005	0.051***	1.000											
CP_Treat	0.058***	0.058***	0.836***	1.000										
DID	0.022*	0.069***	0.960***	0.895***	1.000									
lev	0.092***	0.062***	0.004	0.009	0.002	1.000								
current	-0.097***	-0.101***	-0.081***	-0.114***	-0.073***	-0.650***	1.000							
turnover	0.108***	0.016	-0.012	-0.032	-0.016	0.147***	-0.149***	1.000						
growth	-0.049***	-0.067***	-0.068***	-0.117***	-0.063***	0.095***	-0.018	-0.073***	1.000					
state	0.025*	-0.026**	0.050***	0.059***	0.043***	0.195***	-0.186***	-0.004	0.036***	1.000				
lnage	0.123***	0.199***	0.053***	0.043*	0.048***	0.235***	-0.269***	0.009	0.020	0.326***	1.000			
cocen	0.126***	-0.059***	0.026*	0.078***	0.027**	0.095***	-0.075***	0.061***	-0.017	0.264***	-0.035***	1.000		
topm	-0.090***	-0.048***	-0.009	-0.027	-0.005	-0.246***	0.240***	-0.045***	-0.007	-0.466***	-0.506***	-0.168***	1.000	
gti	0.095***	0.122***	0.019	-0.004	0.023*	0.060***	-0.029**	0.049***	-0.005	0.019	0.024*	-0.023*	-0.021*	1.000

Notes: indicate significance at the *** p <0.01, ** p <0.05, * p <0.1

5.2.3 Multicollinearity Test

This study created 12 models to evaluate the hypotheses H1a-H1b, H2a-H2b, H3a-H3b, H4a-H4b, H5a-H5b, and H6a-H6b. The hypotheses and models are provided in Table 5.3.

Table 5.3

Hypotheses and Models

Research Objectives	Hypothesis Development	Model	Regression Equation
RO1: What are the different impacts of the carbon market mechanisms (i.e., carbon finance, carbon price and carbon trading policy) on the company performance (economic and sustainability) of heavily polluting industries before and after the implementation of carbon trading policy among the pilot and non-carbon trading pilot companies?	H1a	Model 1	$EVA_{i,t} = a_0 + a_1 CF_Post_{i,t} + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}$
	H1b	Model 2	$ESG_{i,t} = a_0 + a_1 CF_Post_{i,t} + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}$
	H2a	Model 3	$EVA_{i,t} = a_0 + a_1 CP_Treat_{i,t} + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}$
	H2b	Model 4	$ESG_{i,t} = a_0 + a_1 \text{CP_}Treat_{i,t} + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}$
	H3a	Model 5	$EVA_{i,t} = a_0 + a_1 DID_{i,t} + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}$
	H3b	Model 6	$ESG_{i,t} = a_0 + a_1 DID_{i,t} + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}$
RO2: What are the different impacts of green technology innovation on the relationship between carbon market mechanisms (carbon finance, carbon price and carbon trading policy) and company performance (economic and sustainability) of heavily polluting industries before and after the implementation of the carbon trading policy between pilot and non-carbon trading pilot companies?	H4a	Model 7	$EVA_{i,t} = a_0 + a_1 CF_Post_{i,t} + a_2 GTI_{i,t} + a_3 \text{CF_}Post_{i,t} * GTI_{i,t} + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}$
	H4b	Model 8	$ESG_{i,t} = a_0 + a_1 CF_Post_{i,t} + a_2 GTI_{i,t} + a_3 \text{CF_}Post_{i,t} * GTI_{i,t} + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}$
	H5a	Model 9	$EVA_{i,t} = a_0 + a_1 CP_Treat_{i,t} + a_2 GTI_{i,t} + a_3 \text{CP_}Treat_{i,t} * GTI_{i,t} + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}$
	H5b	Model 10	$ESG_{i,t} = a_0 + a_1 CP_Treat_{i,t} + a_2 GTI_{i,t} + a_3 \text{CP_}Treat_{i,t} * GTI_{i,t} + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}$
	H6a	Model 11	$EVA_{i,t} = a_0 + a_1 DID_{i,t} + a_2 GTI_{i,t} + a_3 DID_{i,t} * GTI_{i,t} + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}$
	H6b	Model 12	$ESG_{i,t} = a_0 + a_1 DID_{i,t} + a_2 GTI_{i,t} + a_3 DID_{i,t} * GTI_{i,t} + \gamma Control_{i,t} + \mu_i + \delta_i + \varepsilon_{i,t}$

Additional descriptions:

$EVA_{i,t}$= Economic value added

$ESG_{i,t}$= ESG score

$CF_Post_{i,t}$=Carbon finance

$CP_Treat_{i,t}$= Carbon price

$DID_{i,t}$= Carbon trading policy

$GTI_{i,t}$=Green technology innovation

$Control_{i,t}$= Control variables

μ_i= Industry fixed effect

δ_i= Year fixed effect

$\varepsilon_{i,t}$= Error term

A multicollinearity test is conducted on all variables to more effectively exclude the anomalous variables. The primary objective of the multicollinearity test is to ascertain the presence of a strong linear connection among the Independent variables. The objective is to guarantee that the coefficient estimate of the regression model is accurate and to prevent issues such as unstable estimation results and elevated standard errors arising from covariance among independent variables. Table 5.4 presents the Variance Inflation Factors (VIF) for the variables. The average VIF results for this study were as follows: model 1 (1.36), model 2 (1.36), model 3 (1.41), model 4 (1.41), model 5 (1.36), model 6 (1.36), model 7 (1.33), model 8 (1.33), model 9 (1.94), model 10 (1.94), model 11 (1.33), model 12 (1.33). At the same time, the mean value significantly falls below the threshold of 10, indicating the absence of multicollinearity among the variables in this study, thus permitting empirical investigation.

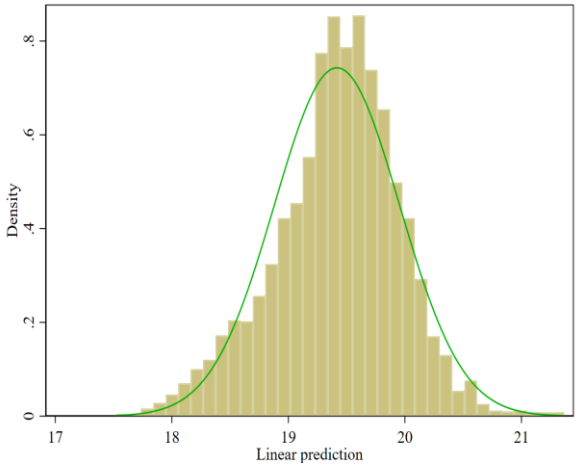
Table 5.4

Multicollinearity Test

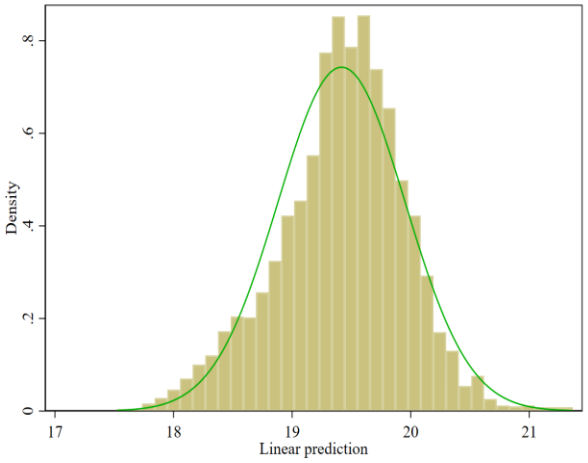
Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**	**Model 9**	**Model 10**	**Model 11**	**Model 12**
CF_Post	1.02	1.02					1.07	1.07				
CP_Treat			1.04	1.04					1.04	1.04		
DID					1.02	1.02					1.07	1.07
CF_Post* gti							1.18	1.18				
CP_Treat* gti									4.29	4.29		
DID* gti											1.17	1.17
current	1.83	1.83	1.85	1.85	1.81	1.81	1.83	1.83	1.85	1.85	1.81	1.81
lev	1.80	1.80	1.86	1.86	1.80	1.80	1.80	1.80	1.87	1.87	1.81	1.81
topm	1.57	1.57	1.67	1.67	1.60	1.60	1.57	1.57	1.67	1.67	1.60	1.60
lnage	1.45	1.45	1.51	1.51	1.45	1.45	1.45	1.45	1.51	1.51	1.45	1.45
state	1.38	1.38	1.56	1.56	1.38	1.38	1.38	1.38	1.57	1.57	1.45	1.45
cocen	1.13	1.13	1.13	1.13	1.12	1.12	1.13	1.13	1.13	1.13	1.38	1.38
turnover	1..04	1.04	1.04	1.04	1.04	1.04	1.05	1.05	1.05	1.05	1.12	1.12
growth	1.03	1.03	1.06	1.06	1.03	1.03	1.03	1.03	1.06	1.06	1.04	1.04
gti							1.14	1.14	4.29	4.29	1.12	1.12
Mean VIF	1.36	1.36	1.41	1.41	1.36	1.36	1.33	1.33	1.94	1.94	1.33	1.33

5.2.4 Histogram Normality Test

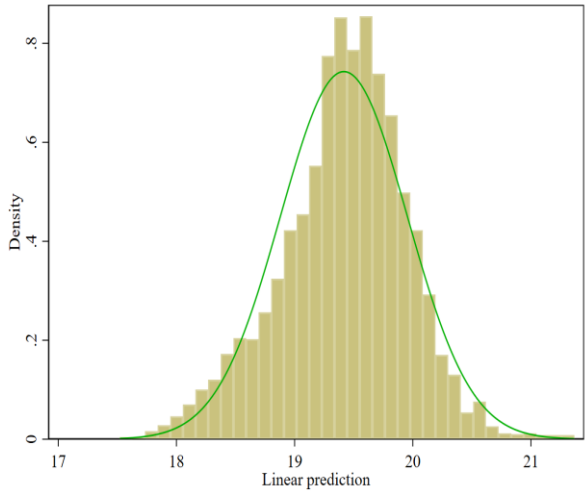
Normality tests assess the probability that the random variable underlying the data set follows a normal distribution. The residual term density serves to determine the model's normalcy. This study employs histograms to illustrate the normality of the residuals. The bell curve represents the normal distribution of the dataset. Figure 5.1 illustrates the bell-shaped distribution of the residuals, with the x-axis denoting the residuals and the y-axis indicating the dataset's density. Consequently, this histogram corroborates the findings of the normality test, indicating that the residuals of the 12 models in this study are normally distributed. The image illustrates that the discrepancies in the distribution of residuals among the various models are minimal, and the overall pattern remains constant, suggesting that the residual characteristics of the models are rather stable.



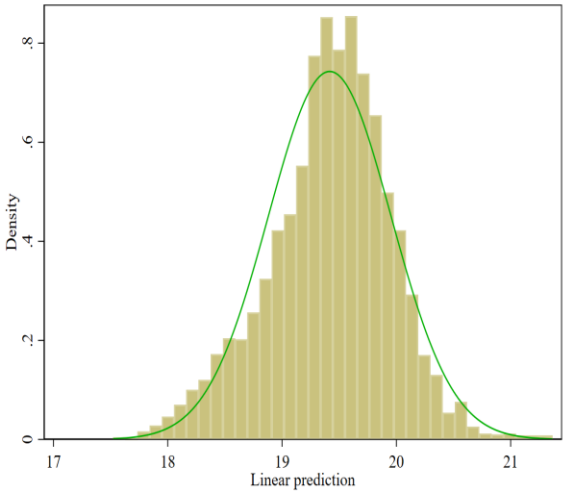
Model 1



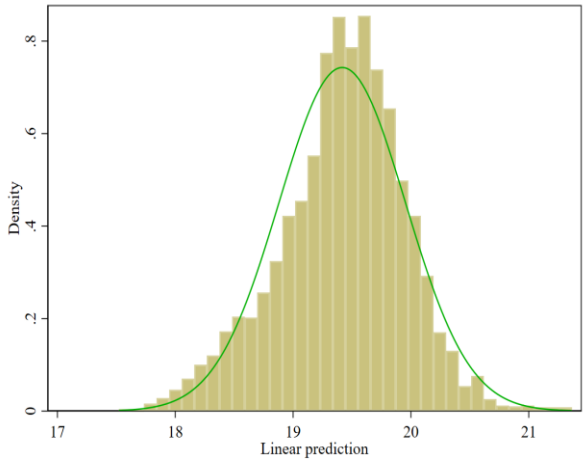
Model 2



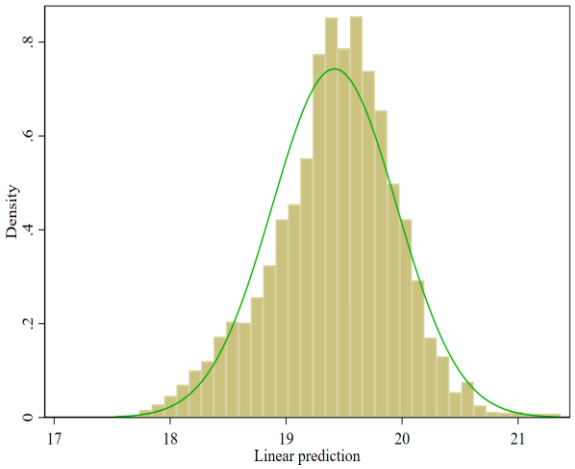
Model 3



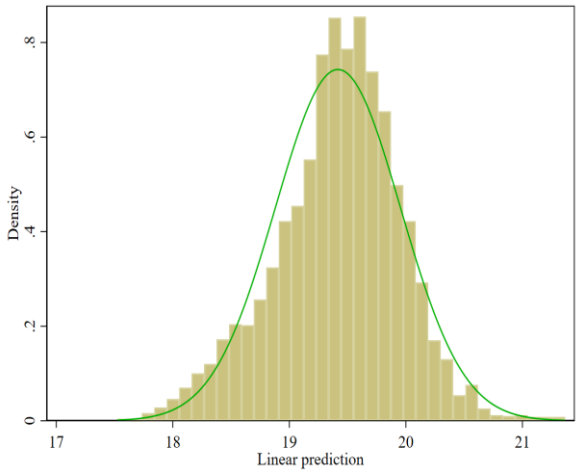
Model 4



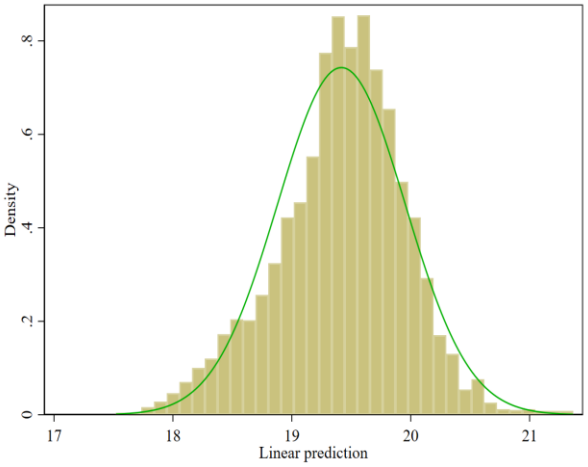
Model 5



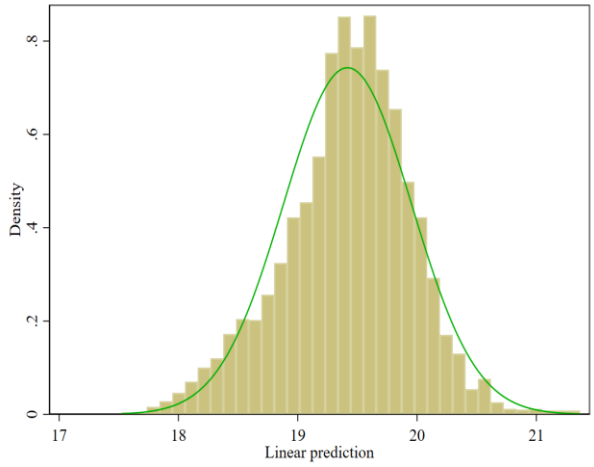
Model 6



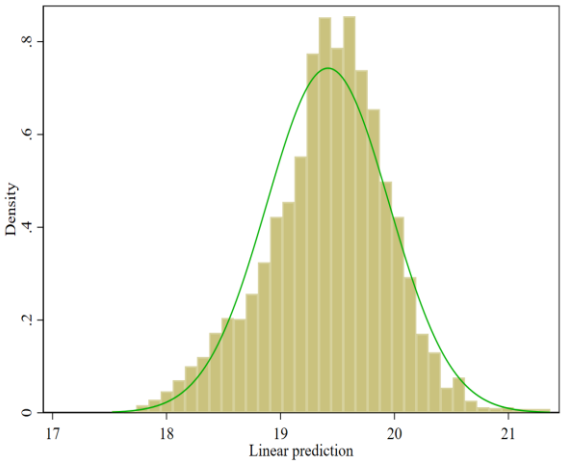
Model 7



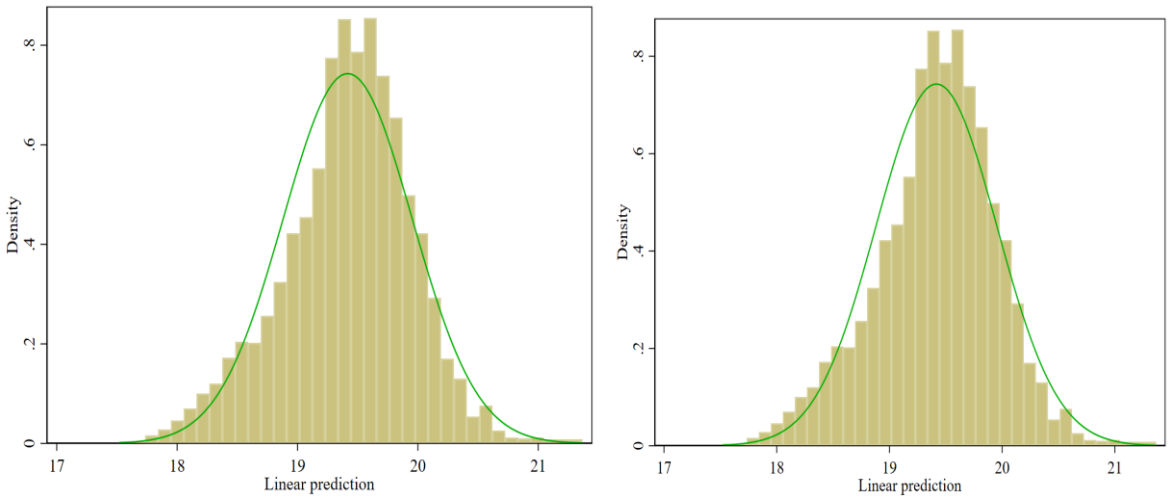
Model 8



Model 9



Model 10



Model 11 Model 12

Figure 5.1 Residual Density

5.2.5 Heteroscedasticity Test and Autocorrelation Test

This work utilizes research data from 1,181 listed companies over a span of 13 years, featuring a substantial cross-sectional dimension and a limited temporal dimension characteristic of short panel data. The random disturbance factors in the short panel data are Independently and Identically Distributed (IID) and, in theory, do not necessitate specific tests for heteroscedasticity and autocorrelation. This work uses resilient standard errors in regression analysis to mitigate potential issues of heteroscedasticity and autocorrelation (Tian et al., 2024).

This study employed the Breusch-Pagan test for heteroscedasticity and the Wooldridge test for autocorrelation. Tables 5.5 and 5.6 present the heteroscedasticity test and the serial correlation test, respectively. Results from the heteroscedasticity test indicated that Models 1 through 12 rejected the null hypothesis due to the presence of heteroscedasticity. The serial correlation test confirms the rejection of the null hypothesis, implying that the models exhibit autocorrelation. Furthermore, the findings suggest a possible bias in the standard errors and a non-spherical issue in 12 models. This research addresses heteroscedasticity and autocorrelation by employing robust standard errors for the regression analyses.

Table 5.5

Heteroscedasticity Test and Serial Correlation Test (i)

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
1. Heteroscedasticity test Prob > chi2 Ho = Homogeneity preferred H1= Heterogeneity preferred	0.0000 Reject Ho	0.0000 Reject Ho	0.0000 Reject Ho	0.0000 Reject Ho	0.0000 Reject Ho	0.0000 Reject Ho
2. Serial correlation test Prob > F Ho = No autocorrelation H1 = Autocorrelation	0.0000 Reject Ho	0.0000 Reject Ho	0.0000 Reject Ho	0.0000 Reject Ho	0.0000 Reject Ho	0.0000 Reject Ho
Results	Errors led to heteroskedastic and auto-correlated	Errors led to heteroskedastic and auto-correlated	Errors led to heteroskedastic and auto-correlated	Errors led to heteroskedastic and auto-correlated	Errors led to heteroskedastic and auto-correlated	Errors led to heteroskedastic and auto-correlated

Notes: Robust p-value in parentheses. *** p <0.01, ** p <0.05, * p <0.1

Table 5.6

Heteroscedasticity Test and Serial Correlation Test (ii)

	Model 7	**Model 8**	**Model 9**	**Model 10**	**Model 11**	**Model 12**
1. Heteroscedasticity test Prob > chi2 Ho = Homogeneity preferred H1= Heterogeneity preferred	0.0000 Reject Ho	0.0000 Reject Ho	0.0000 Reject Ho	0.0000 Reject Ho	0.0000 Reject Ho	0.0000 Reject Ho
2. Serial correlation test Prob > F Ho = No autocorrelation H1 = Autocorrelation	0.0000 Reject Ho	0.0000 Reject Ho	0.0000 Reject Ho	0.0000 Reject Ho	0.0000 Reject Ho	0.0000 Reject Ho
Results	Errors led to heteroskedastic and auto-correlated	Errors led to heteroskedastic and auto-correlated	Errors led to heteroskedastic and auto-correlated	Errors led to heteroskedastic and auto-correlated	Errors led to heteroskedastic and auto-correlated	Errors led to heteroskedastic and auto-correlated

Notes: Robust p-value in parentheses. *** p <0.01, ** p <0.05, * p <0.1

5.2.6 Haussmann Test

The Haussmann test assesses systematic discrepancies in the coefficient estimates between the fixed and random effects models. The primary hypothesis posits that the random effects model is suitable, indicating no systematic disparity between the fixed and random effects models' coefficient estimates. Conversely, the alternative hypothesis asserts the appropriateness of the fixed effects model.

In this study, the null hypothesis is rejected if the p-value in models 1 through 12 is 0.0000, which is below the established significance threshold of 0.05. This indicates a consistent disparity between the coefficient estimates of the fixed effects and random effects models. Hence, the fixed effects model was selected for this investigation, incorporating industry and time-fixed effects into all models.

Table 5.7

Haussmann Test

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Haussmann test	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Prob > chi2	Reject Ho	Reject Ho	Reject Ho	Reject Ho	Reject Ho	Reject Ho
H0 = Random effects	**Model 7**	**Model 8**	**Model 9**	**Model 10**	**Model 11**	**Model 12**
model preferred	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H1 = Fixed effects	Reject Ho	Reject Ho	Reject Ho	Reject Ho	Reject Ho	Reject Ho
model preferred						

Notes: Robust p-value in parentheses. *** p <0.01, ** p <0.05, * p <0.1

5.3 Parallel Trend Test

This section describes the results of parallel trend tests of carbon trading policy on economic performance and sustainable performance.

5.3.1 Carbon Trading Policy on Economic Performance

The accuracy of the estimation results from the double difference model relies on the assumption that the experimental and control groups adhere to the parallel trend assumption, meaning that the trajectory of the outcome variables in both groups would be identical in the absence of policy intervention (Lei & Yu, 2024). Consequently, prior to the policy intervention, there should be no substantial disparity between the actual trends of the experimental group and the control group. This study consists of companies in the pilot provinces of carbon emissions trading and those in the non-pilot provinces, respectively (Randolph & Falbe, 2014). Initially, the interaction terms for the year dummy variables and the experimental group dummy variables were created, followed by their regression as explanatory factors for EVA and ESG to facilitate a more detailed analysis of the patterns in the experimental and control groups.

Figure 5.2 illustrates the outcomes of the parallel trend test regarding the carbon trading pilot policy (DID variable) on lnEVA. This analysis evaluates the trend disparity between the pilot and non-pilot groups prior to and following the carbon trading policy's implementation, thereby validating the parallel trend hypothesis. Figure 5.2 illustrates the horizontal axis as a timeline, segmented into intervals prior to the policy implementation (pre_3, pre_2, pre_1) and subsequent to it (post_1, post_2, post_3). The vertical axis depicts the estimated coefficients or trends in the variation of economic performance, with the red horizontal line denoting the baseline for no change. The blue lines and dots represent the trend shift in the DID variable concerning economic performance, while the vertical error bars denote the confidence ranges.

Figure 5.2 illustrates that the trend of lnEVA prior to the policy implementation (pre_3, pre_2, pre_1) remains predominantly stable and exhibits minimal variation, suggesting that the economic performance of both pilot and non-pilot companies before the policy's enactment follows a similar trajectory, consistent with the parallel trend hypothesis. Following the policy's introduction (post_1, post_2, post_3), a modification

in the direction and extent of the shift in economic performance is evident, likely attributable to the carbon trading pilot policy's impact on the economic performance of the participating companies. Nonetheless, the extensive confidence intervals at particular time points indicate potential uncertainty in these calculations. The parallel trend test indicates a comparable trend between the pilot and non-pilot groups prior to policy implementation, hence satisfying the conditions of the parallel trend hypothesis. This establishes a sound foundation for employing the DID model to assess the causal effect of the carbon trading pilot policy on economic performance.

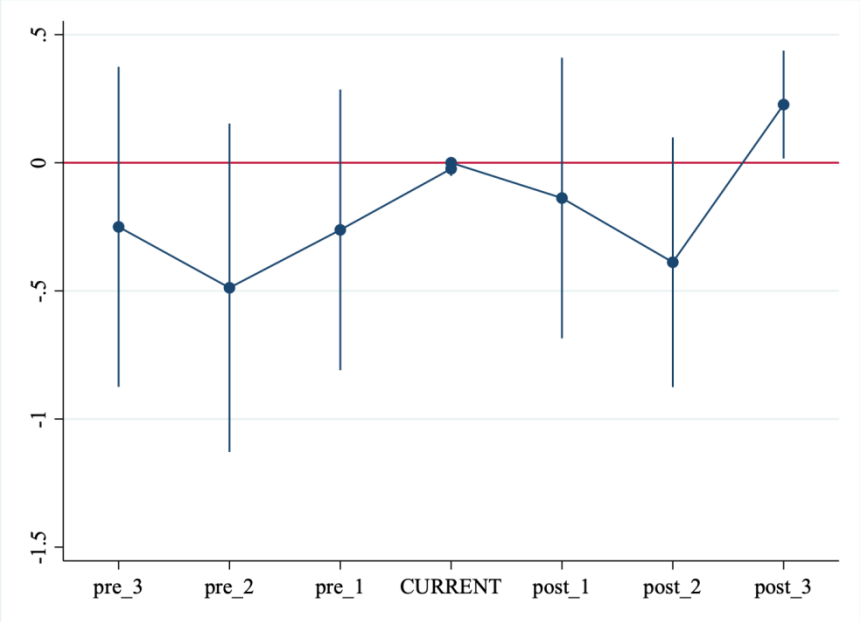


Figure 5.2 Parallel Trend Test (DID on EVA)

5.3.2 Carbon Trading Policy on Sustainable Performance

Figure 5.3 illustrates the outcomes of the parallel trend test evaluating the effect of the carbon trading pilot policy (DID variable) on the sustainable performance (ESG) of companies. The test seeks to compare the trends of the pilot and non-pilot groups prior to and during the policy implementation to ascertain the validity of the parallel trend hypothesis.

Figure 5.3 illustrates that prior to the policy implementation (pre_3, pre_2, pre_1), the ESG performance trends of both the pilot and non-pilot groups exhibit

relative stability with minimal variation. This suggests that the two years preceding the policy implementation demonstrate a comparable trajectory in ESG performance, thereby satisfying the fundamental criteria of the parallel trend hypothesis. Nonetheless, following the policy's implementation (post_1, post_2, post_3), the trajectory of ESG performance exhibits a notable alteration, particularly during the post_3 period, demonstrating a substantial increase. This may indicate the beneficial effect of the carbon trading pilot policy on the ESG performance of the participating companies. This, ultimately, results in enhancements in their environmental, governance, and social responsibility metrics.

The results of this parallel trend test confirm that the pilot and non-pilot groups had comparable trends prior to the policy implementation, hence substantiating the application of the DID model to assess the causal effect of the carbon trading pilot policy on companies' ESG performance. The increase in ESG performance following the policy's introduction suggests that the carbon trading policy positively influences the company's sustainability performance.

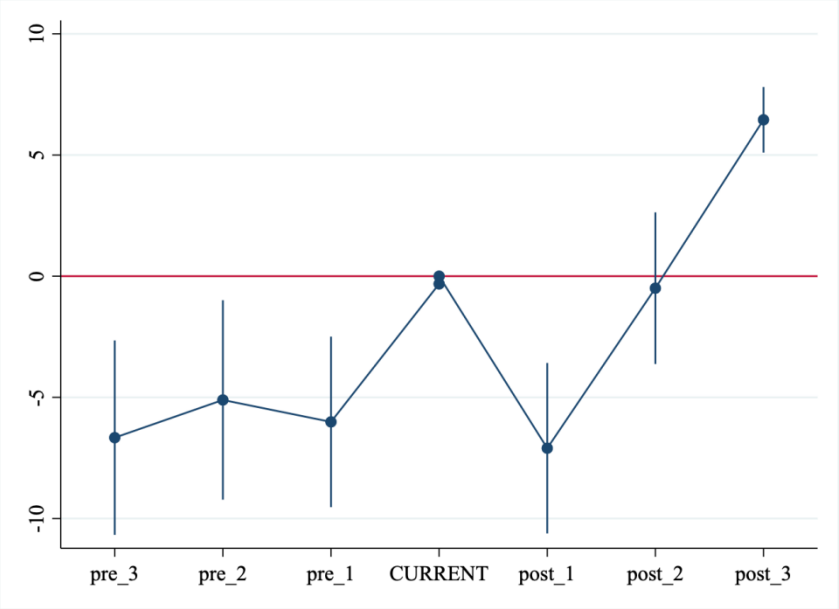


Figure 5.3 Parallel Trend Test (DID on ESG)

5.4 Baseline Regression Test

This section delineates the outcomes of a benchmark regression analyzing the

effects of carbon finance, carbon price, and carbon trading policy on companies' economic and sustainable performance. Benchmark regression results answer RQ1.

5.4.1 Carbon Finance on Company Performance

This section delineates the outcomes of a benchmark regression analyzing the influence of carbon finance on companies' economic and sustainable performance.

5.4.1.1 Carbon Finance on Economic Performance

Table 5.8 presents the outcomes of the benchmark regression, illustrating the influence of carbon finance (CF_Post) and the control variables on the company's economic performance (lnEVA). Model (1), which only includes the core independent variable CF_Post, has a regression coefficient of 0.250. However, it does not reach statistical significance, indicating that the relationship between carbon finance and the lnEVA of the company is unclear when the control variables are not considered. In model (2), after controlling a series of control variables, the regression coefficient of CF_Post is -0.588 and significant at the 5% level (t = -2.360). This indicates that after the implementation of the carbon trading policy, the impact of carbon finance on lnEVA will be negative. A possible reason is that high-carbon-emission industries face greater financing cost pressure and, thus, financing constraints after implementing the carbon trading policy. This leads to a reduction in external investment, which, in the short term, exerts a certain inhibitory effect on their Economic Value Added. Therefore, the results lead to the rejection of H1a.

The results of each control variable indicate a significant negative correlation between lev and lnEVA, suggesting that increased financial leverage substantially diminishes the company's lnEVA. This may result from elevated debt levels, heightening the company's financial risk and diminishing its profitability. The current ratio has an inverse correlation with lnEVA, suggesting that an increase in the current ratio corresponds to a decline in the company's economic success. Additionally, turnover and lnEVA have a considerable positive correlation, indicating that enhanced asset utilization efficiency can substantially elevate the company's lnEVA, perhaps due to the fact that increased turnover can augment the company's profitability.

The correlation between growth and lnEVA is insignificant, suggesting that an increase in the revenue growth rate does not influence the company's lnEVA. The state exhibits a negative correlation with lnEVA, signifying that the lnEVA of state-owned companies markedly surpasses that of non-state-owned companies. This may be attributable to state-owned companies possessing more steady resource backing, enhanced policy advantages, and reduced financing expenses. Age exhibits an inverse correlation with lnEVA, suggesting that a company's lnEVA may deteriorate with age, potentially attributable to a reduction in inventive ability or heightened competitive pressures in the market. At the same time, cocen exhibits a positive correlation with lnEVA, suggesting that overly high shareholding concentration may adversely affect lnEVA, potentially due to the overbearing control of controlling shareholders, which reduces company governance efficiency. The favorable correlation between topm and lnEVA suggests that an increase in management shareholding substantially enhances the company's economic performance, likely since the alignment of management's interests with the company's developmental goals incentivizes a greater focus on the long-term interests of the company.

Model (2) exhibits an R^2 of 0.541, signifying that it accounts for approximately 54.1% of the variation in the dependent variable, demonstrating moderate explanatory power. The model's F-value is 342.683, suggesting a high significance level and indicating a strong overall fit.

The benchmark regression results indicate that carbon finance adversely affects companies' economic performance, implying that rising carbon emission costs may pressure profitability in the short run. Simultaneously, turnover, cocen, and topm have substantial favorable influences on lnEVA, whilst elevated debt ratios, high asset utilization efficiency, state ownership, and age greatly impede the company's lnEVA. These findings offer significant empirical support for adopting carbon finance regulations and practical recommendations for company management to address carbon finance challenges, enhance governance frameworks, and increase resource efficiency.

Table 5.8

Baseline Regression Results of Carbon Finance on Economic Performance

	(1) lnEVA	(2) lnEVA
CF_Post	0.250	-0.588**
	(0.750)	(-2.360)
lev		-2.588***
		(-17.281)
current		-0.019*
		(-1.669)
turnover		0.717***
		(13.010)
growth		0.011
		(1.315)
state		-0.297***
		(-7.303)
lnage		-0.117***
		(-4.151)
cocen		0.006***
		(5.506)
topm		0.002*
		(1.681)
_cons	19.515***	-4.233***
	(914.910)	(-9.874)
Industry FE	YES	YES
Year FE	YES	YES
N	4678	4678
R^2	0.148	0.541
F	0.562	342.683

Notes: indicate significance at the *** p <0.01, ** p <0.05, * p <0.1, values of t-statistics adjusted for robust standard errors are in parentheses.

The relationship between carbon finance and lnEVA is displayed in Figure 5.4.

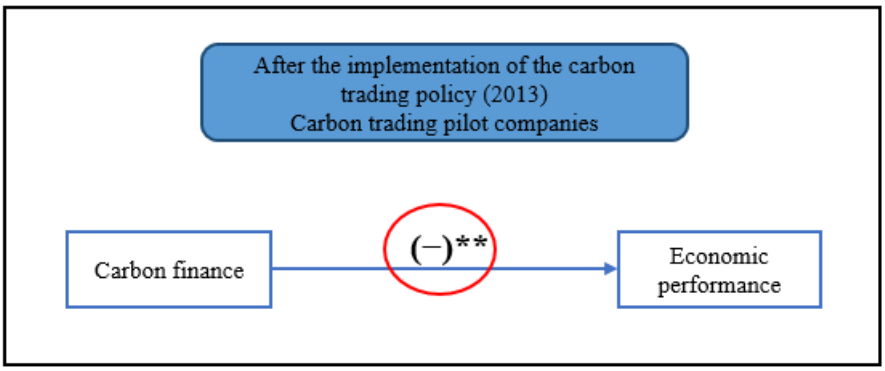


Figure 5.4 Carbon Finance on Economic Performance

5.4.1.2 Carbon Finance on Sustainable Performance

Table 5.9 illustrates the influence of carbon finance (CF_Post) and control variables on company sustainability performance (ESG). The examination of the benchmark regression model indicates that carbon finance significantly contributes to the advancement of company sustainability practices. Simultaneously, the control variables exert differing levels of influence on company sustainability performance in favor of H1b.

Model (1) includes solely the key independent variable CF_Post, which exhibits a regression coefficient of 3.388, significant at the 1% level (t = 2.259), signifying that carbon finance substantially enhances the company's sustainability performance. The regression coefficient of CF_Post is 3.854 in model (2) following the introduction of additional control variables and stays significant at the 1% level (t = 2.649). This corroborates the positive impact of carbon finance policy on improving company ESG performance. This implies that the more a company participates in carbon finance activities after implementing the carbon trading policy, the better its sustainable performance. This suggests that introducing a carbon trading policy has prompted companies to pay more attention to their environmental responsibilities and reduce carbon emissions by increasing the use of green financial products, improving their environmental performance. At the same time, this positive environmental behavior may also help enhance the company's social reputation and brand image, thus indirectly contributing to improving social performance. Therefore, the positive relationship between the increase in carbon finance activities and sustainable performance reflects the company's comprehensive improvement in the three dimensions of environment, society and governance. This finding provides strong support for H1b.

The results of each control variable indicate a significant positive correlation between lev and ESG, implying that increased leverage can substantially enhance a company's sustainability performance. This may result from debt pressure compelling companies to manage resources more effectively while increasing investments in green and social responsibility initiatives to mitigate reputational risk. Note that the current and ESG metrics have a substantial negative correlation, indicating that excessive liquidity may adversely impact companies' sustainability performance. This may result from the excessive allocation of liquidity diminishing the company's capital investment

in ESG-related initiatives. Turnover and ESG exhibit a significant positive correlation, indicating that enhanced asset utilization can markedly elevate a company's sustainability performance. This may arise from the ability of companies to unlock greater capacity to attain environmental and social objectives through more efficient resource utilization.

The insignificance of growth and ESG indicates that growth does not substantially influence companies' sustainability performance. The correlation between state ownership and ESG is highly positive, indicating that state-owned companies excel in ESG practices compared to their non-state-owned counterparts, maybe due to their policy-driven nature or heightened expectations for social responsibility. The correlation between age and ESG is considerably negative, suggesting that a company's ESG performance may deteriorate with age, maybe due to a reduction in its innovative capacity or heightened competitive pressures in the market. Cocen and ESG are negligible, indicating that ownership concentration has a minimal direct impact on ESG. Topm and ESG exhibit a significant negative correlation, indicating that increased management shares may adversely affect companies' ESG performance. This may be attributed to the tendency of larger management shareholding to prioritise financial returns above long-term ESG commitments.

The R^2 values for model (1) and model (2) are 0.566 and 0.587, respectively, signifying that the regression model accounts for approximately 56.6% and 58.7% of the variance in companies' ESG performance, respectively. The F-value of model (2) is 28.095, demonstrating a high significance level, which indicates that the whole model exhibits a strong match.

Benchmark regression results indicate that carbon finance exerts a substantial positive influence on company sustainability performance, demonstrating the efficacy of carbon finance policy in enhancing integrated company performance across environmental, social responsibility, and governance dimensions. The examination of control variables indicates that lev, turnover, and state exert considerable positive influences on ESG performance, whereas current, age, and topm demonstrate some negative impacts on ESG performance. These findings underscore the significant influence of company governance systems on sustainability performance.

Table 5.9

Baseline Regression Results of Carbon Finance on Sustainable Performance

	(1) ESG	(2) ESG
CF_Post	3.388**	3.854***
	(2.259)	(2.649)
lev		6.477***
		(8.023)
current		-0.109*
		(-1.659)
turnover		1.240***
		(3.754)
growth		-0.056
		(-1.497)
state		1.188***
		(4.866)
lnage		-0.453**
		(-2.391)
cocen		0.009
		(1.363)
topm		-0.018**
		(-2.449)
_cons	29.466***	26.429***
	(301.327)	(34.553)
Industry FE	YES	YES
Year FE	YES	YES
N	4678	4678
R^2	0.566	0.587
F	5.102	28.095

Notes: indicate significance at the *** p <0.01, ** p <0.05, * p <0.1, values of t-statistics adjusted for robust standard errors are in parentheses.

The relationship between carbon finance and sustainable performance is illustrated in Figure 5.5.

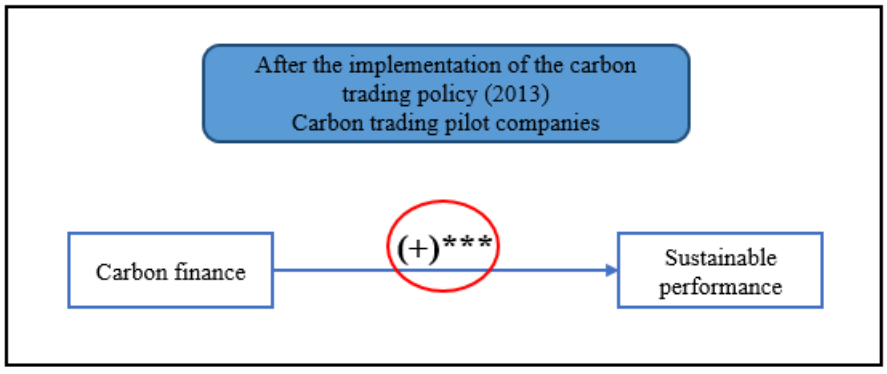


Figure 5.5 Carbon Finance on Sustainable Performance

5.4.2 Carbon Price on Company Performance

This section delineates the outcomes of a benchmark regression analyzing the influence of carbon price on companies' economic and sustainability performance.

5.4.2.1 Carbon Price on Economic Performance

Table 5.10 presents the outcomes of the baseline regression of carbon trading price (CP_Treat) on lnEVA, comprising two regression equations, both featuring lnEVA as the dependent variable. In model (1), the coefficient of the core variable CP_Treat is 0.011, with a significance threshold of 1% (t-value of 2.562), suggesting that the carbon trading price exerts a significant positive influence on lnEVA, hence enhancing the company's lnEVA. Model (2) incorporates many control variables to augment its robustness. The coefficient of CP_Treat is 0.010, which remains significant (t-value of 2.473). It suggests that the positive effect of carbon trading prices on lnEVA remains significant after controlling for other variables. The empirical results illustrate that after implementing the carbon trading policy for the carbon trading pilot regions, the increase in carbon price will positively impact the lnEVA of companies. The impact of carbon price on lnEVA is better in pilot regions than in non-pilot regions. In carbon trading pilot regions, with the increase in carbon price, companies have stronger incentives to take energy-saving and emission reduction measures, optimize production processes and improve resource utilization efficiency. This may prompt companies to eliminate outdated production capacity and increase investment in clean energy and low-carbon technologies. Although it may increase costs in the short term, in the long term, it will help companies to improve competitiveness and reduce carbon emission costs, or even to sell excess carbon allowances to gain additional revenue, thus improving lnEVA. This finding provides strong support for H2a.

The subsequent regression findings of the control variables and their corresponding significance levels are presented below: Lev and lnEVA exhibit a significant positive correlation, suggesting that an increase in lev substantially enhances lnEVA; current and lnEVA are also significantly positively correlated, indicating that higher liquidity in current assets positively influences lnEVA. Turnover and lnEVA are positively correlated, demonstrating that an increase in turnover correlates with

improved lnEVA. The correlation between growth and lnEVA is insignificant, suggesting that growth does not substantially influence lnEVA. Furthermore, a negative correlation exists between state ownership and lnEVA, indicating that state-owned companies underperform relative to their non-state counterparts. Additionally, the carbon price exerts a more pronounced economic enhancement effect on non-state-owned companies. The correlation between age and lnEVA is insignificant, suggesting that age does not substantially influence lnEVA. However, cocen and EVA exhibit a significant positive correlation, indicating that increased shareholding concentration correlates with improved lnEVA. Furthermore, the relationship between topm and lnEVA is also insignificant, implying that the proportion of management shareholding does not significantly affect lnEVA.

The constant term is notable in both models, with coefficient values of 19.491 and 18.172, representing the baseline lnEVA when all explanatory factors are zero. The model has a sample size (N) of 2033, and the R^2 value for model (2) is 0.232, surpassing the R^2 value of model (1) at 0.180, demonstrating an improvement in explanatory power due to the incorporation of control variables. The F-statistic for model (2) is 15.785, indicating that the total regression model is statistically significant.

The benchmark regression results indicate that the carbon trading price (CP_Treat) significantly enhances lnEVA, positively influencing the company's economic outcomes to a certain degree. Moreover, the control variables of leverage, current ratio, turnover, state, and concentration significantly impact lnEVA, indicating their crucial role in shaping company economic outcomes. The results indicate that carbon trading policy positively influences companies' lnEVA, suggesting that focusing companies on carbon trading prices via market mechanisms can enhance their financial success.

Table 5.10
Baseline Regression Results of Carbon Price on Economic Performance

	(1) lnEVA	(2) lnEVA
CP_Treat	0.011**	0.010**
	(2.562)	(2.473)
lev		1.253***
		(4.512)
current		0.059**
		(2.385)
turnover		0.678***

		(6.421)
growth		-0.007
		(-0.617)
state		-0.270***
		(-3.350)
lnage		-0.085
		(-1.516)
cocen		0.013***
		(5.912)
topm		-0.002
		(-1.214)
_cons	19.497***	18.262***
	(550.411)	(73.135)
Industry FE	YES	YES
Year FE	YES	YES
N	1960	1960
R^2	0.180	0.232
F	6.564	14.573

Notes: indicate significance at the *** p <0.01, ** p <0.05, * p <0.1, values of t-statistics adjusted for robust standard errors are in parentheses.

The relationship between carbon price and economic performance is presented in Figure 5.6.

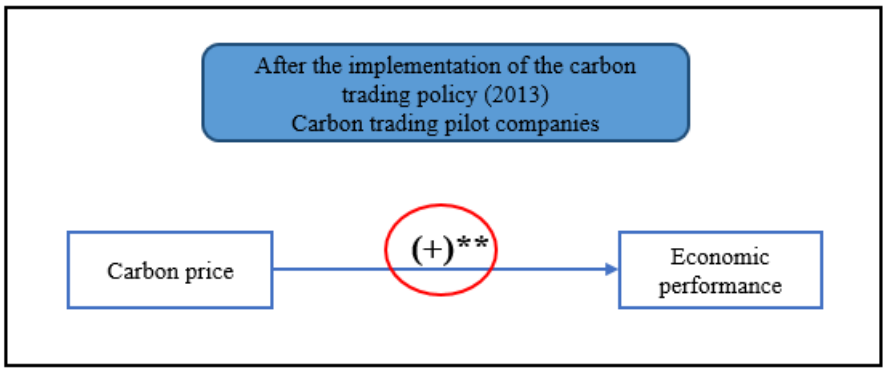


Figure 5.6 Carbon Price on Economic Performance

5.4.2.2 Carbon Price on Sustainable Performance

Table 5.11 presents the outcomes of the benchmark regression of carbon trading price (CP_Treat) on companies' sustainability performance (ESG), with two regression models, both with ESG as the dependent variable. In model (1), the coefficient of the core variable CP_Treat is 0.025, which is not significant (t-value of 1.138). This indicates that the price of carbon trading does not have a significant effect on companies'

ESG performance. In model (2), several control variables are added to enhance the robustness of the model. The coefficient of CP_Treat is 0.018, which is still insignificant (t-value of 0.818). This implies that even after controlling for other variables, the impact of carbon trading price on ESG is still insignificant. It suggests that after the implementation of the carbon trading policy in 2013, there is no apparent linear relationship between the carbon price and the company's sustainable performance for carbon trading pilot regions. In addition, there is no difference in the impact of the carbon price on the company's sustainable performance between pilot regions and non-pilot regions. This may be attributed to the fact that the carbon trading market is still imperfect, and the carbon price is low, failing to act as an incentive to guide the company's sustainable development behaviors effectively. This ensures no significant association between the carbon price and the company's sustainable performance is presented. Therefore, the results lead to the rejection of H2b.

The subsequent regression findings of the control variables and their corresponding significance levels are presented below: Leverage exhibits a significant positive correlation with ESG, suggesting that increased gearing positively influences ESG, and the current ratio is not significantly associated with ESG, indicating no effect on ESG. Turnover reveals no significant relationship with ESG, implying it has no substantial impact. Meanwhile, growth demonstrates a significant negative correlation with ESG, indicating that improved company growth corresponds with a decline in the ESG score. Furthermore, state ownership is significantly positively correlated with ESG performance, suggesting that state-owned companies surpass their non-state counterparts in ESG metrics; lnage exhibits a non-significant correlation with ESG, implying that a company's age does not substantially influence ESG outcomes. Moreover, cocen demonstrates a significant positive correlation with ESG, indicating that increased shareholding concentration correlates with enhanced ESG performance; conversely, topm is significantly negatively correlated with ESG, suggesting that a higher proportion of management's shareholding adversely affects ESG performance.

The constant term is notable in both models, with coefficient values of 31.458 and 29.606, signifying the baseline ESG value when all explanatory factors are zero. The model has a sample size (N) of 2033, and the R^2 value for model (2) is 0.534, surpassing the R^2 value of model (1) at 0.510, demonstrating an enhancement in explanatory power due to the incorporation of control variables.

The benchmark regression results indicate that the carbon trading price (CP_Treat) does not significantly impact companies' ESG performance. The control variables lev, growth, state, cocen, and topm significantly influence ESG, indicating their crucial importance in the company's sustainable performance.

Table 5.11
Baseline Regression Results of Carbon Price on Sustainable Performance

	(1) ESG	(2) ESG
CP_Treat	0.025	0.018
	(1.138)	(0.818)
lev		5.933***
		(4.149)
current		-0.186
		(-1.308)
turnover		-0.175
		(-0.315)
growth		-0.089*
		(-1.854)
state		0.927**
		(2.028)
lnage		-0.487
		(-1.589)
cocen		0.027**
		(2.407)
topm		-0.040***
		(-3.656)
_cons	31.479***	29.631***
	(171.455)	(21.822)
Industry FE	YES	YES
Year FE	YES	YES
N	1960	1960
R^2	0.510	0.534
F	1.294	11.297

Notes: indicate significance at the *** p <0.01, ** p <0.05, * p <0.1, values of t-statistics adjusted for robust standard errors are in parentheses.

The relationship between carbon price and sustainable performance is portrayed in Figure 5.7.

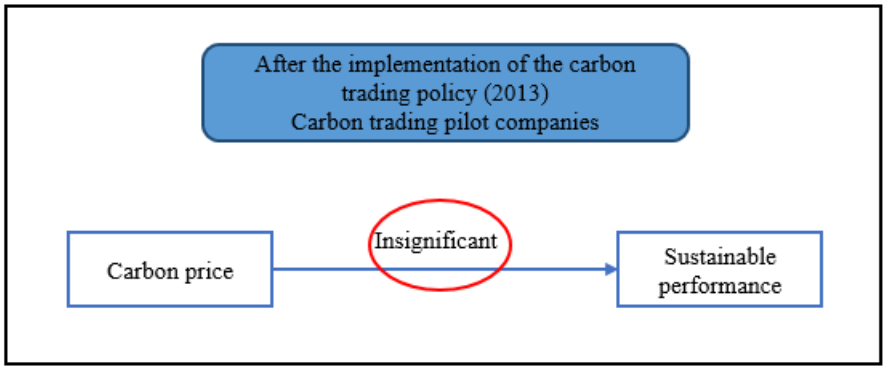


Figure 5.7 Carbon Price on Sustainable Performance

5.4.3 Carbon Trading Policy on Company Performance

This section delineates the outcomes of a benchmark regression analyzing the influence of carbon trading regimes on the economic and sustainable performance of companies.

5.4.3.1 Carbon Trading Policy on Economic Performance

Table 5.12 presents the outcomes of the baseline regression of the carbon trading pilot policy (DID variable) on the company's economic performance, comprising two regression models, both utilizing lnEVA as the dependent variable. In model (1), the coefficient of the core variable DID is 0.100. However, it is not significant (t-value of 0.559), which indicates that the effect of the carbon trading pilot policy on lnEVA is not significant without adding control variables. In model (2), several control variables are added to enhance the explanatory power of the model. The coefficient of DID is 0.085, which is still insignificant (t-value of 0.514), indicating that the effect of the carbon trading pilot policy on lnEVA is still insignificant even after controlling for other variables. Specifically, after implementing the carbon trading policy in 2013, there is no significant linear relationship between the carbon trading policy and the lnEVA of companies. There is no significant difference in the impact of carbon trading policy on lnEVA between pilot and non-pilot regions. The possible reason for this is that there are some practical problems in implementing the carbon trading policy. This includes

insufficient implementation of the policy, low trading activity in the carbon market, loose allocation of allowances, and irrational allocation of allowances. These results in the failure of the policy to effectively exert its influence on the lnEVA of the company. Therefore, the results lead to the rejection of H3a.

The subsequent regression outcomes of the control variables and their significance levels are as follows: Lev exhibits a significant positive correlation with lnEVA, suggesting that an increased gearing ratio positively influences lnEVA and currently does not significantly affect lnEVA. Turnover suggests a significant positive correlation with lnEVA, indicating that a more rapid asset turnover positively impacts lnEVA. In addition, growth has no significant effect on lnEVA. The state has no substantial impact on lnEVA, suggesting no significant disparity in lnEVA between state-owned and non-state-owned companies; age does not significantly influence lnEVA. Shareholding concentration (cocen) is significantly and positively correlated with lnEVA, indicating that increased shareholding concentration correlates with improved lnEVA. Management shareholding (topm) is negatively correlated with lnEVA, suggesting that higher management ownership adversely affects economic performance.

The constant term is notable in both models, with coefficient values of 19.455 and 18.481, respectively, signifying the baseline lnEVA value when all explanatory factors are 0. The model has a sample size (N) of 5889. The R^2 value for model (2) is 0.187, which is significantly more than the R^2 value for model (1) (0.150), suggesting that the explanatory power of the model improves with the addition of control variables.

The benchmark regression results indicate that the carbon trading pilot policy (DID) exerts no substantial impact on lnEVA. The control variables of lev, turnover, cocen, and topm significantly affect lnEVA, suggesting their crucial significance in affecting the company's economic success.

Table 5.12
Baseline Regression Results of Carbon Trading Policy on Economic Performance

	(1) lnEVA	(2) lnEVA
did	0.100	0.085
	(0.559)	(0.514)
lev		0.647**
		(2.379)
current		-0.006

		(-0.240)
turnover		0.526***
		(5.209)
growth		-0.012
		(-1.371)
state		-0.085
		(-0.961)
lnage		0.009
		(0.158)
cocen		0.011***
		(4.698)
topm		-0.004*
		(-1.735)
_cons	19.455***	18.481***
	(541.925)	(74.399)
Industry FE	YES	YES
Year FE	YES	YES
N	5889	5889
R^2	0.150	0.187
F	0.313	9.213

Notes: indicate significance at the *** p <0.01, ** p <0.05, * p <0.1, values of t-statistics adjusted for robust standard errors are in parentheses.

The relationship between carbon trading policy and economic performance is displayed in Figure 5.8.

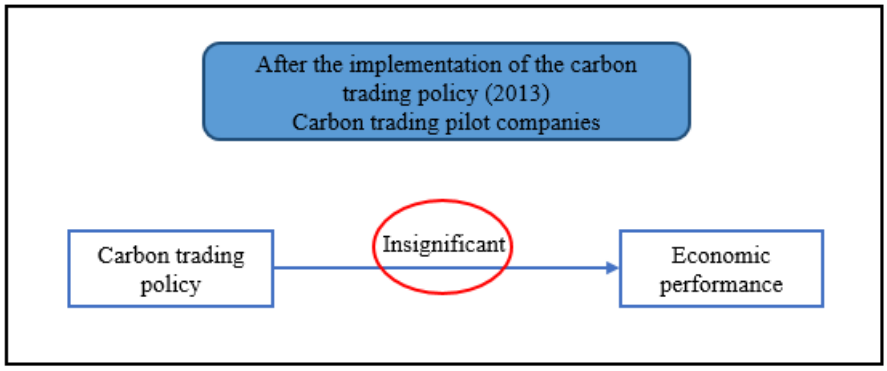


Figure 5.8 Carbon Trading Policy on Economic Performance

5.4.3.2 Carbon Trading Policy on Sustainable Performance

Table 5.13 presents the outcomes of the benchmark regression analysis of the carbon trading pilot policy (DID) on company sustainability performance (ESG), comprising two regression equations, both utilizing ESG as the dependent variable. In model (1), the coefficient of the primary explanatory variable DID is 1.385, with a

significance threshold of 1% (t-value of 2.665), signifying that adopting the carbon trading pilot policy exerts a significant positive effect on ESG. In model (2), many control variables enhance the model's explanatory power. The coefficient of DID is 1.553, with a significance threshold of 1% (t-value of 3.084), indicating that, after adjusting for other variables, the beneficial effect of the carbon trading pilot policy on ESG remains significant. It suggests that after implementing the carbon trading policy in 2013, the sustainable performance of companies in the carbon trading pilot regions has improved significantly more than that in the non-pilot regions. The impact of carbon trading policy on sustainable performance is better in the pilot regions than in non-pilot regions. This may be due to the fact that the carbon trading policy has prompted the pilot companies to pay more attention to their environmental performance and social responsibility. Moreover, by adopting measures such as energy saving and emission reduction and improving resource utilisation efficiency, they have reduced their carbon emissions and enhanced the overall operational efficiency of the companies. These measures help the company achieve sustainable development in the three dimensions of environment, society, and governance, which improves the sustainable performance of the company. This finding provides strong support for H3b.

The subsequent results pertain to the control variables and their respective significance levels: Lev exhibits a significant positive correlation with ESG, suggesting that an increased gearing ratio corresponds to enhanced ESG performance. Conversely, current demonstrates a significant negative correlation with ESG, indicating that a higher current ratio is associated with diminished ESG performance. Turnover demonstrates a significant positive correlation with ESG, implying that greater asset turnover positively influences ESG outcomes. In contrast, growth is significantly negatively correlated with ESG, indicating that superior company growth correlates with reduced ESG performance. Furthermore, state ownership exhibits a significant positive correlation with ESG, suggesting that state-owned companies surpass their non-state counterparts in ESG performance. Age demonstrates a significant negative correlation with ESG, indicating that as age increases, ESG performance diminishes. Cocen exhibits no significant impact on ESG, and topm is significantly negatively correlated with ESG, implying that a higher proportion of management shareholding correlates with poorer ESG performance.

The constant term is noteworthy in both models, with coefficient values of

28.919 and 26.649, signifying the baseline ESG value when all explanatory factors are zero. The sample size (N) of the model is 5889. The R^2 value for model (2) is 0.589, surpassing the R^2 value of 0.572 for model (1), demonstrating an enhancement in explanatory power with the addition of control variables. The F-statistic for model (2) is 27.564, indicating that the whole regression model is statistically significant.

The benchmark regression results indicate that carbon price policy (DID) exerts a considerable beneficial impact on ESG. Moreover, the control variables of leverage, current ratio, turnover, growth, age, state, and top management also significantly influence ESG, indicating that these elements are crucial to a company's sustainable performance. The findings indicate that executing the carbon trading pilot policy may improve companies' ESG performance.

Table 5.13
Baseline Regression Results of Carbon Trading Policy on Sustainable Performance

	(1)	(2)
	ESG	ESG
did	1.385***	1.553***
	(2.665)	(3.084)
lev		5.081***
		(7.391)
current		-0.102*
		(-1.761)
turnover		1.171***
		(4.204)
growth		-0.051*
		(-1.769)
state		1.070***
		(5.088)
lnage		-0.432***
		(-2.642)
cocen		0.006
		(0.940)
topm		-0.016***
		(-2.642)
_cons	28.919***	26.649***
	(344.128)	(41.071)
Industry FE	YES	YES
Year FE	YES	YES
N	5889	5889
R^2	0.572	0.589
F	7.103	27.564

Notes: indicate significance at the *** p <0.01, ** p <0.05, * p <0.1, values of t-statistics adjusted for robust standard errors are in parentheses.

The relationship between carbon trading policy and sustainable performance is

illustrated in Figure 5.9.

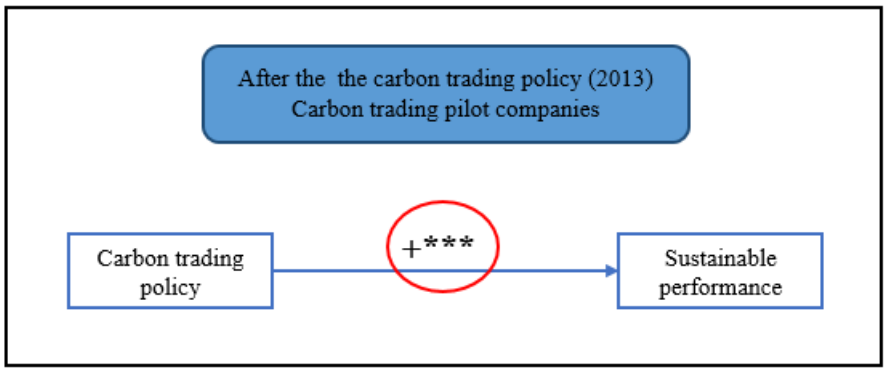


Figure 5.9 Carbon Trading Policy on Sustainable Performance

5.5 Moderating Mechanism Test

This section delineates the test results regarding the moderating influence of green technology innovation on the carbon market mechanisms and company performance. Answer RQ2. This work incorporates the cross-multiplier terms of green technology innovation with CF_Post, CP_Treat, and DID to further validate the regression outcomes about the influence of green technology innovation on company performance.

5.5.1 Carbon Finance, Green Technology Innovation on Company Performance

Table 5.14 delineates the regression outcomes of the moderating mechanism, examining the impact of the interaction term (CF_Post* gti) between carbon finance (CF_Post) and green technology innovation on economic performance and company sustainability performance.

In model (1), where lnEVA is the dependent variable, the coefficient of CF_Post* gti is 0.0263, which fails to achieve statistical significance, suggesting that green technology innovation does not moderate the effect of carbon finance on lnEVA. This finding does not support H4a. The coefficient for CF_Post is 0.1454, and the coefficient for gti is 0.0080. Neither achieves statistical significance, indicating that the direct effects of carbon finance and green technology innovation on lnEVA are not

substantial. The control variables lev, turnover, and cocen exert considerable positive impacts on lnEVA. In contrast, state and topm have negative and significant effects on lnEVA.

In model (2), where company sustainability performance (ESG) serves as the dependent variable, the coefficient of CF_Post* gti is 0.2189, exhibiting a significance level of 1% (t-value of 2.9771). This suggests that green technology innovation significantly enhances the positive moderating effect of carbon finance on ESG. This finding provides strong support for H4b. The coefficient of CF_Post is 3.5643, with a significance level of 5% (t-value of 2.3984), indicating that carbon finance exerts a considerable positive influence on ESG. The green technology innovation has a coefficient of 0.1389 with a significance level of 5% (t-value of 0.0257), indicating that green technology innovation significantly positively influences ESG. The control variables lev, turnover, and state positively influence ESG, whereas current, lnage, and topm negatively affect ESG. The model's R^2 score is 0.590, indicating its substantial explanatory power.

Overall, the moderating regression results reveal that after implementing the carbon trading policy, green technology innovation has not played a moderating role in the impact of carbon finance on lnEVA. The possible reason is that green technology innovation has the characteristics of high up-front investment cost, long payback period, and investment riskiness. Another potential reason is that green technology innovation is at a low level, and the development of the carbon finance business is not sufficiently deep and extensive. In other words, it has not yet formed an effective interaction with green technology innovation. Hence, it cannot have an apparent moderating effect on economic performance.

The moderated regression results suggest that green technology innovation plays a significant positive moderating role in the impact of carbon finance on sustainable performance (ESG) after implementing the carbon trading policy. This implies that green technology innovation strengthens the positive effect of carbon finance activities on sustainable performance. Specifically, when companies have higher levels of green technology innovation, the sustainable performance improvement they obtain through carbon financial activities (after implementing carbon trading policy) is more significant. This may be due to the fact that green technology innovation helps reduce carbon emissions and improve environmental performance. It also

enhances the company's social reputation and market competitiveness through innovative products or services, positively impacting sustainable performance.

Table 5.14
Moderating Regression Results of Carbon Finance, Green Technology Innovation on Company Performance

	(1) lnEVA	(2) ESG
CF_Post* gti	0.0263	0.2189***
	(1.2266)	(2.9771)
CF_Post	0.1454	3.5643**
	(0.4522)	(2.3984)
gti	0.0080	0.1389**
	(1.1099)	(0.0257)
lev	0.7696***	6.2627***
	(4.2375)	(7.7997)
current	-0.0010	-0.1141*
	(-0.0620)	(-1.7440)
turnover	0.4593***	1.1485***
	(6.3998)	(3.4407)
growth	-0.0132	-0.0611
	(-1.4341)	(-1.6169)
state	-0.1130**	1.1431***
	(-2.0859)	(4.6981)
lnage	0.0288	-0.4506**
	(0.7302)	(-2.3857)
cocen	0.0137***	0.0098
	(9.1226)	(1.4333)
topm	-0.0050***	-0.0169**
	(-3.6109)	(-2.3347)
_cons	18.3634***	26.4990***
	(111.5118)	(34.7838)
Industry FE	YES	YES
Year FE	YES	YES
N	4652	4652
R^2	0.196	0.590
F	23.577	25.682

Notes: indicate significance at the *** p <0.01, ** p <0.05, * p <0.1, values of t-statistics adjusted for robust standard errors are in parentheses.

The relationship between carbon finance, green technology innovation and economic performance is presented in Figure 5.10.

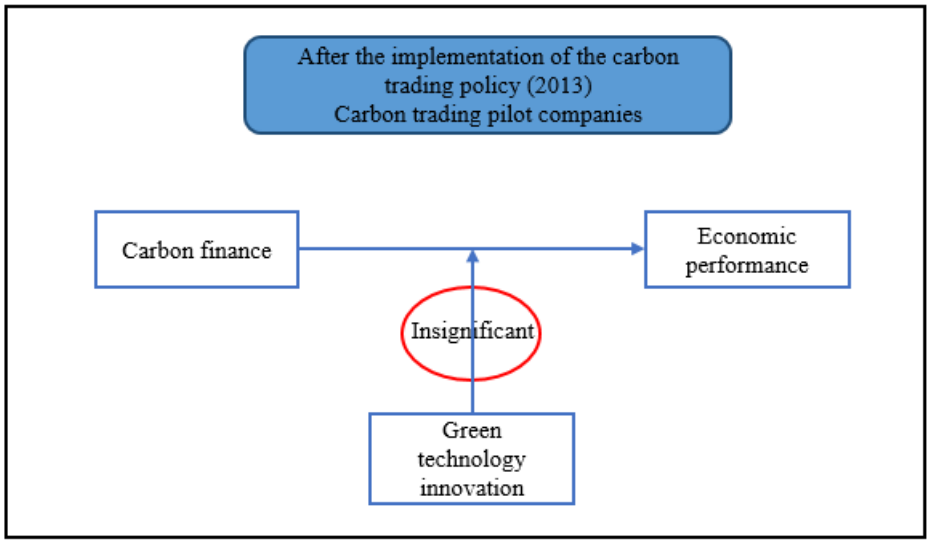


Figure 5.10 Carbon Finance, Green Technology Innovation and Economic Performance

The relationship between carbon finance, green technology innovation, and sustainable performance is depicted in Figure 5.11.

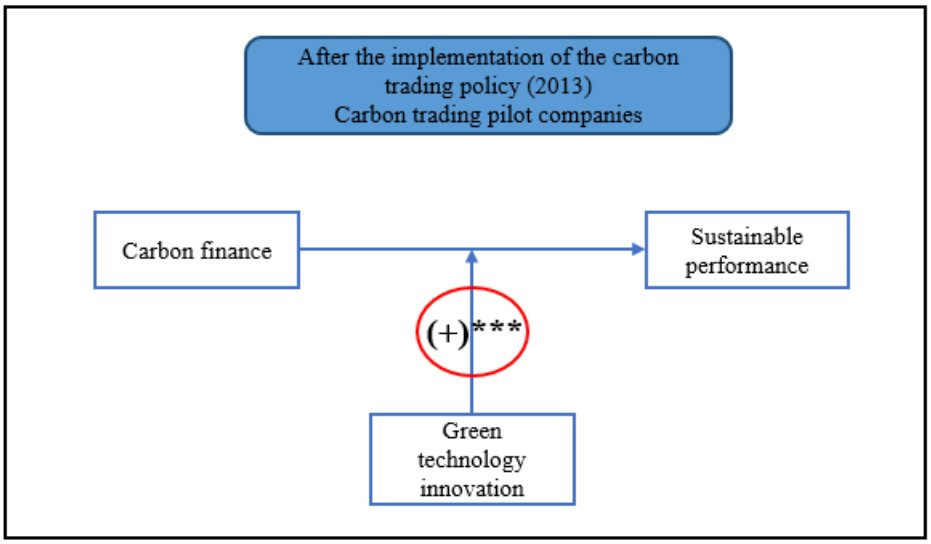


Figure 5.11 Carbon Finance, Green Technology Innovation and Sustainable Performance

5.5.2 Carbon Price, Green Technology Innovation on Company Performance

This section delineates the outcomes of evaluating the moderating influence of green technology innovation on carbon price and the economic and sustainable

performance of companies. Table 5.15 displays the outcomes of the moderating regressions, examining the influence of the interaction term (CP_Treat* gti) between carbon price (CP_Treat) and green technology innovation on companies' economic performance and sustainability performance.

In model (1), where lnEVA is the dependent variable, the coefficient of the interaction term CP_Treat* gti is 0.0002, exhibiting a significance level of 1% (t-value of 3.3090). This indicates that green technology innovation significantly and positively moderate the impact of carbon trading prices on lnEVA. This finding provides strong support for H5a. The coefficient of CP_Treat is 0.0100, with a significance level of 5% (t-value of 2.3860), signifying that the carbon trading price exerts a considerable positive impact on lnEVA. The coefficient of green technology innovation is -0.0007, indicating that the direct impact of green technology innovation on lnEVA is negligible. The control variables lev, current, turnover, and cocen significantly influence lnEVA, with lev, current, turnover, and cocen exhibiting a positive correlation, whereas state negatively impacts lnEVA. The model's R^2 value is 0.236, indicating modest explanatory power.

In model (2), where company sustainability performance (ESG) serves as the dependent variable, the coefficient of the interaction term CP_Treat* gti is 0.0005, with a significance level of 5% (t-value of 1.1136). This indicates that green technology innovation do not significantly moderate the impact of carbon trading prices on ESG. This finding does not support H5b. The coefficient for CP_Treat is 0.0174, although it fails to attain significance (t-value of 0.7750), suggesting that the direct impact of carbon trading price on ESG is not substantial. The coefficient of gti is 0.1306, with a significance level of 5% (t-value = 0.0177), demonstrating that green technological breakthroughs significantly enhance sustainable performance. The control variables lev, state, and cocen exert a strong positive influence on ESG, whereas topm negatively affects ESG. The R^2 value of the model is 0.535, signifying substantial explanatory power.

Overall, the moderated regression results suggest that the pilot effect of carbon trading price (CP_Treat) significantly impacts economic performance and that green technology innovation plays a significant positive moderating role in this relationship. It reveals that after implementing the carbon trading policy and in the carbon trading pilot regions, the higher carbon price will encourage companies to increase investment

in green technology innovation to reduce the cost of carbon emissions and obtain more carbon trading revenues. This, ultimately, will lead to the improvement of economic performance. Moreover, the promotion effect in the pilot regions is better than that in the non-pilot regions. Green technology innovation can help companies save energy and reduce emissions more effectively, reduce production costs, or develop more competitive green products and services to expand market share, thus improving the company's economic performance. Moreover, the higher the level of green technology innovation, the more obvious this facilitating effect is, which further strengthens the positive impact of carbon trading policy and carbon price on the company's economic performance.

For sustainable performance (ESG), it is asserted that green technology innovation does not play a significant moderating role in the impact of carbon price on companies' sustainable performance after the implementation of carbon trading policy and in carbon trading pilot regions. There is no significant difference between pilot and non-pilot regions. Possible reasons for this are the low level of the company's own weak green technology innovation capacity, serious lack of innovation investment, high innovation costs, and the existence of carbon price volatility and low carbon price and insufficient carbon market liquidity on the carbon market side, which leads to a non-significant impact of green technology innovation on sustainable performance.

Table 5.15
Moderating Regression Results of Carbon Price, Green Technology Innovation on Company Performance

	(1) lnEVA	(2) ESG
CP_Treat* gti	0.0002***	0.0005
	(3.3090)	(1.1136)
CP_Treat	0.0100**	0.0174
	(2.3860)	(0.7750)
gti	-0.0007	0.1306**
	(0.9542)	(0.0177)
lev	1.2515***	5.9305***
	(4.5257)	(4.1510)
current	0.0562**	-0.1944
	(2.2712)	(-1.3631)
turnover	0.6550***	-0.2322
	(6.2508)	(-0.4133)
growth	-0.0070	-0.0886*
	(-0.6091)	(-1.8440)
state	-0.2807***	0.8990**
	(-3.4521)	(1.9710)

lnage	-0.0872	-0.4931
	(-1.5551)	(-1.6102)
cocen	0.0131***	0.0276**
	(5.9453)	(2.4294)
topm	-0.0024	-0.0394***
	(-1.1516)	(-3.6267)
_cons	18.2741***	29.6606***
	(73.2787)	(21.8800)
Industry FE	YES	YES
Year FE	YES	YES
N	1960	1960
R^2	0.236	0.535
F	13.917	10.201

Notes: indicate significance at the *** p <0.01, ** p <0.05, * p <0.1, values of t-statistics adjusted for robust standard errors are in parentheses.

The relationship between carbon price, green technology innovation, and economic performance is displayed in Figure 5.12.

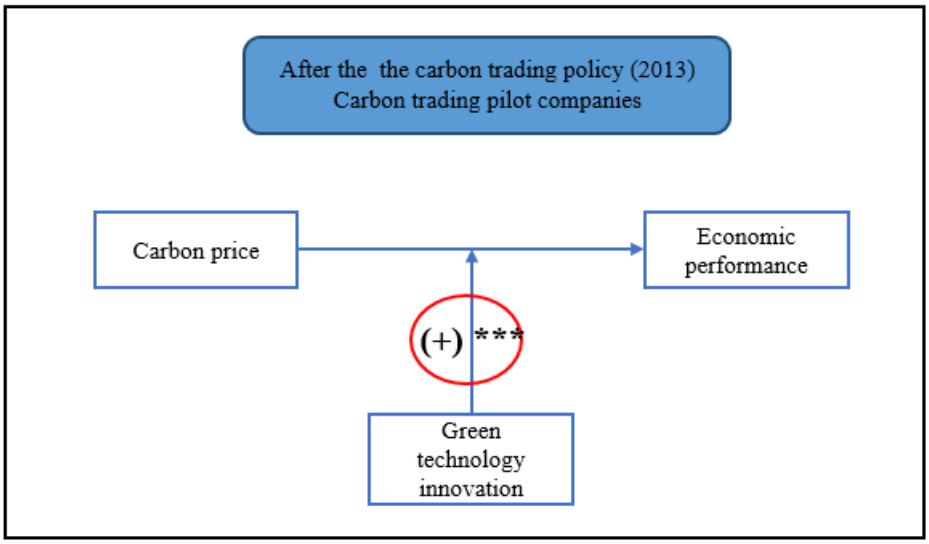


Figure 5.12 Carbon Price, Green Technology Innovation and Economic Performance

The relationship between carbon price, green technology innovation, and sustainable performance is illustrated in Figure 5.13.

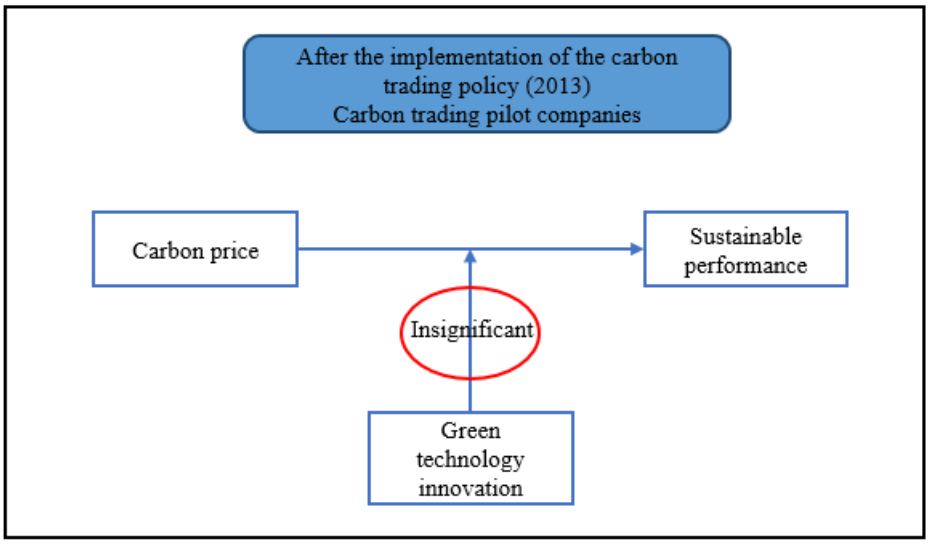


Figure 5.13 Carbon Price, Green Technology Innovation and Sustainable Performance

5.5.3 Carbon Trading Policy, Green Technology Innovation on Company Performance

This section delineates the outcomes of evaluating the moderating influence of green technology innovation on carbon price regimes and the economic and sustainability performance of companies. Table 5.16 displays the outcomes of the moderating regressions, examining the impact of the interaction term (did* gti) between carbon trading policy (DID variable) and green technology innovation on economic performance and company sustainability performance.

In model (1), where lnEVA is the dependent variable, the coefficient of the interaction term did* gti is 0.0072 and statistically significant (t-value of 2.5845), suggesting that green technology innovation positively moderates the relationship between carbon trading policy and lnEVA. This finding provides strong support for H6a. The coefficient of did is 0.0667; nevertheless, it fails to attain statistical significance, suggesting that the carbon trading pilot policy does not substantially impact lnEVA. The coefficient of gti is 0.0164, with a significance threshold of 1% (t-value of 0.0001), indicating that green technology innovation significantly enhances lnEVA. Among the control variables, lev, turnover, state, cocen, and topm significantly influence lnEVA, with lev, turnover, and cocen exhibiting a positive correlation, whilst state and topm demonstrate a negative impact on lnEVA. The R^2 value of the model is 0.187, signifying

that the model possesses little explanatory capability.

In model (2), where company sustainability performance (ESG) is the dependent variable, the coefficient of the interaction term did* gti is -0.0689, with a significance level of 1% (t-value of -4.5184). This indicates that the moderating effect of green technology innovation within the carbon trading policy on ESG is negative, suggesting that, in the context of the pilot policy, an increase in green technology innovation may exert a certain inhibitory effect on ESG. This finding does not support H6b. The DID coefficient is 1.7250, with a significance level of 1% (t-value of 3.3954), demonstrating that carbon price policy exerts a considerable positive impact on ESG. The coefficient of gti is 0.0935, with a significance level of 1% (t-value 0.0000), indicating that green technology innovation exerts a considerable positive impact on sustainable development performance. The control factors lev, current, turnover, age, growth, state, and topm significantly influence ESG. Notably, lev, turnover, and state exert a favorable impact on ESG, whereas current, growth, lnage, and topm negatively affect ESG. The model's R^2 value is 0.590, indicating substantial explanatory power.

Overall, the moderated regression results report that green technology innovation enhances the positive impact of carbon trading policy on company economic performance. It suggests that after the implementation of the carbon trading policy, for companies in carbon trading pilot regions, the stronger the green technology innovation ability, the more obvious the company's economic performance is enhanced. Pilot regions are better than non-pilot regions. This is attributed to the fact that the carbon trading policy puts pressure on and motivates pilot companies to reduce carbon emissions. Furthermore, green technology innovation can help companies reduce carbon emissions more effectively while also potentially bringing benefits such as improved productivity, product quality, and lower costs. For example, by developing more efficient energy-saving technologies and adopting cleaner energy sources to replace traditional energy sources, the company may reduce the cost of purchasing carbon allowances. However, it may also develop more market-competitive green products or services, thereby expanding market share, increasing revenue, and ultimately driving up the company's economic performance.

The interaction term between green technology innovation and carbon trading policy (did* gti) has a significant negative moderating effect in the ESG model, suggesting that in the pilot regions after the implementation of the carbon trading policy

after 2013, green technology innovation undermines the positive effect of the pilot policy on ESG performance to some extent. Notably, pilot regions are worse than non-pilot regions. Possible reasons for this are that the R&D and application of green technology innovation may require higher costs. This may increase the company's financial pressure in the short term, offsetting the benefits of the carbon trading policy and thus reducing sustainable performance. Green technology innovation is characterized by a long payback period, the effects of which fail to show up in time, and the loose allocation of quotas in the Chinese carbon market, which fails to create incentives for green technology innovation.

This outcome indicates that while green technology innovation is crucial for companies to comply with carbon policy, its moderating impact varies across different performance metrics during the pilot policy implementation. Consequently, companies must judiciously allocate resources and innovation strategies based on distinct performance objectives to attain comprehensive sustainable development goals.

Table 5.16
Moderating Regression Results of Carbon Trading Policy, Green Technology Innovation on Company Performance

	(1) lnEVA	(2) ESG
did* gti	0.0072***	-0.0689***
	(2.5845)	(-4.5184)
did	0.0667	1.7250***
	(0.6234)	(3.3954)
gti	0.0164***	0.0935***
	(0.0001)	(0.0000)
lev	0.6447***	5.1036***
	(4.1288)	(7.4221)
current	-0.0062	-0.1022*
	(-0.4349)	(-1.7567)
turnover	0.5253***	1.1749***
	(8.8222)	(4.2176)
growth	-0.0123	-0.0505*
	(-1.6386)	(-1.7649)
state	-0.0853*	1.0745***
	(-1.8335)	(5.1109)
lnage	0.0097	-0.4339***
	(0.2956)	(-2.6554)
cocen	0.0109***	0.0056
	(8.5624)	(0.9361)
topm	-0.0038***	-0.0165***
	(-3.0679)	(-2.6458)
_cons	18.4818***	26.6393***
	(132.9907)	(41.0534)

Industry FE	YES	YES
Year FE	YES	YES
N	5889	5889
R^2	0.187	0.590
F	27.366	26.258

Notes: indicate significance at the *** p <0.01, ** p <0.05, * p <0.1, values of t-statistics adjusted for robust standard errors are in parentheses.

The relationship between carbon trading policy, green technology innovation, and economic performance is presented in Figure 5.14.

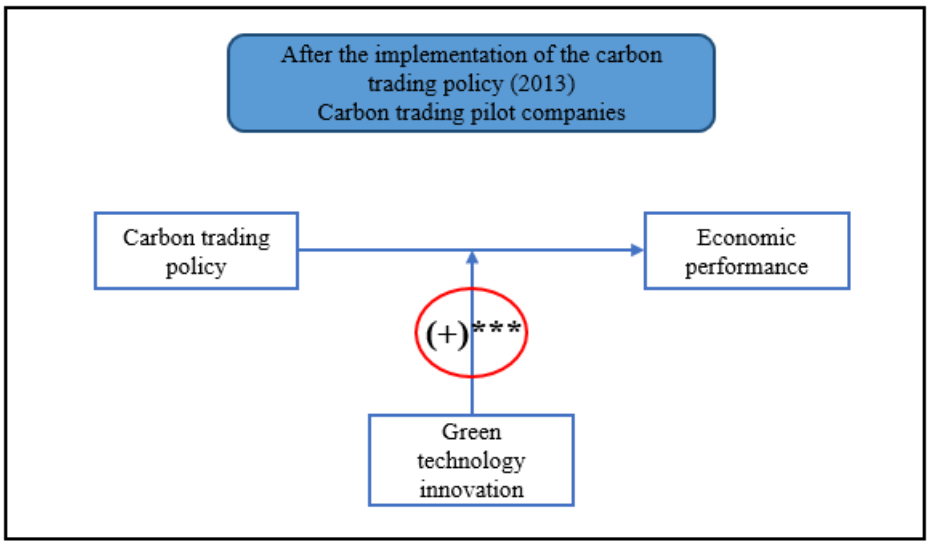


Figure 5.14 Carbon Trading Policy, Green Technology Innovation and Economic Performance

The relationship between carbon trading policy, green technology innovation, and sustainable performance is displayed in Figure 5.15.

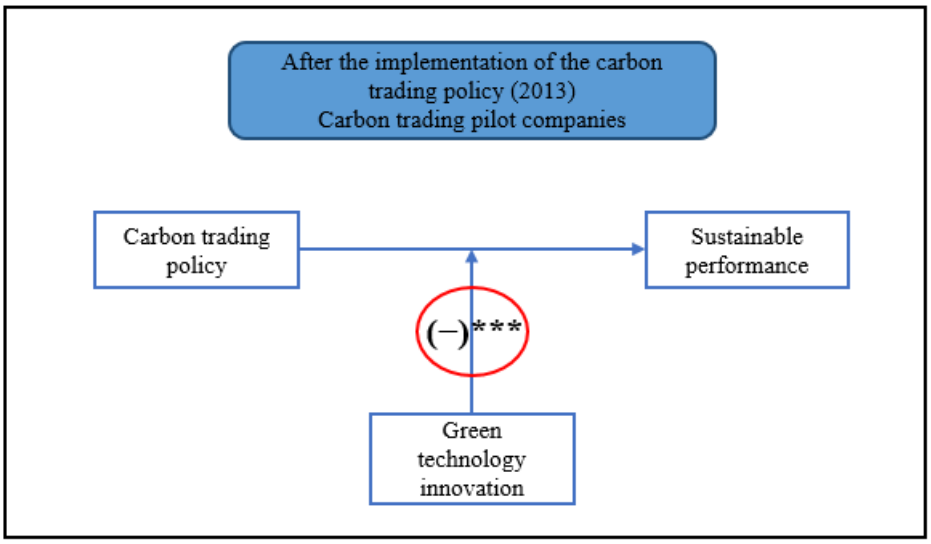


Figure 5.15 Carbon Trading Policy, Green Technology Innovation and Sustainable Performance

5.6 Robustness Test

Based on the results of the benchmark regression, the results of the robustness test of the impact of carbon finance, carbon price, and carbon trading policy on company performance are discussed below.

5.6.1 Carbon Finance on Company Performance

This section describes the results of robustness tests of the impact of carbon finance on the economic and sustainable performance of companies.

5.6.1.1 Carbon Finance on Economic Performance

For the robustness examination of carbon finance (Models 1-2), this paper uses four methods of robustness testing, i.e., replacing robust standard errors, adding control variables, lagging the independent variable by one period, and reducing fixed effects.

Referring to the study of Feng et al. (2024), the first robustness test is to replace the robust standard errors in the regression model with industry-clustered robust standard errors. When there is intra-group correlation in the data, the method of clustering robust standard errors is to divide the data according to certain clusters

(clusters) and consider intra-cluster correlation when calculating the standard errors, thus obtaining a more accurate estimate of the robust standard errors. When there is a clustering structure in the data, for example, the data are clustered by region or company, observations within the same cluster may be correlated, and the common standard error may underestimate the standard error, leading to erroneous statistical inferences. Accordingly, clustered standard errors can adjust for this clustered correlation and make the estimates more robust.

The data on carbon finance and carbon price may be affected by regional differences and industry characteristics. Standard error cluster analysis can classify observations with similar characteristics into different groups to better control the interference of heterogeneity on the results and enhance the explanatory power and robustness of the regression results. The introduction of standard error clustering analysis effectively mitigates the impact of data noise and potential bias on the regression results. In this paper, the robustness test is carried out using standard error industry clustering, company clustering, and city clustering.

The second method of robustness testing is to add control variables to the regression model. The cash flow (cf) control variable is added to the original regression model. The regression coefficients remain stable (little change in sign and significance) with the addition of the new variable, indicating that the original regression results are robust.

The third method of the robustness test is to change the independent variable CF_Post one period lag to L.CF_Post and then regress it. The regression coefficients have the same direction of sign, which means the results are robust. The one-period lagged robustness test of the independent variable is a simple yet effective method to alleviate the indigeneity problem using time order and helps the researcher verify the reliability and stability of the regression analysis results.

The fourth robustness test is to reduce the fixed effects; reducing the fixed effects dimension is a viable approach in robustness testing. It is based on the principle of testing whether the original results are overly dependent on the control of certain fixed effects. If the results are still robust after reducing the fixed effects, the original results are not due to overly strict fixed effect settings. This study conducts a robustness analysis by retaining only industry-fixed effects (rather than controlling for both time and industry-fixed effects) and thus testing the sensitivity of the model results to the

control for fixed effects.

Table 5.17 demonstrates the results of the four robustness test regressions of carbon finance (CF_Post) on the company's lnEVA. In model (1), the coefficient of CF_Post is -0.588 and significant at a 10% significance level (t-value of -1.833). In model (2), the coefficient of CF_Post is -0.594 and significant at a 5% significance level (t-value of -2.383). Meanwhile, in model (3), the coefficient of L.CF_Post is -0.560 and is significant at a 5% level of significance (t-value of -2.179). In model (4), the coefficient of CF_Post is -0.677 and is significant at a 10% significance level (t-value is -2.724), and the R^2 of the model is 0.541, 0.542, 0.554, and 0.539 respectively, which has good explanatory power. This result may reflect that carbon finance has a certain inhibitory effect on lnEVA in the short term due to the increase in financing cost and investment inhibition effect. Although H1a has been verified to be invalid, the result is robust.

Table 5.17
Robustness Regression Results of Carbon Finance on Economic Performance

	(1) lnEVA	(2) lnEVA	(3) lnEVA	(4) lnEVA
	Industry clustering robust standard errors	Add control variables	Independent variable lagged one period	Retain industry fixed effects
CI_Post	-0.588*	-0.594**		-0.677***
	(-1.833)	(-2.383)		(-2.724)
lev	-2.588***	-2.561***	-2.610***	-2.555***
	(-12.047)	(-16.941)	(-14.336)	(-17.550)
current	-0.019	-0.017	-0.013	-0.017
	(-0.779)	(-1.496)	(-0.967)	(-1.451)
turnover	0.717***	0.715***	0.677***	0.724***
	(6.639)	(12.985)	(10.188)	(13.115)
growth	0.011	0.011	0.016	0.009
	(1.299)	(1.325)	(1.156)	(1.092)
state	-0.297***	-0.299***	-0.265***	-0.290***
	(-4.271)	(-7.336)	(-5.555)	(-7.194)
lnage	-0.117*	-0.122***	-0.157***	-0.118***
	(-1.948)	(-4.328)	(-4.370)	(-4.350)
cocen	0.006***	0.006***	0.006***	0.006***
	(5.052)	(5.441)	(4.619)	(5.264)
topm	0.002	0.002*	0.001	0.002
	(1.532)	(1.689)	(0.837)	(1.606)
cf		0.000**		
		(2.167)		
L.CI_Post			-0.560**	
			(-2.179)	
_cons	-4.233***	-4.466***	-4.090***	-4.299***
	(-5.646)	(-9.893)	(-8.111)	(-10.893)

Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	NO
N	4678	4678	3273	4678
R^2	0.541	0.542	0.554	0.539
F	175.758	313.347	245.806	397.242

Notes: indicate significance at the *** p <0.01, ** p <0.05, * p <0.1, values of t-statistics adjusted for robust standard errors are in parentheses.

5.6.1.2 Carbon Finance on Sustainable Performance

Table 5.18 demonstrates the results of four robustness test regressions of carbon finance (CF_Post) on company sustainability performance (ESG). In model (1), the coefficient of CF_Post is 3.854 and is significant at a 10% significance level (t-value of 1.703). In model (2), the coefficient of CF_Post is 3.819 and is significant at a 1% significance level (t-value of 2.634). In model (3), the coefficient of L.CF_Post is 3.022 and is a level of significance (t-value of 1.753). In model (4), the coefficient of CF_Post is 4.356 and significant at a 5% significance level (t-value of 2.104). The R^2 of the model is 0.587, 0.590, 0.579, and 0.136, respectively, with moderate explanatory power. It is further verified that carbon finance policy can effectively contribute to the overall performance of companies in terms of environmental, social responsibility and governance. This result may suggest that carbon finance policy significantly enhances ESG performance by exerting external environmental pressure on companies to pay more attention to sustainable development goals. H1b was tested, and the results were robust.

Table 5.18
Robustness Regression Results Carbon Finance on Sustainable Performance

	(1) ESG	(2) ESG	(3) ESG	(4) ESG
	Industry clustering robust standard errors	Add control variables	Independent variable lagged one period	Retain industry fixed effects
CI_Post	3.854*	3.819***		4.356**
	(1.703)	(2.634)		(2.104)
lev	6.477***	5.423***	7.445***	5.016***
	(4.598)	(6.565)	(7.445)	(4.285)
current	-0.109	-0.145**	-0.171**	-0.186*
	(-1.095)	(-2.188)	(-2.086)	(-1.794)
turnover	1.240*	1.313***	1.599***	-1.375***
	(1.954)	(3.993)	(3.668)	(-2.783)
growth	-0.056	-0.055	-0.062	-0.181***

	(-1.195)	(-1.463)	(-1.032)	(-3.190)
state	1.188***	1.179***	1.113***	-1.474***
	(2.871)	(4.848)	(3.687)	(-4.117)
lnage	-0.453	-0.377**	-0.223	3.406***
	(-1.456)	(-1.999)	(-0.899)	(12.821)
cocen	0.009	0.009	0.012	-0.002
	(0.585)	(1.354)	(1.456)	(-0.177)
topm	-0.018*	-0.017**	-0.016*	0.032***
	(-1.831)	(-2.304)	(-1.797)	(3.055)
cf		-0.000***		
		(-4.103)		
L.CI_Post			3.022*	
			(1.753)	
_cons	26.429***	26.606***	26.194***	20.951***
	(19.903)	(34.816)	(27.142)	(18.531)
Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	NO
N	4678	4678	3273	4678
R^2	0.587	0.590	0.579	0.136
F	10.497	26.610	25.265	34.531

Notes: indicate significance at the *** p <0.01, ** p <0.05, * p <0.1, values of t-statistics adjusted for robust standard errors are in parentheses.

5.6.2 Carbon Price on Company Performance

This section describes the results of robustness tests on the impact of a carbon price on a company's economic performance and sustainable performance.

5.6.2.1 Carbon Price on Economic Performance

For the robustness examination of the carbon price (models 3-4), this paper uses four methods of robustness testing: replacing the robust standard errors, adding control variables, the one-period lag of the independent variable, and reducing fixed effects.

The first robustness test is to replace the robust standard errors in the regression model with industry clustering robust standard errors. The second robustness test is to add the cash flow (cf) control variable to the original regression model. A third robustness test is to change the independent variable CP_Treat one period lagged to L. CP_Treat and then run the regression. The fourth robustness test is to reduce the fixed effects, and this study does this by retaining only the industry fixed effects (rather than controlling for both time and industry fixed effects) and thus testing the sensitivity of the model results to the control of fixed effects.

Table 5.19 demonstrates the results of the four robustness test regressions of the carbon trading price pilot effect (CP_Treat) on the company's lnEVA. In model (1), the coefficient of CP_Treat is 0.010 and significant at the 10% significance level (t-value of 1.759). In model (2), the coefficient of CP_Treat is 0.011 and significant at the 1% significance level (t-value of 2.582), and in model (3) L. The coefficient of CP_Treat is 0.010 and significant at the 5% level of significance (t-value of 2.314). In model (4), the coefficient of CP_Treat is 0.007 and is significant at a 10% significance level (t-value is 1.780), and the model R^2 is 0.232, 0.258, 0.264 and 0.188, respectively, which has some explanatory power. The positive effect of carbon trading prices on lnEVA is further verified. This suggests that implementing carbon trading price may have contributed to the company's lnEVA by guiding the company in optimizing resource allocation and improving operational efficiency. H2a is verified, and the results are robust.

Table 5.19
Robustness Regression Results of Carbon Price on Economic Performance

	(1) lnEVA	(2) lnEVA	(3) lnEVA	(4) lnEVA
	Industry clustering robust standard errors	Add control variables	Independent variable lagged one period	Retain industry fixed effects
CP_Treat	0.011*	0.012***		0.008**
	(1.928)	(2.799)		(2.042)
lev	1.279***	0.854***	1.620***	1.384***
	(2.998)	(3.092)	(4.924)	(4.918)
current	0.066*	0.049**	0.079***	0.070***
	(1.887)	(2.018)	(2.712)	(2.650)
turnover	0.686***	0.718***	0.586***	0.603***
	(4.492)	(6.973)	(4.444)	(5.629)
growth	-0.007	-0.003	0.004	-0.014
	(-0.548)	(-0.304)	(0.204)	(-1.312)
state	-0.262*	-0.289***	-0.372***	-0.316***
	(-1.897)	(-3.761)	(-3.915)	(-3.933)
lnage	-0.073	-0.037	-0.115	0.026
	(-0.848)	(-0.684)	(-1.606)	(0.477)
cocen	0.013***	0.014***	0.011***	0.012***
	(3.750)	(6.452)	(4.507)	(5.364)
topm	-0.002	-0.002	-0.004*	-0.003
	(-1.000)	(-1.009)	(-1.724)	(-1.230)
cf		-0.000***		
		(-6.114)		
L.CP_Treat			0.011***	
			(2.650)	
_cons	18.172***	18.218***	18.535***	18.024***
	(48.787)	(74.891)	(61.528)	(70.031)

Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	NO
N	2033	2033	1391	2033
R^2	0.230	0.256	0.262	0.189
F	7.980	18.651	10.769	12.844

Notes: indicate significance at the *** p <0.01, ** p <0.05, * p <0.1, values of t-statistics adjusted for robust standard errors are in parentheses.

5.6.2.2 Carbon Price on Sustainable Performance

Table 5.20 demonstrates the regression results of the four robustness tests of the carbon trading price pilot effect (CP_Treat) on company sustainable performance (ESG). In model (1), the coefficient of CP_Treat is 0.018, which is not significant (t-value of 1.057). In model (2), the coefficient of CP_Treat is 0.020, which is not significant (t-value of 0.875), and in model (3), the coefficient of L. CP_Treat is 0.004, which is not significant (t-value of 0.151). In model (4), the coefficient of CP_Treat is -0.032, which is not significant (t-value is -1.076). The R^2 of the model is 0.534, 0.537, 0.513, and 0.179, respectively, which has some explanatory power. The possible reason is that the current Chinese carbon trading pilot quota allocation is loose, the price is low, and the carbon price fails to play an incentive role in the company's ESG performance. H2b is verified, and the results are robust.

Table 5.20
Robustness Regression Result of Carbon Price on Sustainable Performance

	(1) ESG	(2) ESG	(3) ESG	(4) ESG
	Industry clustering robust standard errors	Add control variables	Independent variable lagged one period	Retain industry fixed effects
CP_Treat	0.023	0.024		-0.026
	(1.465)	(1.124)		(-0.895)
lev	5.829**	4.876***	6.424***	7.477***
	(2.532)	(3.390)	(3.624)	(4.122)
current	-0.211	-0.249*	-0.361**	-0.135
	(-0.739)	(-1.746)	(-2.120)	(-0.719)
turnover	-0.158	-0.087	0.128	-1.801**
	(-0.140)	(-0.159)	(0.165)	(-2.376)
growth	-0.090	-0.081*	-0.109	-0.239***
	(-1.350)	(-1.828)	(-1.376)	(-3.578)
state	0.984	0.924**	0.584	0.045
	(1.117)	(2.068)	(0.989)	(0.079)
lnage	-0.450	-0.370	-0.548	1.333***
	(-0.926)	(-1.240)	(-1.358)	(3.499)

cocen	0.026	0.027**	0.033**	0.003
	(0.953)	(2.401)	(2.294)	(0.211)
topm	-0.038**	-0.037***	-0.047***	-0.041***
	(-2.325)	(-3.543)	(-3.496)	(-2.787)
cf		-0.000***		
		(-2.727)		
L.CP_Treat			0.010	
			(0.383)	
_cons	29.606***	29.707***	31.107***	27.141***
	(11.519)	(22.526)	(18.736)	(15.589)
Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	NO
N	2033	2033	1391	2033
R^2	0.529	0.532	0.509	0.180
F	6.711	11.309	10.481	11.778

Notes: indicate significance at the *** p <0.01, ** p <0.05, * p <0.1, values of t-statistics adjusted for robust standard errors are in parentheses.

5.6.3 Carbon Trading Policy on Company Performance

This section describes the results of robustness tests on the impact of carbon trading policy on a company's economic performance and sustainable performance.

5.6.3.1 Carbon Trading Policy on Economic Performance

For the robustness examination of carbon trading policy (models 5-6), this paper uses f independent variable e robustness tests: placebo test, replacement of robust standard errors, addition of control variables, lagging of independent variables by one period, and reduction of fixed effects.

a) Policy Placebo Test

The placebo test is a method used to test the robustness of model results. The purpose of the placebo test is to test the causality and reliability of the results by constructing dummy policy pilots or randomizing the timing of policy implementation to ensure that the regression results are not due to chance in the model set-up or sample selection. This approach further verifies the significance of the impact of carbon trading policy pilots on company performance (Goodman-Bacon, 2021). The adoption of the placebo test is particularly suitable for policy evaluation type of research and can

effectively avoid spurious correlations due to factors other than policy implementation (Abadie, 2005).

In statistical methods such as regression analysis, the researcher wants to ensure that the results obtained are not due to random or model-setting errors (Goodman-Bacon, 2021). Hence, placebo tests are performed by randomly generating spurious treatment variables (or other key variables) and re-running the model to see if the results are still significant. If the results obtained under the spurious treatment variable are not significant, then the results of the original model are more likely to be reliable (Athey & Imbens, 2022).

Referring to Chen et al. (2023), Zhang et al. (2020) and Liu et al. (2022), in order to ensure the accuracy of the regression results and to reduce the influence of unforeseen factors, a placebo test was conducted. A fictitious experimental and control groups are randomly generated and then regressed. If the results are significant, the original estimates are not robust and biased. Along the above lines, this paper randomly selects among the original samples and unfolds multiple regressions in which the dummy experimental group is consistent with the baseline regression model. Firstly, 500 samples were obtained from the sample of all listed companies, and 61 companies were randomly selected as the simulated experimental group and the rest of the companies as the control group for 500 regressions in the results of each sample. The distribution of the estimated coefficients of the simulated variables and the corresponding p-values were plotted to see whether the coefficient results were significant or not.

Figure 5.4 illustrates the results of the placebo test of the carbon trading pilot policy (DID) on the company's lnEVA. The spurious estimated DID coefficients and p-values are represented by the horizontal and vertical axes, respectively, and the dots represent the estimates for each simulation. The red vertical dashed line indicates the true estimate of DID of 0.085. Meanwhile, the red horizontal dashed line, $p = 0.01$, represents the significance level, with scatters below this dashed line indicating that the coefficients are at least significant at the 10% level and, conversely, insignificant.

As can be observed from the figure, although most of the placebo-tested spurious estimated DID coefficients are clustered around 0, all to the left of the vertical red dashed line, and the pseudo-DID means are close to the true values, some of the p-values are located below the dashed line. This indicates that some of the coefficients are

significant. In addition, this suggests that the impact of the carbon trading pilot policy on the company's lnEVA fails to pass the significance test in the placebo test, further verifying that hypothesis H3a does not hold. This result suggests that under the existing model setting and sample conditions, the carbon trading pilot policy does not exhibit a significant promotion effect on companies' lnEVA. This may be related to the adjustment of the market mechanism or the lag of companies' coping strategies at the early stage of the policy implementation. H3a is verified, and the results are robust.

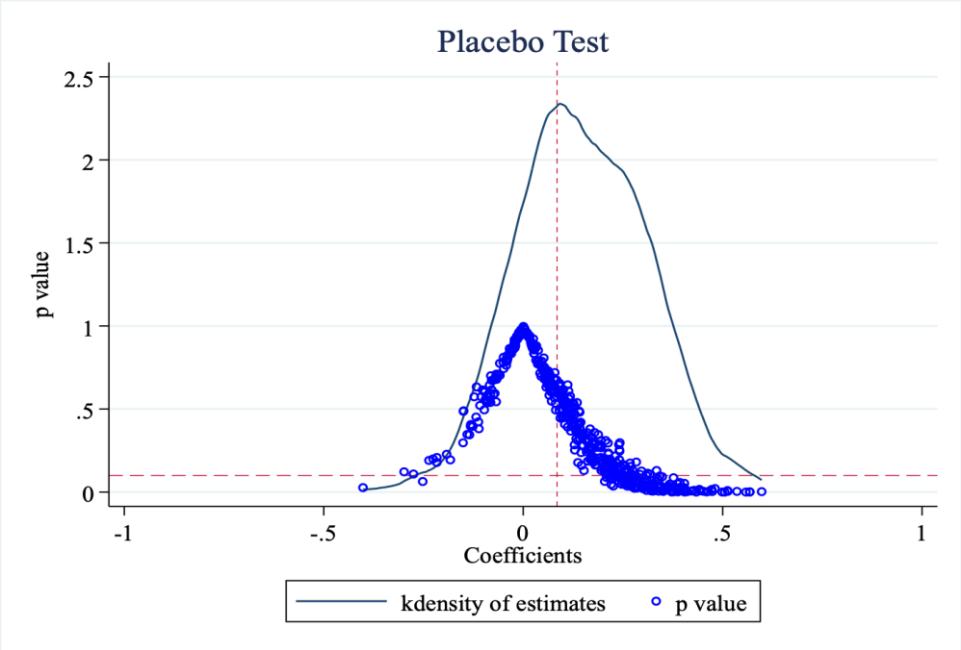


Figure 5.16 Placebo Test (DID on lnEVA)

b) Other Robustness Tests

Referring to Colin Cameron and Miller (2015), Moody and Marvell (2020), Teng et al. (2014) and Civilization et al. (2021), the second robustness test is to replace the robust standard errors in the regression model with industry clustering robust standard errors. The third robustness test is to add the cash flow (cf) control variable to the original regression model. The fourth robustness test is to change the independent variable DID lagged by one period to L. DID, with the regression coefficients sign direction unchanged, indicating that the results are robust. The fifth robustness test is to

reduce the fixed effects, and this study goes on to test the sensitivity of the model results to the control of fixed effects by retaining only the industry fixed effects (rather than controlling for both time and industry fixed effects).

Table 5.21 demonstrates the results of four robustness test regressions of carbon trading policy effects (DID) on a company's lnEVA. In model (1), the coefficient of DID is 0.085, which is not significant (t-value of 0.317). In model (2), the coefficient of DID is 0.076, which is not significant (t-value of 0.717). In model (3), the coefficient of L. DID is 0.085, which is not significant (t-value of 0.716), and in model (4), the coefficient of DID is 0.103, which is not significant (t-value of 0.948). The R^2 of the model is 0.187, 0.213, 0.194 and 0.132, respectively, which has some explanatory power. The possible reasons are that the carbon trading policy fails to promote the company's lnEVA due to the current loose allocation of quotas in China's carbon trading pilot, irrational way of quota allocation, and imbalance between abatement costs and benefits. The hypothesis H3a is verified, and the results are robust.

Table 5.21
Robustness Regression Result of Carbon Trading Policy on Economic Performance

	(1) lnEVA	(2) lnEVA	(3) lnEVA	(4) lnEVA
	Industry clustering robust standard errors	Add control variables	Independent variable lagged one period	Retain industry fixed effects
did	0.085	0.076		0.103
	(0.317)	(0.717)		(0.948)
lev	0.647**	0.185	0.800***	0.548***
	(2.047)	(1.145)	(4.241)	(3.426)
current	-0.006	-0.022	0.011	-0.013
	(-0.192)	(-1.580)	(0.602)	(-0.872)
turnover	0.526***	0.562***	0.512***	0.413***
	(4.786)	(9.528)	(7.227)	(6.832)
growth	-0.012	-0.012	-0.003	-0.018**
	(-1.345)	(-1.643)	(-0.237)	(-2.362)
state	-0.085	-0.090**	-0.072	-0.207***
	(-1.200)	(-1.979)	(-1.323)	(-4.356)
lnage	0.009	0.040	0.004	0.196***
	(0.144)	(1.241)	(0.088)	(5.980)
cocen	0.011***	0.011***	0.009***	0.010***
	(4.183)	(8.717)	(6.209)	(7.858)
topm	-0.004**	-0.003***	-0.004***	-0.002
	(-2.178)	(-2.775)	(-2.945)	(-1.494)
cf		-0.000***		
		(-8.853)		
L.did			0.085	
			(0.716)	
_cons	18.481***	18.560***	18.680***	18.231***

	(68.847)	(134.888)	(109.696)	(125.909)
Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	NO
N	5889	5889	4117	5889
R^2	0.187	0.213	0.194	0.132
F	15.353	36.235	17.984	26.649

Notes: indicate significance at the *** p <0.01, ** p <0.05, * p <0.1, values of t-statistics adjusted for robust standard errors are in parentheses.

5.6.3.2 Carbon Trading Policy on Sustainable Performance

a) Policy Placebo Test

Referring to Wang et al. (2024) and Tang et al. (2022), the robustness test is conducted with the help of a fictitious experimental group approach: The pseudo-policy dummy variable DID is constructed by randomly selecting companies in the full sample as the experimental group, with treat taken as 1 and the rest of the companies treat taken as 0. It is then brought into the baseline model for a regression test to see if the coefficient of DID is significant. Suppose the coefficient of DID is still significant after randomly selecting the experimental group. In that case, it means that the change in companies' sustainable performance is likely to be influenced by other policies or random factors. In this paper, the above process was randomly simulated 500 times using Stata17 software. The coefficients and p-values of all the pseudo-DID regression results are plotted graphically, with the results of the placebo test displayed visually in Figure 5.5.

The pseudo-DID coefficients and p-values are represented by the horizontal and vertical axes, respectively. The estimates for each simulation are represented by the dots, with the red vertical dashed line indicating the true estimate of the DID of 1.553. The red horizontal dashed line of p = 0.01 represents the level of significance, with the scatters located below this dashed line, indicating that the coefficients are significant at least at the 10% level and, conversely, not significant. It can be noticed that the vast majority of scatters are centrally distributed around 0, all to the left of the vertical red dashed line. The distance of the pseudo DID means from the true values, the truly estimated coefficients of DID (red vertical dashed line position) are significant outliers in the placebo test, and the vast majority of the estimated coefficients above the dashed

line are insignificant. This implies that the impact of the carbon trading pilot policy on the sustainable performance of the companies is not affected by other unobserved factors. This, in turn, suggests that the effect of the pilot policy of carbon trading on the ESG in the placebo test passes, supporting H3b. This result validates the actual effect of the carbon trading pilot policy in enhancing the company's ESG ratings, further confirming that the causal effect of the policy is robust. H3b was evaluated, and the results were robust.

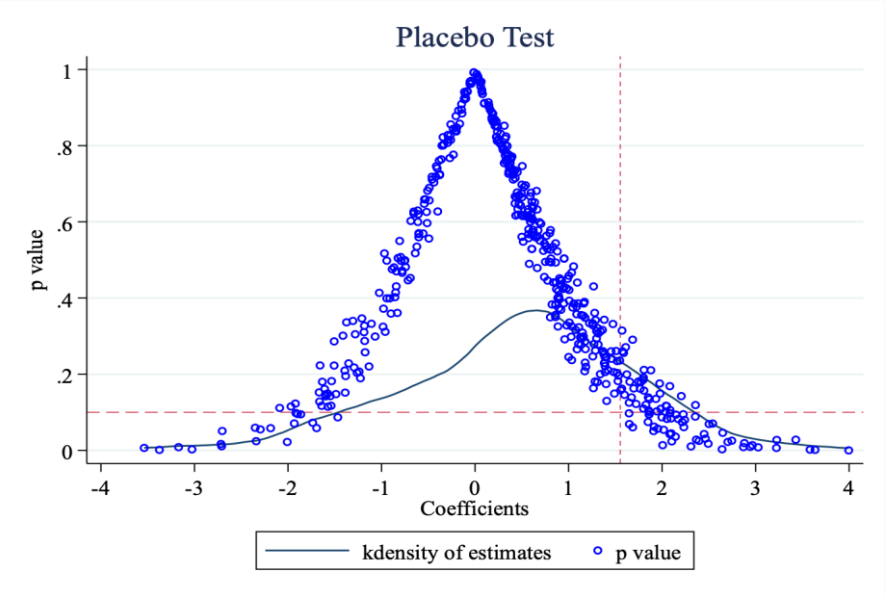


Figure 5.17 Placebo Test (DID on ESG)

b) Other Robustness Tests

Table 5.22 demonstrates the regression results of the four robustness tests of the carbon trading policy effect (DID) on a company's sustainable performance (ESG). In model (1), the coefficient of DID is 1.553 and significant at the 10% significance level (t-value of 1.896). In model (2), the coefficient of DID is 1.531 and significant at the 1% significance level (t-value of 3.047), and in model (3) L. The coefficient of DID is 1.614 and significant at the 1% significance level (t-value of 2.629). In model (4), the coefficient of DID is 2.055 and significant at a 1% significance level (t-value of 2.892), and the model R^2 is 0.589, 0593, 0.581 and 0.144, respectively, which has moderate explanatory power. The positive effect of carbon trading policy on sustainable

performance is further verified. This suggests that implementing the carbon trading policy may have promoted the company's ESG performance through carbon emission reduction, optimization of energy structure and promotion of technological innovation. Hypothesis H3b is verified, and the results are robust.

Table 5.22
Robustness Regression Result of Carbon Trading Policy on Sustainable Performance

	(1) ESG	(2) ESG	(3) ESG	(4) ESG
	Industry clustering robust standard errors	Add control variables	Independent variable lagged one period	Retain industry fixed effects
did	1.553*	1.531***		2.055***
	(1.896)	(3.047)		(2.892)
lev	5.081***	4.004***	5.373***	3.194***
	(4.613)	(5.685)	(6.251)	(3.209)
current	-0.102	-0.140**	-0.171**	-0.224**
	(-1.208)	(-2.396)	(-2.223)	(-2.482)
turnover	1.171**	1.256***	1.569***	-0.941**
	(2.298)	(4.531)	(4.246)	(-2.328)
growth	-0.051	-0.050*	-0.056	-0.163***
	(-1.272)	(-1.759)	(-1.276)	(-3.729)
state	1.070***	1.057***	0.966***	-1.214***
	(3.260)	(5.050)	(3.705)	(-3.925)
lnage	-0.432	-0.361**	-0.201	3.031***
	(-1.629)	(-2.222)	(-0.957)	(13.599)
cocen	0.006	0.006	0.007	-0.003
	(0.397)	(0.950)	(0.952)	(-0.382)
topm	-0.016*	-0.016**	-0.016**	0.021**
	(-1.849)	(-2.500)	(-2.106)	(2.339)
cf		-0.000***		
		(-4.750)		
L.did			1.614***	
			(2.629)	
_cons	26.649***	26.834***	26.741***	21.959***
	(24.048)	(41.417)	(32.710)	(23.300)
Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	NO
N	5889	5889	4117	5889
R^2	0.589	0.593	0.581	0.144
F	12.228	26.752	23.040	38.441

Notes: indicate significance at the *** p <0.01, ** p <0.05, * p <0.1, values of t-statistics adjusted for robust standard errors are in parentheses.

5.7 Results and Discussion

Chapter 3 delineates 12 hypotheses, six of which examine the influence of carbon market mechanisms (carbon finance, carbon price, and carbon trading policy)

on company performance (economic and sustainable performance), while the remaining six investigate the moderating effect of green technology innovation on the relationship between carbon market mechanisms and company performance. The findings of the hypothesis and empirical analyses are encapsulated in Table 5.23.

This section addresses the quantitative results of the impact of carbon market mechanisms (carbon finance, carbon price, and carbon trading policy) on company performance (economic performance and sustainable performance) and the moderating role of green technology innovation, completing RO1 and RO2.

Table 5.23

Summary Results of All Hypothesized Relationships for Phase I

Hypothesis	Descriptions	Expected Sign	Actual Sign	Decision	Conclusion
H1a	There is a significant positive relationship between carbon finance and company economic performance.	(+)	(-)**	Not supported	Carbon finance and company economic performance are negatively related.
H1b	There is a significant positive relationship between carbon finance and environmental score.	(+)	(+)***	Supported	Carbon finance positively promotes the improvement of a company's sustainable performance.
H2a	Carbon price is positively related to the company's economic performance.	(+)	(+)**	Supported	Carbon price positively promotes the improvement of a company's economic performance.
H2b	The carbon price is positively related to the environmental score.	(+)	Insignificant	Not supported	The relationship between carbon price and a company's sustainable performance is not significant.
H3a	Carbon trading policy is positively associated with the company's economic performance.	(+)	Insignificant	Not supported	The relationship between carbon trading policy and the company's economic performance is not significant.
H3b	Carbon trading policy is positively associated with environmental score.	(+)	(+)***	Supported	Carbon trading policy positively promotes the improvement of the company's sustainable performance.
H4a	Green technology innovation moderates the relationship between carbon finance and company economic performance.	(+)	Insignificant	Not supported	The moderating effect of green technology innovation on carbon finance and company economic performance is not significant.
H4b	Green technology innovation moderates the relationship between carbon finance and environmental score.	(+)	(+)***	Supported	Green technology innovation positively moderates the relationship between carbon finance and company sustainability performance.
H5a	Green technology innovation moderates the relationship between the carbon price and a company's economic performance.	(+)	(+)***	Supported	Green technology innovation positively moderates the relationship between the carbon price and the company's economic performance.
H5b	Green technology innovation moderates the relationship between carbon price and environmental score.	(+)	Insignificant	Not supported	The moderating effect of green technology innovation on carbon price and company sustainable performance is not significant.
H6a	Green technology innovation moderates the	(+)	(+)***	Supported	Green technology innovation positively moderates

	relationship between carbon trading policy and a company's economic performance.				the relationship between carbon trading policy and company economic performance.
H6b	Green technology innovation moderates the relationship between carbon trading policy and environmental score.	**(+)**	**(-)*** **	Not supported	Green technology innovation negatively moderates the relationship between carbon trading policy and company sustainable performance.

5.7.1 Carbon Finance on Company Performance

5.7.1.1 Carbon Finance on Economic Performance

This study's results indicate that carbon finance adversely impacts company economic performance, contradicting hypothesis H1a. Carbon finance fundamentally involves credit rationing influenced by environmental limitations, directing money predominantly towards green companies and imposing substantial financing penalties and investment deterrents on heavily polluting companies (Xue et al., 2023). Suppose commercial banks utilize a company's environmental policy as a criterion for loan approval. In that case, the company's financing costs will rise, particularly as debt financing, primarily through bank loans, is likely to diminish (Wang et al., 2023). Additionally, the government reveals information about companies that lack proactivity, which reduces external investors' willingness to provide funding (Chen et al., 2024). With the escalation of environmental legislation, excessively polluting companies encounter administrative measures, including substantial pollution fees and fines (Liu et al., 2022). The company must either reduce or defer productive investments to enhance funding for environmental pollution control, resulting in financial difficulties and an overall decrease in investment (Yang et al., 2023). Consequently, Green Finance (GF) can place significantly polluting companies in a predicament characterized by challenging financing, reduced investment, and declining company performance, as illustrated in Figure 5.6.

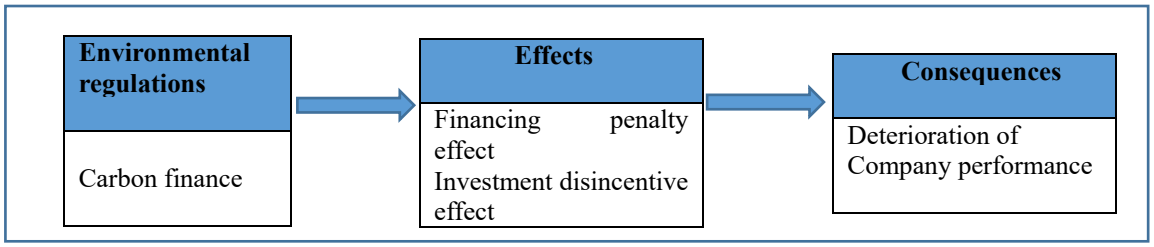


Figure 5.18 Carbon Finance and Company Performance

The findings contradict the findings from the previous studies (e.g., Wang, 2021; Xue & Liu, 2022; Li & Di, 2021; Zhang & Ke, 2022; Fatica & Panzica, 2021), which

noted a positive relationship between carbon finance and company economic performance. Similarly, many studies have supported the positive relationship. According to Liu et al. (2021), a substantial positive link exists between GF and high-quality economic development, with industrial structure upgrading and technological innovation serving as partial mediators. Jiakui et al. (2023) examined the effects of GF, financial development, and green technical innovation on GTFP across 28 provinces in China from 2011 to 2021. The study's results indicated that GF markedly enhanced green productivity. Additional variables, including financial development and technological innovation, substantially contribute to green production. Banani and Sunarko (2022) gathered financial statement data from 20 central banks in developing countries from 2009 to 2020. The findings indicated that green investment, green credit, energy accounting, and inventiveness are favorably correlated with the financial performance of the banking sector in emerging nations.

An empirical study conducted by Han et al. (2023) utilizing data from 30 regions in China between 2011 and 2021 demonstrated that GF facilitates high-quality economic development by mitigating resource misallocation and fostering advancements in green technology. Simultaneously, a clear variety in GF fosters high-quality economic development. Green credit and green insurance are vital mechanisms for fostering high-quality economic development. Ma et al. (2023) constructed a regional GF development index in China to examine the impact of GF on the financial performance of green companies. It is discovered that GF can significantly enhance the financial performance of green companies through capital aggregation and information transfer. In addition, R&D innovation also bridges the influence of GF. Moreover, Lim and Prakash (2023) analyzed the influence of renewable energy investments, including geothermal, solar, bioenergy, hydropower, and wind projects, as well as GF, on the economic performance of Organization for Economic Co-operation and Development (OECD) countries. The findings indicate that investments in renewable energy and GF significantly enhance the economic performance of OECD countries.

5.7.1.2 Carbon Finance on Sustainable Performance

This study's results indicate that carbon finance positively influences sustainable performance (ESG), hence fully supporting H1b. This is similar to previous

findings (e.g., Lei & Yu, 2024; Wang & Wang, 2022; Guo et al., 2022). Numerous research corroborate this positive link, indicating that adopting a green financing policy enhances the ESG performance of heavily polluting companies. The beneficial effects of GF regulations on companies' ESG performance are more significant for those with superior internal and external governance (Qian & Yu, 2024). GF regulations can markedly improve company ESG performance, particularly for non-state-owned companies, companies with substantial executive social capital, low-polluting companies, and those located in developed areas. The reduction of company funding constraints and the impact of regional environmental regulations from local green financial policy are significant methods for enhancing company ESG performance. Moreover, municipal GF regulations amplify the beneficial impact of company ESG performance on enhancing company value, hence promoting sustainable development for companies (Xue et al., 2023). Green financing positively influences the ESG performance of publicly traded companies. Heterogeneity analyses reveal that state-owned companies, high-pollution companies, and companies located in low-carbon pilot towns exhibit superior performance in the contribution of GF to ESG scores (Wu & Liew, 2023). The aforementioned data corroborate the validity of Porter's hypothesis.

However, some studies report the opposite results, namely that GF increases financing constraints and financial pressures, negatively affecting green innovation and environmental performance. Green credit rules restrict funding and investment for small and medium-sized companies and deter green innovation among private companies. In contrast, GF has constraints in fostering sustainable development within pollution-intensive sectors (Chen et al., 2022).

5.7.2 Carbon Price on Company Performance

5.7.2.1 Carbon Price on Economic Performance

This study's results indicate that carbon price positively influences a company's economic performance, hence fully supporting hypothesis H2a. This finding is consistent with past studies (e.g., Bento & Gianfrate, 2020; Zhang et al., 2018; Joltreau & Sommerfeld, 2019; Mo, 2023). Similarly, many studies have supported the positive relationship. Chen et al. (2017) determined that carbon price positively influences

companies' operational efficiency and market competitiveness. They asserted that the carbon price mechanism enables manufacturing companies to make optimal operational decisions and enhance overall performance. Guo and Gong (2023) discovered that the execution of ETS significantly enhanced the financial performance of pilot companies. The carbon price exerts a moderating influence on the relationship between ETS and companies' financial performance. Specifically, an increase in carbon price amplifies the effect of ETS on companies' financial performance. The impact mechanism revealed that the improvement of company financial performance through the carbon ETS is mostly driven by the advancement of green innovation capability and the augmentation of company social responsibility. Significantly, only the sample group with elevated carbon price demonstrates this effect. Bento et al. (2021) contended that carbon price exerts a comprehensive economic impact, influencing the productivity and efficiency of an economy across all dimensions, necessitating that companies consider alterations in macroeconomic variables and formulate Internal Carbon Price (ICP) strategies. The findings of the aforementioned investigations demonstrate the validity of Porter's concept.

In contrast with the result of this study, some studies have demonstrated a negative relationship between carbon price and company value (e.g., Zhang et al., 2018; Krokida et al., 2020). Bolton et al. (2023) indicated that the rise in daily carbon price is positively connected with the decline in stock price throughout the same timeframe. The results of these studies proved that the traditional hypothesis (compliance cost theory), i.e., Porter's hypothesis, is not valid.

5.7.2.2 Carbon Price on Sustainable Performance

This study's results indicate that carbon price has an insignificant effect on sustainable performance (ESG), hence failing to support hypothesis H2b. This aligns with research indicating that overall emission reductions from carbon price are constrained, generally varying from 0% to 2% annually. An analysis of the first EU ETS indicates that the average reductions in carbon emissions are constrained, varying from 0% to 1.5% annually, as noted by Green (2021).

Researchers including Lin and Jia 2019, Venmans et al. 2020, and Flachsland et al. 2020 contended that reduced carbon price adversely affect company value and

competitiveness. The carbon market was initially created to facilitate the reduction of carbon emissions, with the price of carbon emission allowances serving as its primary motivator. An increase in the price of carbon emission rights incentivizes emission control companies to invest in R&D of energy-efficient and emission-reducing technologies, potentially yielding long-term benefits such as decreased carbon emissions and enhanced economic performance. Since the introduction of China's pilot Carbon Emission Trading (CET) mechanism, carbon price have remained low and exhibit significant volatility. As such, a low carbon price does not positively influence the company's sustainability performance.

The cost of carbon emissions trading is the principal factor influencing a company's technological innovation plan (Lv & Bai, 2021). The carbon price has remained low due to China's over-allotment of initial allowances (Tang et al., 2020). As per Statista data, the global direct carbon price in 2023 is projected to average approximately $23 per ton of CO_2 equivalent (around $167.87). The average transaction price in China's national carbon market is $68.15 per ton, while the average carbon price in the EU ETS is €83.66 (approximately $633.76), which is roughly nine times higher than the Chinese carbon price. In the United States (US) and Canada, the average carbon price is $48 per ton (about $350.34), approximately five times the Chinese carbon price. The average carbon price in the EU ETS is 83.66 euros (about 633.76 yuan), which is roughly nine times higher than the carbon price in China. In contrast, the average carbon price in the US and Canada is 48 US dollars (around 350.34 yuan) per ton, approximately five times the carbon price in China. The carbon price in China is comparatively low compared to other countries, hindering companies from enhancing their environmental performance via technological innovation to achieve Porter's effect (Tang et al., 2020). Therefore, it is fundamental to determine a reasonable carbon price level at the primary stage of the development of China's carbon emissions trading market.

The World Bank: State and Trends of carbon price 2021 indicates that China's carbon price potential remains underexploited (Luo et al., 2021). This implies that devoid of any obligation or advantage, Chinese companies may disregard the low carbon price in distress, potentially resulting in ineffectual outcomes for China's carbon price system. A study indicates that to achieve China's 2030 carbon emissions peak, the carbon market price is projected to exceed 180 yuan per ton (Cao et al., 2021). Tang et

al. (2020) determined the ideal carbon price within the sectoral coverage scenario by modelling the marginal abatement cost curves of several sectors in China's carbon emissions trading system, adhering to criteria that sequentially involved eight sectors. The researchers determined that the ideal carbon price for meeting carbon emission reduction objectives varies between RMB 345 per ton and RMB 1,140 per ton. Consequently, the carbon price system can only be effective if it guarantees a long-term increase in the carbon price to incentivize companies to implement emission reduction strategies.

However, some researches demonstrate the contrary, indicating that carbon price facilitates carbon reduction. Many studies support this positive correlation (e.g., Döbbeling-Hildebrandt et al., 2023; Anser, Khan, et al., 2021; Wu, 2022; Narassimhan et al., 2018; Li et al., 2022; Zhu et al., 2022). Khurshid et al. (2023) demonstrated that carbon price in Central and Eastern Europe reduces intra-regional emissions and serves as an effective short-term mechanism for attaining sustainable development objectives. This is in line with the studies of Gaigné et al. (2020) and Adamolekun (2024). Through a sample of 1,591 companies across 23 European nations, they evidenced that a rise in carbon price diminished company greenhouse gas emissions. The EU carbon market successfully incentivized emission reductions, mostly due to its carbon price exceeding that of the Chinese carbon market, achieving the intended impact.

5.7.3 Carbon Trading Policy on Company Performance

5.7.3.1 Carbon Trading Policy on Economic Performance

The results of this study revealed that the effect of carbon trading policy on the economic performance of the company is insignificant and does not support H3a. There are three possible reasons for this:

a) China's carbon market suffers from lax allocation of carbon allowances (Wang & Zhou, 2020). China's nascent carbon emissions trading system features a significant amount of free allowances. During the preliminary phase of carbon trading policy implementation, the government may provide comparatively ample carbon allowances based on various considerations (e.g., to ensure industry stability) (Long & Goulder, 2023). In certain conventional energy-intensive sectors, such as thermal power

generating, the initial carbon permits provided by the government can satisfy the majority, if not all, of a company's carbon emission requirements. This leads to companies avoiding additional expenses for purchasing carbon permits or implementing technological enhancements to lower carbon emissions. This includes rendering the effect of carbon trading rules on companies' cost structures minimal and hence inconsequential regarding economic performance (Guo & Gong, 2023).

b) China's carbon market suffers from an irrational allocation of allowances. The efficacy of the carbon trading scheme will diminish if carbon allowances are distributed without considering the real production circumstances and the emission reduction capabilities of companies (Yu et al., 2018). Allocating allowances based on a company's prior emission levels is inequitable to companies already implementing partial emission reduction strategies (Peng et al., 2021). These companies may struggle to secure adequate incentives from the carbon trading policy, such as generating revenue from the sale of surplus carbon allowances, due to the allocation of allowances not aligning with their emission reduction benefits. Consequently, the carbon trading policy may have a limited effect on the company's economic performance (Han et al., 2024). Hybrid carbon allowance allocation programs, which combine free and auctioned allowances, are more effective in enhancing the market value of companies than solely free allocation systems. These hybrid programs elevate market value by fostering low-carbon technological innovation and are more effective through this mechanism (Niu et al., 2024).

c) Companies will weigh whether the costs and benefits of reducing emissions can be balanced (Yang et al., 2018). Companies must allocate substantial financial resources, personnel, and materials to implement emission-reduction strategies, including acquiring emission-reduction equipment, innovating low-carbon technologies, and modifying manufacturing processes (Rokhmawati, 2020). If abatement costs are high and the benefits from carbon trading do not offset these expenses, or if the company has limited capacity to pass on abatement costs through alternative methods (e.g., raising product prices), the positive impact of the carbon trading policy on the company's economic performance will be diminished (Zhang et al., 2019).

This is in line with previous studies, where differences in initial quota allocation methods and abatement costs, as well as the volatility of the carbon market, lead to a non-significant effect of carbon trading policy on company value. A study by Nie et al.

(2021) noted that environmental control could not produce a regional Porter's impact. Porter's effect was relatively negated by the pollution haven effect induced by the carbon emissions trading pilot policy. This perspective corroborates the uncertainty hypothesis notion.

However, two contrasting findings are based on the classic hypothesis theory, which posits that carbon trading programs diminish economic performance. Numerous studies from China corroborate this perspective. For example, Ma et al. (2020), Liu et al. (2021), Jafarinejad and Jory (2022) and Adu et al. (2023), utilizing a sample of United Kingdom (UK) non-financial companies from 2009 to 2018, discovered that the real carbon performance of these companies did not enhance their financial or market performance.

According to Porter's hypothesis, carbon trading regimes improve economic performance. Carbon trading programs foster technical innovation, reward emission reductions, and establish a carbon premium, enhancing stock and company values. Previous studies from China (e.g., Zhou et al., 2022; Hang & Chunguang, 2019; Wang et al., 2022) reported similar results.

5.7.3.2 Carbon Trading Policy on Sustainable Performance

This study's results indicate that carbon price policy has a positive and significant effect on sustainable performance (ESG), therefore fully supporting hypothesis H3b. Prior research has indicated analogous results (e.g., Guo et al., 2022; Zhang et al., 2023; Jia, 2023). Li et al. (2024) concluded that after implementing the ETS, energy efficiency is higher in pilot provinces than in non-pilot provinces, and the reduction in carbon emissions from energy efficiency improvements is about 31.4%. The carbon trading mechanism in China's power industry substantially influences emissions reduction, leading to an average decrease of 2.7% in CO_2 emissions and 6.7% in PM2.5 emissions in pilot area power plants, with coal-fired power plants exhibiting even more pronounced reductions (Han et al., 2023). The deployment of the pilot carbon emissions trading system in China resulted in carbon emission reductions of around 24.7%, air pollutant emission reductions of around 10.1%, and synergistic reductions of carbon and air pollutants of about 22.0% (Shi et al., 2024). The execution of China's carbon trading strategy not only diminishes regional carbon emissions but also curtails

per capita CO_2 emissions, yielding long-term benefits. The carbon reduction impact of the carbon pilot strategy exhibits notable heterogeneity in relation to regional carbon emissions and the level of environmental control. The impact is more pronounced in areas with elevated carbon emission density and stringent legal restrictions (Shi et al., 2022).

Carbon trading programs diminish the carbon emission intensity of companies to varying extents, with notable disparities based on ownership types, degrees of marketization, and levels of digitalization. The carbon trading program efficiently mitigates many adverse spillover effects by demonstrating and fostering competitive behaviors among nearby companies. Hence, it promotes carbon emission reduction practices among non-participating industries (Han et al., 2024). The EU ETS, the inaugural and most extensive market-oriented climate strategy globally, prompted regulated industrial companies to decrease their CO_2 emissions by 14 to 16% without a notable decline in economic activity. The EU CETS facilitates worldwide emission reductions, which are essential for mitigating climate change (Wintr, 2021). These studies demonstrate the efficacy of carbon trading policy.

5.7.4 Carbon Finance, Green Technology Innovation on Company Performance

The analysis and discussion of the moderating influence of green technology innovation on carbon finance and company performance are provided here.

5.7.4.1 Carbon Finance, Green Technology Innovation on Economic Performance

The results of empirical analyses in this study do not support hypothesis H4a. The moderating effect of green technology innovation between carbon finance and the company's economic performance is not significant, and the reasons are analyzed in the following from the aspects of green technology innovation itself and carbon finance.

Factors influencing green technology innovation:

a) The company has the problem of insufficient innovation ability. The company's restricted investment in green technology R&D, coupled with a deficiency of R&D personnel, results in minimal green technology innovation. It fails to significantly influence the relationship between carbon finance and company success

(Liu & Zhang, 2024). For instance, certain small, heavily polluting companies lack the financial resources and technical expertise necessary to advance green technology R&D (Lv et al., 2021).

b) The company has difficulties transforming innovation achievements. Numerous impediments exist in transitioning from green technology innovation outcomes to practical implementation in production and operations, including insufficient supporting equipment, challenges in process adjustment, and low market adoption (Huang et al., 2022). Consequently, the breakthrough in green technology fails to promptly demonstrate its advantages in the company's production and operations, thereby inadequately managing the correlation between carbon finance and the company's performance (Abadzhiev et al., 2022).

c) Green technology innovation is characterized by high innovation costs and risks. Green technology innovation is defined by substantial capital investment, extended payback periods, and significant technological risks (Zhang et al., 2022). R&D in green technology necessitates significant financial backing, and the Company may struggle to maintain its investment due to constrained resources (Taghizadeh & Yoshino, 2020). The process of green technology creation, from initial input to economic and environmental advantages, is protracted, making it challenging for the company to perceive short-term benefits (Xie, 2024). There exists uncertainty in green technology R&D, and the company may encounter the danger of failing to overcome technological challenges and succeeding in R&D. These reasons will diminish the company's excitement for green technology innovation, which is detrimental to carbon neutrality (Shao et al., 2021).

Factors influencing the carbon financial market:

a) China's carbon trading pilot market is limited in size. Currently, China's carbon financial market remains in its nascent phase, characterized by a relatively modest market size. From 2013 to 2022, only 230 carbon trading pilot companies were established, resulting in a limited number of participants, which may impose constraints on green technology innovation within the realm of carbon finance financing and application (Zhu et al., 2022).

b) There is a problem with a single variety of products in the carbon market. Currently, the variety of carbon financial products is limited, mostly concentrating on carbon emission rights trading and associated derivatives, with a deficiency of diverse

green financial products to address the financing requirements of various companies (Zhou & Li, 2019). Inadequate liquidity in the carbon finance market may impair the pricing and trading efficiency of green technology innovation products, thus constraining their capacity to improve companies' economic performance (Song et al., 2019).

However, some studies come to the opposite conclusion. Pan (2022), Xie et al. (2022), and Chouaibi et al. (2022) argued that GF promotes technological innovation and economic growth. Similarly, many studies have supported the positive relationship. GF and financial inclusion promote global development. Financial inclusion rose by 0.031%, while trademarks and patents increased by 0.062% (Zhang et al., 2022). A substantial positive correlation exists between GF and green innovation across 30 provinces in China, with GF's direct and indirect effects on green innovation exhibiting significant positive coefficients. GF facilitates the advancement of green innovation in both local and adjacent provinces (Huang et al., 2022). Ma et al. (2023) discovered that GF facilitates green innovation in poor nations and countries with minimal GF levels. Chen et al. (2022) contended that China's green credit policy could substantially enhance low-carbon technological innovation, with a more pronounced effect in state-owned and ESG-certified companies. Furthermore, the policy fosters low-carbon technological innovation by augmenting R&D investment and management efficiency within companies. Gong et al. (2023) demonstrated that environmental innovation, GF, and renewable energy in China can facilitate economic growth.

5.7.4.2 Carbon Finance, Green Technology Innovation on Sustainable Performance

The empirical analysis results in this paper corroborate hypothesis H4b, indicating that green technology innovation significantly moderates the relationship between carbon finance and company sustainable performance. This study is similar to Chen and Chen (2021), Cai and Song (2022), and Zheng et al. (2022), who reported that there is a positive correlation between carbon finance, green technology innovation and sustainable performance. Similarly, many studies have supported the positive relationship. Pilot GF policies have a strong catalytic effect on increasing the degree of emergence of green technologies and promoting innovative activities to treat end-use pollutants and improve green processes. Moreover, pilot GF policy not only promotes

technology diffusion and ESG scores of industrial companies but also reduces the carbon emission intensity of companies (Xu et al., 2023). A study of 639 Chinese companies from 2016 to 2019 reveals that GF significantly reduces urban haze pollution. Each standard deviation improvement in GF corresponds to a reduction of 8.8 $\mu g/m^3$ in PM2.5 concentration. In essence, green financial instruments facilitate environmentally sustainable technical advancement, whereas GF enhances environmental quality by encouraging technological innovation (Zeng et al., 2022).

Zhang and Liu (2022) contended that carbon emission efficiency serves as a metric for assessing carbon emission reduction and sustainable economic development. They asserted that green technology innovation in China significantly influences carbon emission efficiency and that the synergistic effect of digital finance and green technology innovation markedly enhances local carbon emission efficiency. Dong et al. (2022a) discovered that green technology innovation markedly enhances carbon emission efficiency in a study involving 32 developed nations that have established carbon neutrality objectives. Innovations in green technology can indirectly impact carbon emission efficiency by shaping economic development and urbanization. Jian and Afshan (2023) examined the impact of GF and green technologies on achieving carbon neutrality in the G10 economies from 2000 to 2018. Both long-term and short-term projections affirm that GF and technical innovation facilitate carbon neutrality.

5.7.5 Carbon Price, Green Technology Innovation on Company Performance

The analysis and discussion of the moderating effect of green technology innovation on the relationship between carbon price and company performance are detailed here.

5.7.5.1 Carbon Price, Green Technology Innovation on Economic Performance

The empirical analysis results of this work substantiate H5a, indicating that green technology innovation significantly moderates the relationship between carbon price and company economic performance for the following reasons. Carbon price, as a manifestation of market-based incentive environmental control, is a crucial institutional framework for China to expedite the achievement of its carbon peaking and

carbon neutrality objectives (Jia & Lin, 2020). Confronted with carbon emission restrictions, companies may acquire carbon credits in the market to exceed these limits or use technological innovations and reforms to enhance production processes for energy conservation and emission reduction objectives. The cost of carbon trading will compel companies to improve green innovation by influencing their emission expenses (Cai & Ye, 2022).

As the cost of carbon trading escalates, energy-intensive, high-emission and polluting companies will be required to incur substantial expenses for carbon allowances (Shi et al., 2022). To mitigate this environmental cost, the company will pursue transformation by enhancing green R&D investment, upgrading production equipment, refining production processes, elevating product quality, minimizing carbon trading expenses and reducing pollution at the source (Hermeling et al., 2013).

The findings of this study are consistent with the findings of Zhu et al. (2022), Yang et al. (2022), and Anser, Abbas, et al. (2021), who argued that a higher carbon price would push companies to innovate technologically and adopt cleaner technologies, which in turn increases company value. Cui et al. (2018) utilised patent data from Chinese publicly traded companies to provide consistent and solid evidence of an innovation effect produced by an ETS. The research indicated that pilots facing elevated carbon price stimulate patent innovation in low-carbon technology, validating the induced innovation effect of ETS. Conversely, it generates beneficial spillover effects on innovation in sectors beyond low-carbon technologies.

Similarly, many studies have supported the positive relationship. Lim and Prakash (2023) investigated the impact of carbon price on climate innovation. A dynamic panel data analysis of 38 OECD countries over 34 years revealed that the implementation of carbon price policy correlated with an increase in patent applications for climate mitigation technologies, yielding 3.1 patent applications per million in the year of enactment and 5.2 patent applications per million in the long term. Cantone et al. (2023), utilizing data from nations included in the EU ETS, stated that the patenting rate of low-carbon innovations will rise by 1.4% for each $1 increment in the future carbon price. The research additionally revealed that companies systematically revise their anticipations of future carbon price in response to recent price fluctuations. The results indicated that an elevated carbon price serves as a potent catalyst for low-carbon innovation.

5.7.5.2 Carbon Price, Green Technology Innovation on Sustainable Performance

The empirical analysis results in this study do not substantiate hypothesis H5b, indicating that the moderating effect of green technology innovation on the relationship between carbon price and sustainable performance is insignificant. Possible explanations for this include the following:

a) Carbon markets suffer from carbon price volatility and low carbon price. carbon price are influenced by numerous factors, including policy alterations, market demand, and supply dynamics (Zeng et al., 2023). The fluctuation of carbon price may hinder companies' ability to effectively forecast their future carbon emission expenses. This is particularly true in emerging nations where carbon price are more prone to instability due to lower levels of social development and technological progress (Yu et al., 2022). This impacts the efficacy of green technology innovation in carbon price regulation. The initial distribution of carbon allowances in China's carbon market is ample, and as the price is dictated by supply and demand, an excess of carbon allowances will decrease their price (Zhang et al., 2022). The expense of carbon emission permits for high-polluting companies is less than that of green technology innovation. Consequently, high-polluting companies are more inclined to allocate R&D resources to acquire carbon emission allowances (Tang et al., 2015). This induces a crowding-out effect on R&D spending, diminishing the company's capacity to develop green technology.

b) There is insufficient liquidity in the carbon market. China's carbon trading market remains underdeveloped, characterized by limited market activity, low efficiency, and flawed trading regulations, which diminishes the efficacy of carbon emissions trading, resulting in carbon price that may not accurately represent a company's emissions costs (Zhang et al., 2022). The inability to incentivize green technology innovation through effective carbon trading affects sustainable performance (Zhang & Zhang, 2020).

c) Green technology innovation often require high R&D costs and may have higher production costs in the early stages of production due to the immaturity of the technology and the lack of scale effects (Wang & Zhang, 2022). This may make it challenging for companies to achieve significant economic benefits from green

technology innovation in the short term. This impacts its moderating role between the carbon price and sustainable performance (Sadawi et al., 2021).

The findings are contradictory to the findings of Khurshid et al. (2023), Dong et al. (2022), Chen and Wang (2023), and Xie (2022), who argued that a reasonable carbon price mechanism could promote green technology innovation and thus reduce carbon emissions and achieving sustainable performance. Similarly, many studies have supported the positive relationship. Chen and Wang (2023) indicated that to attain China's peak carbon and carbon neutrality objectives, carbon price and technological innovation will assume an increasingly significant role in the near future. Feng et al. (2024) investigated the effects of carbon price on environmentally sustainable innovation. The results of the DID estimation indicate that carbon price substantially enhances green innovation, encompassing both invention patents and utility model patents. Moderator variable, including ESG disclosure, price stabilization mechanisms, and free-quota allocation, can enhance the positive effects of carbon price on sustainable innovation. Note that a heterogeneity analysis indicates that state-owned and large companies, particularly those in the power and pollution sectors, exhibit greater sensitivity to price signals influencing green innovation.

5.7.6 Carbon Trading Policy, Green Technology Innovation on Sustainable Performance

The analysis and discussion below focus on the moderating effect of green technology innovation on the relationship between carbon price policy and company performance.

5.7.6.1 Carbon Trading Policy, Green Technology Innovation on Economic Performance

The results of the empirical analyses in this study support H6a, that green technology innovation plays a positive moderating role between carbon trading policy and economic performance, as evidenced by a number of studies from China (e.g., Zhou & Wang, 2022; Li et al., 2022; Weng et al., 2022; Liu et al., 2022). In contrast to non-pilot regions, carbon emissions trading regimes in pilot regions can stimulate green

technology innovation activities. In all pilot regions, the ETS policy markedly enhances both the quantity and quality of green technology innovation. However, the effect on quantity is considerably more pronounced than on quality. Specifically, in the individual pilot regions of Guangdong, Hubei, and Tianjin, the ETS policy significantly boosts the quantity of green technology innovation and low-quality green technology innovation (Fu et al., 2023).

China's carbon market significantly stimulated green technical innovation among companies, as evidenced by a 28.8% rise in patent applications for green inventions by publicly listed companies following the implementation of the carbon trading program. The execution of the carbon trading regime produced a spatial spillover impact on adjacent cities (Sun et al., 2023). Research on A-share listed companies in China from 2008 to 2018 revealed that the initiation of carbon trading pilots substantially enhanced the green innovation output of the participating companies. Regarding the quality of green innovations initiated by the pilot, companies in the pilot region preferred high-quality green invention patents over low-quality green utility model patents (Liu et al., 2022).

Companies are increasingly focused on disclosing environmental information, and their emissions trading systems have a more pronounced effect on green technology production and its market dominance (Hu et al., 2023). The execution of the carbon trading policy has markedly and consistently influenced the advancement and improvement of green innovation efficiency in pilot locations. Carbon trading stimulates technological innovation and unleashes the potential for green innovation. Carbon trading improves regional green innovation efficiency through the impact of energy substitution and structural upgrading (Liu et al., 2021). The carbon trading program promotes the enhancement of green technology among companies, and this incentivizing effect is enduring. The mediating factors of finance limitations and R&D investment demonstrate sequential mediation effects and nonlinear attributes (Xi & Jia, 2024).

Carbon trading laws foster green innovation in regulated companies, particularly among state-owned entities, companies located in the eastern area, and small to medium-sized companies, with this innovation diffusion occurring via the pricing mechanism (Wu, 2024). Carbon emissions trading positively influences green technology innovation within energy companies, particularly those that are state-owned.

Established companies are more inclined to prioritize green technology innovation than their younger counterparts inside a carbon emissions trading system (Jia et al., 2024). The carbon price program has substantially advanced the coordinated development of green technology throughout China's provinces and has exhibited a localized syphoning impact. The pilot regions of the strategy have drawn talent from adjacent areas, fostered local collaboration, and enabled the synergistic invention of green technologies inside the region (Wang & Simin, 2024).

The findings are contradictory to the findings of Chen et al. (2021), Liu et al. (2020), and Zhang et al. (2022), who argued that carbon emissions trading policy inhibits green technology innovation. Sun et al. (2023) noted that the pilot policy decreased green technology innovation in the energy industry to some degree due to the substantial costs associated with environmental regulatory compliance. The ETS pilot diminished the green technology innovation capabilities of both pollution-intensive and non-pollution-intensive companies. The influence of green technology innovation in the energy industry within the pilot region on similar innovations in neighboring regions is minimal.

Chen et al. (2021) demonstrated that the weak Porter's hypothesis has not been actualized in the existing Chinese carbon trading market. The pilot program results in a significant decline of approximately 9.26% in the proportion of green patents. The pilot policy exhibits a considerable lag effect on suppressing companies' green innovation. The company mostly opted to decrease production instead of enhancing green technology innovation to meet the emission reduction target. The company's diminished investment in R&D, stemming from decreased cash flow and anticipated revenue, is detrimental to green innovation. Zhang et al. (2022b) discovered that carbon trading impedes green technology innovation, although it significantly decreases carbon emissions and intensity. The primary mechanisms are carbon price and R&D spending, while carbon emissions trading exerts a crowding-out impact on company R&D expenditures.

5.7.6.2 Carbon Trading Policy, Green Technology Innovation on Sustainable Performance

The results of the empirical analyses in this study do not support H6b, that green

technology innovation plays a negative moderating role between carbon trading policy and sustainable performance, as evidenced by a number of studies from China (e.g., Liu et al., 2021; Shao et al., 2021; Du et al., 2019). Potential explanations for this finding include the following:

a) There are problems of unreasonable quota allocation and excessive looseness in China's carbon market (Zhang, 2022). The inadequate regulation of total carbon emission quotas undermines the efficacy of carbon emissions trading. A greater carbon emission quota facilitates companies' acquisition of carbon emission quotas from the primary market. Consequently, when the supply of carbon emission allowances sufficiently meets demand, companies' inclination to pursue green technology innovation will diminish (Zhang et al., 2022). China's carbon emissions trading remains in the pilot phase, with the initial allocation of allowances being relatively lenient, primarily utilizing the historical emissions method for free allocation. This gratuitous distribution significantly diminishes the incentive for companies to pursue technological innovation (Lo, 2016).

b) Carbon trading policy lead to increased compliance and governance costs. Neoclassical economic theory posits that heightened environmental regulation intensifies a company's compliance costs and diminishes the competitiveness of its products, hence stifling its inventive endeavors (Sun et al., 2023). As a result of the carbon emissions trading strategy, stringent environmental rules will be enforced in many locations, and the company will be constrained by CO_2 emissions limits. To enhance end-of-pipe carbon emissions management, companies will augment their investment in pollution control. The adoption of ETS elevates the expenses for local industries, particularly those that are pollution-intensive. This includes the direct expenses associated with upgrading environmental equipment and the indirect costs of educating staff to acclimate to new equipment and processes (Sun et al., 2023). To achieve emission reduction targets, companies must incur compliance expenses, displacing creative investment capital (Stoever & Weche, 2018). For instance, financial resources are allocated to carbon emission control instead of R&D initiatives, diminishing the extent of green technology innovation in the area (Li & Jia, 2016).

c) The incremental rise in carbon price will elevate the expense of acquiring carbon allowances, exerting a more pronounced crowding-out effect on the company's short-term investment in green technology innovation (Lyu et al., 2020). Despite the

increasing carbon price in China, it remains comparatively low relative to developed nations (Ghosh et al., 2020). Furthermore, owing to the substantial investment, elevated risk, and extended duration of green technology innovation, the expenses associated with green technology innovation may exceed the costs of acquiring carbon emission allowances (Zhang et al., 2022). The company will allocate more funds to purchase carbon emission allowances, hindering green technology innovation for a specific duration.

The findings are contradictory to the findings of Zhang et al. (2023), Yao et al. (2023), and Huang and Tian (2023), who concluded that the carbon market mechanisms significantly stimulate green technology innovation in pilot companies. This, in turn, promotes carbon emission reduction. The enactment of carbon emission rules can substantially aid in decreasing carbon emissions, with technical innovation serving as the primary mechanism by which these policies facilitate this reduction (Feng et al., 2024). Innovations in environmentally relevant green technology markedly enhance carbon emission efficiency. Enhancing green technology innovation is a method to augment the efficiency of carbon emissions (Dong et al., 2022b). Carbon market policy to enhance the synergistic efficiency of pollution and carbon emission reduction via energy and green production technologies in China (Gan et al., 2024). The execution of CETS led to a 23% rise in the number of patents awarded, substantiating Porter's hypothesis (Yu et al., 2024).

In the process of emission reduction, companies with established technological innovation capabilities achieve more substantial effects. The research indicated that diminishing energy consumption, optimizing energy composition, and enhancing energy efficiency are efficient methods for ETS to attain synergistic emission reductions (Chen et al., 2022). Carbon trading has substantially aided the environmental improvement of manufacturing companies. It has promoted the global energy transition by enhancing government subsidies, R&D investment, and financial limitations (Wang et al., 2024). The researchers indicate that China's National Development and Reform Commission (NDRC) may implement suitable innovation subsidy programs to encourage companies to develop low-carbon technologies (Qi et al., 2021). Building on this, the government can develop a strategic plan for carbon-neutral technological innovation and facilitate coordinated technical advancement (Zou et al., 2021; Hou et al., 2023).

Table 5.24 summarizes the results of the quantitative analysis.

Table 5.24

Summary of Quantitative Findings

Research Questions	Research Objectives	Hypothesis Development	Decision	Research Conclusions
1. What are the different impacts of the carbon market mechanisms (i.e., carbon finance, carbon price and carbon trading policy) on the company performance (economic and sustainability) of heavily polluting industries before and after the implementation of carbon trading policy among the pilot and non-carbon trading pilot companies?	1. To examine the differential impacts of carbon market mechanisms (carbon finance, carbon price and carbon trading policy) on company performance (economic and sustainability) of heavily polluting industries before and after carbon trading policy implementation, compared between pilot and non-carbon trading pilot companies.	H1a: There is a significant positive relationship between carbon finance and company economic performance.	Not supported	Carbon finance and company economic performance are negatively related.
		H1b: There is a significant positive relationship between carbon finance and environmental score.	Supported	Carbon finance positively promotes the improvement of a company's sustainable performance.
		H2a: Carbon price is positively related to the company's economic performance.	Supported	Carbon price positively promotes the improvement of a company's economic performance.
		H2b: Carbon price is positively related to environmental score.	Not supported	The relationship between carbon price and a company's sustainable performance is not significant.
		H3a: Carbon trading policy is positively associated with company economic performance.	Not supported	The relationship between carbon trading policy and the company's economic performance is not significant.
		H3b: Carbon trading policy is positively associated with environmental score.	Supported	Carbon trading policy positively promotes the improvement of the company's sustainable performance.
2. What are the different impacts of green technology innovation on the relationship between carbon market mechanisms (carbon finance, carbon price and carbon trading policy) and company performance (economic and sustainability) of	2. To analyse green technology innovation moderates the impacts of carbon market mechanisms (carbon finance, carbon price and carbon trading policy) on company performance (economic and sustainability) of heavily polluting	H4a: Green technology innovation moderates the relationship between carbon finance and company economic performance.	Not supported	The moderating effect of green technology innovation on carbon finance and company economic performance is not significant.
		H4b: Green technology innovation moderates the relationship between carbon finance and environmental score.	Supported	Green technology innovation positively moderates the relationship between carbon finance and company sustainability performance.
		H5a: Green technology innovation moderates the relationship between carbon price and company economic performance.	Supported	Green technology innovation positively moderates the relationship between the carbon price and a company's economic

heavily polluting industries before and after the implementation of the carbon trading policy between pilot and non-carbon trading pilot companies?	industries, before and after carbon trading policy implementation, compared between pilot and non-carbon trading pilot companies.			performance.
		H5b: Green technology innovation moderates the relationship between carbon price and environmental score.	Not supported	The moderating effect of green technology innovation on carbon price and company sustainable performance is not significant.
		H6a: Green technology innovation moderates the relationship between carbon trading policy and company economic performance.	Supported	Green technology innovation positively moderates the relationship between carbon trading policy and company economic performance.
		H6b: Green technology innovation moderates the relationship between carbon trading policy and environmental score.	Not supported	Green technology innovation negatively moderates the relationship between carbon trading policy and company sustainable performance.

5.8 Focus Areas for Qualitative Discussions

This chapter presents the quantitative findings, revealing that both the baseline regression and the testing of the moderating mechanism yielded inconclusive results. The quantitative data examined represent merely a fraction of the impact and fail to elucidate the underlying reasons for the phenomena. In a qualitative study, it is necessary to investigate the influence of each variable on company performance further. This study will explore the 'why' and 'how' within the framework of China's market economy and social environment.

The EU ETS was initiated in early 2005 as a pilot program and commenced official operations in early 2008, two decades after its inception. In 2013, California created the California CETS, marking it as the inaugural carbon emissions trading system in the US. The Tokyo CET System was instituted in Japan in April 2010, the South Korean carbon market commenced on 1 January 2015, and Australia implemented its carbon price mechanism in July 2012. China initiated seven carbon emissions trading pilots in 2013, and the nationwide carbon market commenced operations in 2022. The duration of carbon market operations differs by country, as do the market's scope of coverage, allowance allocation methods, trading mechanisms, carbon price, and regulatory intensity, among other factors.

This study will examine the operational characteristics of China's carbon market mechanisms, selecting 30 interviewees from both carbon trading pilot and non-carbon trading pilot companies and employing semi-structured interviews to investigate the intricate relationship between the carbon market mechanisms, green technology innovation and company performance.

The qualitative research discussion centers on the motivations of carbon trading pilot companies to engage in carbon trading, the influence of carbon market mechanisms (carbon finance, carbon price, and carbon trading policy) and green technology innovation on company performance (economic and sustainable), the opportunities and challenges encountered by both carbon trading pilot and non-pilot companies, along with the associated issues and proposed solutions. The qualitative findings will be elucidated comprehensively in Chapter 6.

5.9 Summary

This chapter commences with an exposition of the quantitative findings, encompassing diagnostic assessments, parallel trend analyses for carbon trading policy, benchmark regressions, regulatory mechanism evaluations, and robustness tests. This is succeeded by the results and discussion, culminating in a qualitative analysis addressing focal areas. The results of the qualitative research will be elaborated on in Chapter 6.

CHAPTER 6

QUALITATIVE DATA ANALYSIS AND FINDINGS

6.1 Introduction

This chapter examines the qualitative results, the main answer to RQ3. The chapter comprises seven sections: Section 6.2 presents fundamental information about the interviewees; Section 6.3 examines the motivations of companies for engaging in carbon trading; Section 6.4 investigates the impact of carbon market mechanisms (carbon finance, carbon price, and carbon trading policy) and green technology innovation on company performance; Section 6.5 analyzes the opportunities and challenges faced by carbon trading pilot and non-carbon trading pilot companies, and Section 6.6 examines the problems and countermeasures of carbon trading pilot and non-carbon trading pilot companies. Finally, the chapter is summarized.

6.2 Basic Information on Respondents (Participants)

This section presents Research Question 3 (RQ3), which employs an inductive approach to encapsulate the respondents' perspectives, reflecting the selected sample companies in this study. This study primarily utilized Microsoft Voice and telephone interviews to deliver optimal explanations and responses to the research questions.

The interview results examined hitherto uncharted territories, hence enhancing the significance and value of this work. This study categorized the interviewees into two groups of 30 individuals each: one group comprised participants from carbon trading pilot companies throughout seven provinces. In contrast, the other group consisted of individuals from non-carbon trading pilot companies located in areas outside the carbon trading initiatives. All 30 interviewees were from the eight major heavy-polluting industries of electric power, petrochemicals, chemicals, building materials, iron and steel, non-ferrous metals, paper making, and domestic civil aviation, which are more representative of the eight heavy-polluting industries that generate a large amount of Carbon Dioxide (CO_2) in the production process. A total of 15 interviews

were from carbon trading pilot companies (P1-P15) and 15 from non-carbon trading pilot companies (P16-P30), all aged between 30 and over 50 years. This study included 15 females and 15 guys. All respondents possessed over three years of work experience, with the maximum exceeding ten years. Accordingly, 30 respondents represented eight industries, with precise details provided in Tables 6.1 and 6.2.

Table 6.1

Basic Description of Participants (i)

Participants	Industry	Participation in Carbon Trading or not	Age	Gender	Position	Educational Background	Years of Working Experience (Years)	Site
P1	electrical power	Yes	Above 50	F	Finance Manager	CPA	15	Chongqing
P2	electrical power	Yes	Above 40	M	Administrator	Master	10	Tianjin
P3	steel	Yes	Above 40	F	Finance Manager	Bachelor	8	Shanghai
P4	steel	Yes	Above 30	M	Administrator	Bachelor	5	Hubei
P5	petrochemical	Yes	Above 30	F	Administrator	Master	8	Beijing
P6	petrochemical	Yes	Above 40	M	Finance Manager	CPA	10	Shenzhen
P7	paper	Yes	Above 30	M	Administrator	Bachelor	5	Guangdong
P8	paper	Yes	Above 40	M	Finance Manager	Bachelor	10	Shanghai
P9	Chemical	Yes	Above 40	F	Administrator	Bachelor	12	Beijing
P10	Chemical	Yes	Above 50	F	Finance Manager	CPA	15	Shenzhen
P11	Building Materials	Yes	Above 30	M	Finance Manager	Master	5	Guangdong
P12	Building Materials	Yes	Above 40	M	Administrator	Bachelor	12	Chongqing
P13	Non-Ferrous Metals	Yes	Above 30	F	Finance Manager	Master	5	Tianjin
P14	Non-Ferrous Metals	Yes	Above 30	M	Finance Manager	Bachelor	6	Shanghai
P15	Aviation	Yes	Above 30	F	Administrator	Bachelor	5	Hubei

Note: CPA is China Certified Public Accountant

Table 6.2

Basic Description of Participants (ii)

Participants	Industry	Participation in Carbon Trading or not	Age	Gender	Position	Educational Background	Years of Working Experience (Years)	Site
P16	steel	No	Above 50	F	Finance Manager	CPA	14	Qinghai
P17	steel	No	Above 30	F	Administrator	Bachelor	8	Shandong
P18	steel	No	Above 40	M	Finance Manager	Master	12	Shanxi
P19	petrochemical	No	Above 30	M	Administrator	Bachelor	6	Zhejiang
P20	petrochemical	No	Above 30	F	Administrator	Master	5	Heilongjiang
P21	paper	No	Above 40	F	Finance Manager	CPA	12	Anhui
P22	paper	No	Above 30	M	Administrator	Bachelor	5	Henan
P23	Chemical	No	Above 40	M	Finance Manager	Bachelor	10	Liaoning
P24	Chemical	No	Above30	M	Administrator	Master	5	Jiangsu
P25	Building Materials	No	Above 50	F	Finance Manager	CPA	15	Guizhou
P26	Building Materials	No	Above 30	F	Administrator	Master	5	Hubei
P27	Non-Ferrous Metals	No	Above 40	M	Administrator	Bachelor	10	Henan
P28	Non-Ferrous Metals	No	Above 40	F	Finance Manager	CPA	12	Jilin
P29	Aviation	No	Above 30	M	Finance Manager	Bachelor	6	Guangxi
P30	Aviation	No	Above30	F	Administrator	Bachelor	5	Neimeng

Note: CPA is China Certified Public Accountant

The researcher consolidates the findings from the responses of interviewees involved in both carbon trading and non-carbon trading pilots. The motivations for engaging in carbon trading and the impact of the carbon market mechanisms and green technology innovation on company performance are delineated below. This includes the opportunities, challenges, issues, and solutions encountered by both carbon trading pilot and non-carbon trading pilot participants.

6.3 Motivation to Participate in Carbon Trading

The primary interview subjects regarding the company's motivation to engage in carbon trading were 15 individuals from pilot-listed carbon trading companies. Companies engage in carbon trading mostly due to economic motivations, as articulated by interviewers from pilot companies in the electric power sector, who assert that the foremost reason is the opportunity to sell surplus allowances for profit, augmenting the company's revenue. This primarily pertains to companies exhibiting high carbon emission efficiency alongside effective energy conservation and emission reduction practices. The interviewee explained:

> *"Why is my company involved in carbon trading? First of all, it is to make money. The company will compare the purchase of quotas and their own efforts to reduce emissions, which is more cost-effective, and try to find ways to make their own carbon emissions lower than the government's allocation of quotas. The extra quotas can be sold on the market, which will make money, so you can also save some costs." (P1)*

This aligns with prior research indicating that companies can improve green technology advances to diminish carbon emissions, therefore conserving carbon allowances and profiting from the sale of excess permits in the market (Fujimori et al., 2015).

Participants from carbon trading pilot companies in the energy sector recognized a secondary incentive for engaging in carbon trading: the acquisition of policy backing and financial stability. P1 remarked:

> *"The government typically offers financial subsidies and tax advantages to companies innovating in low-carbon technologies, so enhancing their financial security for technological advancement."(P1)*

A respondent from a carbon trading pilot company in the power sector cited a third motive for engaging in carbon trading: technological innovation and competitiveness advancement. P2 confirmed:

> *"To further diminish carbon emissions, our company has augmented the use of renewable and clean energy sources, including solar, wind, hydro, and nuclear energy, enhanced the efficiency of coal-fired power generation, advocated for natural gas power generation, and implemented various innovative technological methods to mitigate carbon emissions. Moreover, the revenue generated from the sale of surplus permits might further stimulate technical innovation, establishing a virtuous cycle."(P2)*

This validates prior studies indicating that China's pilot carbon emissions trading scheme can substantially enhance low-carbon technological innovation (Liu & Sun, 2021). Within the carbon emissions trading framework, low-carbon technology innovation has exhibited a consistent annual development trajectory; sophisticated low-carbon technologies have further augmented the competitive edge of companies in the market (Yao et al., 2024). Qi et al. (2021) indicated that pilot carbon trading policy enhances the low-carbon international competitiveness of companies by fostering low-carbon technology advancement.

Respondent P3 from a carbon trading pilot company in the iron and steel sector asserts that the primary motive for engaging in carbon trading is the impetus for carbon reduction and the cultivation of an environmentally sustainable image. As P3 noted:

> *"Our company was among the initial cohort of pilot companies to engage in carbon trading. Since entering the carbon market in 2013, the annual decrease rate of the company's carbon emissions has ranged from 1% to 2%. "(P3)*

This aligns with prior research indicating that CET has substantially decreased pilot carbon emissions since 2013. Carbon emissions in the pilot's adjacent regions have diminished, demonstrating the presence of spatial spillover effects of CET. Over time, the impact of CET on carbon emissions escalates, although the spatial spillover effect wanes with increasing distance. CET also aids in diminishing carbon intensity (Li & Wang, 2022). The introduction of ETS substantially decreases CO_2 emissions and concurrently produces reductions in the air pollutant Sulfur dioxide (SO2) (Chen et al., 2022). The enactment of carbon trading rules led to a 24.2% reduction in industrial CO_2

emissions across seven pilot locations in China (Zhang et al., 2020).

P3 continue to add:

> *"Consumers prefer companies that have a positive environmental reputation and strong standing. Engaging in carbon trading illustrates our company's commitment to mitigating greenhouse gas emissions, and we frequently showcase our carbon reduction accomplishments on our official website and promotional materials, thereby enhancing the company's reputation and resulting in increased product sales."(P3)*

Interviewees from carbon trading pilot companies within the iron and steel sector recognized an ancillary reason for engaging in carbon trading: enhancing their company's competitiveness in the carbon market. Carbon trading initiatives enhance market competitiveness via carbon assets, people management in carbon sectors, and technological advancements. P3 noted:

> *"To enhance compliance with carbon market laws, our company has established a dedicated carbon asset management department staffed with specialized professionals to oversee carbon emission accounting, carbon quota management, carbon trading strategies, and related services. Enhance the company's competitiveness in the carbon trading sector. "(P3)*

This validates previous research. Luo et al. (2021) investigated all electric power companies in Guangdong Province, China. They also discovered that company behaviors (including low-carbon management, carbon asset trading, and energy-saving and emission reduction technologies) involved in carbon emissions trading affect company competitiveness (i.e., cost competitiveness and green competitiveness). These three types of company behaviors reflect the depth of the company's participation in the Emission Trading System (ETS), and the higher the company's participation, the greater the mediating effect of company behaviors on company competitiveness. Wang and Li (2024) indicated that the carbon emissions pricing mechanism boosts the competitiveness of manufacturing companies by fostering technological innovation and optimizing resource allocation efficiency.

An additional interviewee from a carbon trading pilot company within the steel sector indicated that a third incentive for engaging in carbon trading was to comply with regulatory mandates and evade penalties. Carbon trading is a significant market-oriented regulatory mechanism designed primarily to diminish carbon emissions. P4

remarked:

> *"As the global greenhouse effect intensifies, governmental control of carbon emissions has become progressively strict. Steel companies are the inaugural sector to be incorporated into the carbon trading market, and engagement in carbon trading can mitigate carbon emissions, fulfil emission regulations, and avert penalties for surpassing emission thresholds."(P4)*

The incentives for companies to engage in carbon trading, as summarized from the responses of 15 respondents, include commercial interests, technological innovation, carbon emission reduction, market competitiveness, and compliance with policy to mitigate risks.

Table 6.3 summarizes the results of the qualitative analysis of the motivations of the carbon trading pilots to participate in carbon trading.

Table 6.3
Qualitative Results of Motivations for Carbon Trading

Deductive	Codes	Categorizing	Final theme
Making money	Carbon emissions are lower than the government's allocated allowances Cost savings Financial subsidies and tax incentives	Financial security	Economic interest-driven
Low-carbon, zero-carbon technologies	Improving the efficiency of coal-fired power generation Promoting natural gas-fired power generation Adoption of various new technologies Solar, wind, hydro, nuclear	New energy utilization	Technology innovation-driven
Carbon reduction rate	Carbon emission reduction rate between 1 to 2% Demonstrate carbon reduction results Improve company image Green brand image	Environmental image	Carbon emission reduction drive
Carbon asset management	Carbon accounting Carbon allowance management Carbon trading strategy Fulfillment of customer needs	Carbon management	Market competitiveness
Carbon emission requirements	Limiting carbon emissions Strict regulatory requirements Meet carbon emission requirements Avoid penalties for exceeding emission limits	Carbon regulation	Policy compliance and risk avoidance

Table 6.4 summarizes the PESTLE analysis of companies' motivations for participating in carbon trading, expressed as economic, technological, environmental, social and legal benefits.

Table 6.4
PESTLE Analysis of Motivations for Participation in Carbon Trading

		P	E	S	T	L	E
i	Financial security		/				
ii	New energy utilization				/		
iii	Environmental image						/
iv	Carbon management			/			
v	Carbon regulation					/	

Note: F–Political, E–Economic, S–Social, T–Technological, L–Legal, E–Environmental.

6.4 Carbon Market Mechanisms, Green Technology Innovation and Company Performance

This study aims to validate and further examine the quantitative results by investigating the impact of carbon market mechanisms and green technology innovation on company performance. This work is structured and synthesized from the viewpoints of carbon finance, carbon price, and carbon trading policy, respectively.

6.4.1 Carbon Finance, Green Technology Innovation and Company Performance

Concerning the interplay between carbon finance, green technology innovation, and company performance, participants from the carbon trading pilot in the energy sector highlighted that the primary function of carbon finance is to offer financial assistance and incentives. Respondent P1 provided the following response, citing his company as an illustration:

> *"Our company is developing a large and small cogeneration facility in Yangchuan District, which will significantly reduce emissions upon completion. The project necessitates substantial upfront funding to procure essential equipment from the manufacturer. The Industrial Bank of Chongqing Branch has provided green credit support to our company through a carbon-linked loan program, wherein carbon emissions are correlated with the loan interest rate. Should our company achieve a reduction in carbon emissions to the stipulated threshold (e.g., 1 million tons/year) during the loan term, we may request a reduction in the loan interest rate from the Industrial Bank of Chongqing Branch. This new carbon finance product not only supplies our company with essential capital but also motivates it to decrease carbon emissions, which is a commendable*

decision."(P1)

Participants asserted that carbon finance offers adequate financial assistance for the industry's ecological transformation and improves the company's carbon asset management proficiency. P1 elucidated it as follows:

> *"The local industrial and commercial bank introduced carbon financial instruments, including green bonds and green credit, to our company to offer financial assistance and facilitate our green transformation. Furthermore, our company has optimized the value of carbon emission rights via carbon asset management." (P1)*

Carbon finance promotes Research and Development (R&D) investment and technical advancement. It prompts the company to invest significantly in the R&D of innovative environmental technologies and processes to enhance resource efficiency while minimizing energy consumption and carbon emissions. P1 confirmed:

> *"To secure reduced loan interest rates, our company has augmented its investment in research and development (R&D) by implementing more efficient combustion technologies, energy-saving equipment, and clean energy alternatives while further increasing our R&D expenditure to bolster our green innovation output." (P1)*

> *"Our company has successfully developed a technology for equalizing pressure gas recovery at the summit of the blast furnace, facilitating the efficient utilization of blast furnace gas. Furthermore, our company has implemented DDS biological desulphurization technology, which employs microorganisms to convert supplied in coke oven gas into innocuous molecules, thereby achieving excellent waste gas purification." (P1)*

Interviewer insights corroborate earlier conclusions regarding the favorable correlation between Green Finance (GF) and green technology innovation. The advancement of GF in China enhances the quantity of companies' green technology inventions, and mechanism analyses indicate that GF can motivate companies to augment green technology innovation by mitigating their financing restrictions (Lu et al., 2022). Lin and Bai (2023) examined Chinese listed companies to analyse the correlation between GF development and green innovation, revealing that GF favorably influences green technology innovation.

Innovations in green technology have resulted in additional cost savings, as

noted by respondent P3:

> *"Green technology innovation has numerous advantages; it diminishes carbon emissions while simultaneously lowering energy usage and governance expenses in the production process, resulting in cost savings."(P3)*

The combined impact of carbon finance and green technology innovation enhances the company's financial performance, as articulated by interviewee P5:

> *"The endorsement of preferential loans and the execution of green technical innovations have allowed our company to diminish production costs, manufacture superior chemical products, enhance sales revenues, and bolster our debt-servicing and operational capacities."(P5)*

The interviewers' views validate the previous positive relationship between GF and financial performance. Yu et al. (2023) constructed a regional GF development index to examine the impact of GF on the financial performance of green companies in China. It was discovered that GF can significantly enhance the financial performance of green companies through capital aggregation and information transfer. In addition, R&D innovation plays a bridging role in the impact of GF. Li and Lin (2024) constructed a regional GF development index using empirical data from 2012 - 2022 with green-listed companies as the research object and analyzed the relationship between green financing and company financial capability using the GMM model. The study reveals that regional GF promotes improving a company's financial performance. Mechanism analysis indicates that R&D plays a key role. Xiliang et al. (2023) discovered that company social responsibility and GF significantly positively affect the financial performance of the iron and steel industry. Du et al. (2022) revealed that green credit guidelines have an incentive effect on the green technology innovation and financial performance of Chinese listed companies. In essence, GF is conducive to stimulating the technological innovation and financial performance of green companies.

Respondent P7 stated that integrating carbon finance and green technology innovation enhances the company's environmental performance and brand image.

> *"Through ongoing technological innovation, the company simultaneously decreases CO_2 emissions and enhances the production of environmentally friendly and efficient products and services. Consequently, the company's*

brand image has significantly improved, its sense of social responsibility has been reinforced, and its ESG rating from CSI has escalated from BB to AA. "(P7)

The company's performance has been markedly enhanced through the synergistic interplay of carbon finance and green technology innovation. Respondent P7 examined the four dimensions of economic, technological, environmental, and social advantages. As mentioned by the P7:

"Initially, our company has benefited from a preferential loan interest rate, thereby decreasing the financing cost. Secondly, regarding technical advantages, the implementation of advanced production processes and environmental protection technologies reduces production costs and enhances market competitiveness. Subsequently, regarding environmental advantages, pollutant emissions are efficiently regulated, carbon emission objectives align with carbon market standards, and product reputation is elevated. Ultimately, the company's reputation and commitment to social responsibility are bolstered, and its green transformation fosters low-carbon and sustainable development across the whole industry." (P7)

This case illustrates that carbon finance offers financial support and diminishes financing expenses for the company. In particular, green technology innovation reduces costs and enhances product quality and market competitiveness. The enhancement of company performance subsequently generates additional resources and incentives for carbon finance and green technology innovation. These three entities mutually reinforce one another, creating a positive feedback loop that together expedites the green transformation of the entire company.

Interviewer insights corroborate the prior favorable correlation between green money and sustainable performance. China's GF initiatives effectively diminished industrial gas emissions throughout the research period (Wang et al., 2022). The use of carbon emissions trading markedly enhances the company's ESG performance. The influence of carbon emissions trading on enhancing ESG is especially significant in areas with advanced GF development (Liu et al., 2024). This study analyses the effect of the GF system on micro-level sustainable development, namely companies' ESG, utilizing panel data from A-share listed companies between 2011 and 2022. The research indicates that, notwithstanding a considerable two-year delay in policy impacts, the GF system substantially enhances companies' ESG performance (Jiang et al., 2022).

Green credit strategies markedly improve the environmental and social performance of the relevant companies. The green credit strategy enhances companies' ESG performance by optimizing credit resource allocation, promoting management's environmental consciousness, and augmenting investment in R&D (Ma et al., 2024).

The responses from P1, P3, P5, and P7 align with Porter's prediction that green technology innovation amplifies the impact of carbon finance on company performance. Carbon finance enhances the company's funding sources and facilitates its green transformation. Innovations in green technology enhance the company's production efficiency and product quality while decreasing carbon and pollution emission costs. Carbon finance and green technology innovation collaboratively enhance the company's economic, environmental, and social advantages.

China is a significant industrial and manufacturing nation characterized by elevated carbon emissions from conventional sectors such as steel, chemicals, and cement (Zhao et al., 2022). Chemical companies are progressively prioritizing carbon finance and green technology innovation to adjust to carbon emission mechanisms and low-carbon development effectively. Interviewee P9 hails from a prominent chemical company and evaluates it through the lens of compliance expenditures and financial limitations. As P9 stated:

> *"Financial institutions favor green industries, and the implementation of green credit policy prompts banks to enhance their front-end emissions audits of companies in high-pollution sectors, resulting in increased compliance costs for these companies, specifically the expenses associated with adhering to green credit regulations. This indicates an escalation in funding constraints for companies in substantially polluting sectors as the rigor of green finance laws intensifies." (P9)*

> *"Green credit establishes a stringent environmental compliance standard for companies in highly polluting sectors to secure bank financing. Carbon finance will impede the company's development, as it faces pressure from environmental policy to enhance investments in pollution control and technological research and development. Consequently, production and operational costs will escalate, leading to financing constraints. The company must allocate funds for environmental protection, thereby restricting resources available for technological innovation and production process reforms due to increased compliance costs and heightened financing limitations. Thus, carbon finance will diminish the positive impact of environmental regulation on company performance." (P9)*

Respondent P9's perspective aligns with the compliance cost hypothesis, corroborating the quantitative analysis result H1a in Chapter 5 of this study, which indicates that heightened compliance costs and financing constraints adversely affect the impact of carbon finance on company performance. The GF strategy enforces differential lending criteria, imposes tight limitations on loans to polluting companies, and heightens external funding restrictions for polluting sectors inside manufacturing (Wang, 2023). Credit policy have curtailed financing for heavily polluting industries by elevating the financing threshold and denying loans to highly polluting companies, thereby regulating the funding of companies and projects that violate credit policy and environmental standards (Yin et al., 2023). Industries that significantly pollute must adhere to GF policy and incur higher environmental costs and risks, resulting in increased debt financing costs and a punitive effect. Moreover, the credit limitations and disincentives for investment imposed by GF rules impede innovation in heavily polluting sectors, diminishing the efficacy of green innovation within these industries and thereby impacting company performance.

Table 6.5 presents the qualitative analysis of the relationship between carbon finance, green technology innovation, and company performance.

Table 6.5

Qualitative Results of Carbon Finance, Green Technology Innovation and Company Performance

Deductive	Codes	Categorizing	Final theme
Favorable policy	Green credit support Linking carbon emissions to lending rates Reduced lending rates Carbon financial products such as green bonds and green credits Reduced production costs and enhanced product market competitiveness Preferential loan rate support reduces financing costs Financial flows to low-carbon, high-efficiency projects Diversified financing channels Optimization of resource allocation	Financing support	Economic benefits
Green innovation outputs	Adoption of more efficient combustion technologies, energy-saving equipment or clean energy alternatives Effective utilization of blast	Technology upgrade	Technical benefits

	furnace gas Effective purification of exhaust gases Reduction of energy consumption and treatment costs Enhancing technological competitiveness Promote the improvement of technical system			Positive impact
Environmentally friendly image	Reduced CO_2 emissions Greener and more efficient products and services Hua Zheng ESG Rating upgraded from BB to AA Optimizing the energy mix Promoting environmental protection industry	Brand image	Environmental benefits	
Company governance	Company reputation enhancement Social responsibility enhancement Promoting low-carbon awareness in society Create green employment opportunities Enhance social recognition and reputation	Social responsibility	Social benefits	
Emission audits	Front-end emissions audits Increased compliance costs Monitoring and reporting costs Quota management costs Compliance training and consulting costs	Environmental compliance	Compliance costs	Negative impact
Governance investments	Increase investment in pollution control Squeezing production and operation funds to fulfill environmental protection goals Constraining funds for technological innovation and production process reforms	Financing costs	Financing constraints	

Table 6.6 summarizes the PESTLE analysis of the relationship between carbon finance, green technology innovation and company performance in terms of economic benefits, technological benefits, environmental benefits, social benefits, compliance costs and financing constraints.

Table 6.6

PESTLE Analysis of the Relationship between Carbon Finance, Green Technology Innovation and Company Performances

		P	E	S	T	L	E
i	Financing support		/				
ii	Technology upgrade				/		
iii	Brand image						/
iv	Social responsibility			/			
v	Environmental compliance					/	
vi	Financing costs		/				

Note: F–Political, E–Economic, S–Social, T–Technological, L–Legal, E–Environmental.

6.4.2 Carbon price, Green Technology Innovation and Company Performance

The power sector is a fundamental component of the national economy, and the thermal power industry generates significant CO_2 emissions during production. The government enforces stringent carbon emission regulations on the power sector, and the carbon price mechanism has progressively emerged as a crucial economic incentive to encourage power companies to reduce carbon emissions. Concurrently, green technology innovation has become vital for these companies to transition to a low-carbon model and achieve sustainable development.

The respondent from the power sector, P2, stated that the carbon price mechanism had a dual impact on companies. On one hand, the carbon price system compels companies to incur elevated expenses associated with carbon emissions. Per market regulations, a company that surpasses the designated carbon quota must remit a tax for every tonne of CO_2 emitted. This imposes more financial pressure on electricity companies with larger generation capacities. Conversely, the carbon price mechanism serves as an incentive for companies to diminish emissions, he stated:

> *"Upon entering the carbon market in its nascent stage, the company's carbon emissions surpassed its allocated limit, with the carbon price at $30 per ton, while the expense for acquiring supplementary allowances reached $200,000 per ton. This financial strain compelled the company's executives to critically evaluate strategies for reducing carbon emissions." (P2)*

In response to the cost challenges posed by the carbon price, the company undertook a reconfiguration of its energy sourcing. As mentioned by the P2:

"The share of renewable energy sources, including solar and wind, has been

augmented in energy procurement. The efficiency of energy utilization has been enhanced by optimizing the operational parameters of power-producing apparatus, augmenting equipment maintenance, and implementing additional measures."(P2)

In order to reduce carbon emissions and meet the challenges posed by the carbon price mechanism, the company has significantly increased its R&D investment in green technology innovation. P2 added that:

"In recent years, R&D spending as a proportion of the company's operating expenses has risen annually from 20% to 38%."(P2)

"The company has achieved advancements in power production and energy storage technologies, effectively developing highly efficient solar photovoltaic and wind power generation systems, hence enhancing energy conversion efficiency. The company has engineered sophisticated energy storage battery systems capable of efficiently storing surplus power, hence facilitating the extensive implementation of sustainable energy."(P2)

This corroborates prior literature indicating that the price-market size dual-effects model can enhance the number of green technology breakthroughs via carbon trading prices, market size, and the extent of government intervention (Chang & Zhao, 2024). Carbon price exerts a modest beneficial impact on productivity and creativity. All studies indicate a statistically significant rise in patent applications. Thus, implementing a favorable and consistent carbon price, even at a modest beginning level, would convey a definitive policy direction to engaged companies. Ultimately, encouraging companies to implement improved pollution control technologies would mitigate competitiveness risks (Venmans et al., 2020).

Innovations in green technology have effectively managed the company's production costs. In contrast, company expansion has augmented Return on Assets (ROA) and return on net assets, culminating in increased financial performance and enhanced profitability. Interviewee P2 from the energy sector and interviewee P3 from the steel sector elucidated:

"Efficient solar and wind power initiatives have substantially contributed to the Company's profit expansion and asset improvement. In the previous year, the company accomplished a 10% decrease in total expenses and a 15% rise in net profit."(P2)

> *"Despite the rise in expenses due to the implementation of a carbon price, the cost reductions and enhanced product competitiveness resulting from green technology innovation allowed the company to achieve consistent growth in operating income and net profit margin."(P3)*

This aligns with hypothesis H2a of this study, which asserts that carbon price enhances companies' economic performance. It further corroborates prior research findings. Tang et al. (2022) indicated that CET regulations enhance the market value of publicly traded companies by affecting carbon price, fostering creative operations, and promoting carbon transparency. Similarly, Scholtens and Van Der Goot (2014) highlighted that subsequent to the initial phase of the EU ETS, fluctuations in carbon price exert a substantial beneficial influence on stock market returns across all four sectors: oil and gas, electricity and heat, cement and lime, and steel.

Green technology innovation is manifested in the R&D of novel technologies and in the optimization and enhancement of manufacturing processes. P1 clarified:

> *"The company optimally utilizes the residual heat and pressure produced during power generation by implementing heat recovery systems, thereby repurposing the residual heat for heating or industrial production, which enhances the overall energy utilization efficiency. Furthermore, enhancing the power generation process diminishes the emission of waste gases, wastewater, and other pollutants, so achieving the objectives of energy conservation and emission reduction."(P1)*

By implementing green technological advancements, the company has attained substantial benefits and diminished its overall carbon emissions. P6 from the petrochemical sector stated:

> *"The carbon price functions as a mechanism compelling high carbon emission industries to diminish their emissions. In comparison to the period prior to the adoption of green technology innovation, our carbon emission intensity has decreased by 10%, establishing a robust basis for our company to confront the challenges posed by the carbon price."(P6)*

Consequently, corroborating prior studies, carbon price incentivize decreases in carbon emissions. In a carbon emissions trading system, elevated carbon taxes and permit prices diminish carbon emissions. An increase of $10 per ton in the carbon tax results in a 1.3% reduction in per capita CO_2 emissions in the short term and a 4.6% reduction in the long term (Kohlscheen et al., 2021). The EU ETS is the inaugural and

most extensive market-oriented climate strategy globally. At the same time, the CET policy has compelled regulated manufacturing companies to diminish their CO_2 emissions by 14-16% without a notable decline in economic activity (Wintr, 2021).

Augmented non-financial performance and elevated company reputation. The company's active engagement in green technology innovation and emission reduction activities has fostered a positive reputation throughout the community. This aids the company in attracting exceptional people and partners and fosters a conducive external environment for the company's sustained success. P8 noted:

> *"Our company achieved the highest position in the ESG score rankings published by reputable companies such as CSI, so augmenting our brand image and social impact."(P8)*

> *"Our company has received honorable titles such as ecologically advanced company and sustainable development Model Company, garnering widespread recognition and acclaim from the government, the public, and customers."(P8)*

Execution of social obligation. The company achieves energy conservation, emission reduction, and resource recycling through innovations in green technology, contributing positively to environmental protection and sustainable development. P9 confirmed:

> *"The company engages in public welfare initiatives, advocates for green environmental protection, and upholds its social duty. This amplifies the company's commitment to social responsibility and mission, hence augmenting social value."(P9)*

Augmented capability for sustainable development. Innovations in green technology have established a robust foundation for the company's sustainable development. The company exhibits enhanced competitiveness and agility in the carbon market through ongoing research, development, and implementation of modern green technologies. P9 stated:

> *"Our company engages in public welfare initiatives focused on environmental protection and fosters collaboration with government entities, social companies, and other companies, thereby enhancing our sustainable development capacity to collectively advance the industry's sustainability."(P9)*

Carbon price schemes offer both prospects and obstacles for the advancement of significantly polluting sectors. Implementing a favorable and consistent carbon price, even at a modest beginning level, would convey a definite policy direction to companies engaged in carbon trading. Faced with a carbon price, the heavily polluting industry must lower production costs and enhance energy efficiency via technical innovation. Hence, innovations in green technology enhance both the financial and non-financial performance of the company, yielding significant economic, technological, environmental, and social advantages. This, ultimately, facilitates the sustainable development of the entire industry.

The carbon price embodies the polluter pays concept, as indicated by respondent P11 from the building materials sector, who noted that an increase in carbon price correlates with elevated carbon expenses for the company. P11 confirmed:

> *"Carbon price, it's like a carbon tax, whoever emits more carbon has to pay more."(P11)*

The carbon tax has significantly affected the high-carbon emission building materials sector. To enhance adaptation to the carbon market mechanisms and diminish carbon emissions, the company has augmented its investment in the R&D of sophisticated energy-saving, emission reduction, and environmental protection technologies. Elevated carbon price augment the R&D expenditures of emission control companies, thereby diminishing their economic performance in the short run. P11 noted:

> *"As the market price of carbon emission rights increases, the associated carbon costs for the company will likewise escalate. The construction materials sector is characterized by significant carbon emissions, resulting in elevated carbon costs that may adversely affect the company's valuation."(P11)*

> *"Our company has significantly invested in the research and development of flue gas desulfurization, denitrification technology, and dust control technology. This substantial investment in R&D will impact the company's free cash flow, subsequently influencing economic performance."(P11)*

The carbon market was created to incentivize companies to reduce carbon emissions, with the price of carbon emission rights serving as its primary motivator. An increase in the price of carbon emission rights incentivizes emission control companies

to invest in R&D of energy-efficient and emission-reducing technologies, potentially benefiting these companies in the long term. However, in the short term, this may diminish their value by directly impacting R&D expenditures over a few years. Thus, in alignment with the prior report, elevated carbon price may adversely affect company valuations in the short term. Zhang and Zhang (2023) revealed that carbon price adversely affect the stock returns of companies within regional markets, with the impact being particularly significant in the Shenzhen and Guangdong areas. Moreover, companies with high carbon intensity are more susceptible to this adverse effect than those with low carbon intensity. Zhang et al. (2018) examined the influence of carbon price on the valuation of thermally listed companies and the degree of its effect across several pilot programs in China. The findings indicated that carbon price substantially negatively affects stock valuation, with variations observed across different markets.

P13 commented on the current carbon market price in China:

> *"Carbon price have remained low due to China's excessive allocation of initial allowances, with Beijing recording the highest average annual carbon price from 2013 to 2023, approximately $66 per ton. Shanghai possesses the second-highest average annual carbon price in the nation, almost $37 per ton. Shenzhen's average yearly carbon price is approximately RMB 33 per ton. The mean yearly carbon price in Guangdong Province is approximately $38 per ton. Chongqing's average annual carbon price is approximately 22 yuan per ton, but both Tianjin and Fujian have an average annual carbon price of around 20 yuan per ton. From 2013 to 2023, the carbon price in the European Union attained 40 euros per ton (about 300 yuan), whereas in the United States, it reached 48 US dollars per ton (around 345 yuan). In comparison to other nations, China's carbon price is insufficiently elevated, hindering the advancement of company technological breakthroughs aimed at enhancing company value and achieving Porter's effect."(P13)*

This aligns with hypothesis H2b in Chapter 5 of this study, as the low carbon price in the Chinese carbon market does not enhance sustainable performance. Therefore, establishing an appropriate carbon price level is essential in the initial phase of China's carbon emissions trading market growth, and the carbon price should be sustained within a fair range. The fundamental principle of the carbon market mechanisms is to incentivize companies to adopt emission reduction strategies by leveraging price signals within the carbon market to optimize their own interests. An

illogical carbon price will adversely affect both the functioning of the carbon market and the regulated entities. An unduly elevated carbon price will impose an unjustified production and operational cost on companies, whereas an excessively low carbon price will fail to incentivize companies to adopt emission reduction measures proactively. Establishing a standard supply and demand dynamic in the carbon market necessitates regulators devise a methodical strategy for the total quantity of carbon emission allowances and their distribution.

Table 6.7 presents the qualitative analysis of the relationship between carbon price, green technology innovation, and company performance.

Table 6.7
Qualitative Results of Carbon Price, Green Technology Innovation and Company Performance

Deductive	Codes	Categorizing	Final theme	
Asset enhancement	Cost savings Improved product competitiveness Steady growth in operating income and net profitability Reduced total costs by 10% and increased net profit by 15% Sale of surplus quotas Lower carbon footprint of products	Profit growth	Economic benefits	
New energy	Increased investment in research and development Highly efficient solar photovoltaic and wind power technologies Improved energy conversion efficiency Advanced energy storage battery system Dynamics of Innovation Technology Introduction and Cooperation	R&D investment	Technical benefits	Positive impact
Pollutant emissions	Improved the comprehensive use of energy efficiency Reduced emissions of waste gas, wastewater and other pollutants Reduced carbon emission intensity by 10% Improvement of regional environmental quality Mitigating climate change	Energy saving and emission reduction	Environmental benefits	
ESG score	ESG scores rise Environmentally advanced company Sustainable development demonstration company Enhanced sense of social responsibility and mission of the company	Social responsibility	Social benefits	

	Enhanced sustainable development capability Employment and industrial development Enhancement of public recognition and trust in companies			
Purchase of additional quota	Whoever emits more carbon will have to pay more Rising cost of carbon Investing large amounts of money R&D investment affects a company's free cash flow Increased direct costs Investment and transformation costs Excessive carbon price can increase business costs significantly	Cost of carbon	Cost pressure	Negative impact
Quota allocation	Over-allocation of initial allowances Carbon price too low Insufficient incentive to reduce emissions Inability to effectively guide the flow of social capital to the low-carbon sector Increased market uncertainty	Carbon price level	Reasonable carbon price	

Table 6.8 summarizes the PESTLE analysis of the relationship between carbon price, green technology innovation and company performance in terms of economic benefits, technological benefits, environmental benefits, social benefits, cost pressures, and carbon price level impacts.

Table 6.8

PESTLE Analysis of the Relationship between Carbon Price, Green Technology Innovation and Company Performances

		P	**E**	**S**	**T**	**L**	**E**
i	Profit growth		/				
ii	R&D investment				/		
iii	Energy saving and emission reduction						/
iv	Social responsibility			/			
v	Cost of carbon		/				
vi	Carbon price level		/				

Note: F–Political, E–Economic, S–Social, T–Technological, L–Legal, E–Environmental.

6.4.3 Carbon Trading, Green Technology Innovation and Company Performance

As worldwide apprehension regarding climate change escalates, reducing carbon emissions has emerged as a critical objective for governments and companies. In this context, carbon trading has arisen. Interviewee P14 from the non-ferrous metals sector elucidated the fundamental principles of carbon trading and aggregate control in accessible language. He stated:

> *"Carbon trading assigns a monetary value to a company's carbon emissions. A company that emits significant carbon must purchase emission rights; conversely, if it reduces its emissions, it may profit from the surplus rights. Consequently, the company will be motivated to decrease carbon emissions, as it can achieve cost savings."(P14)*

Company performance typically exhibits variations before and after participation in a carbon trading pilot. Participants from carbon trading pilot companies in the energy sector evaluated alterations in financial performance. Financial performance is quantified by quota trading gains. P1 noted:

> *"Our company has significantly diminished its carbon emissions through the implementation of Carbon Capture, Utilization, and Storage (CCUS) and Smart Grid technology, resulting in a surplus of allowances that we sell for additional profit. "(P1)*

Financial performance is characterized by cost savings and an improved financing environment. P1 added:

> *"Our company has improved the efficiency of energy use and reduced the cost of carbon emissions by improving the production process and upgrading equipment."(P1)*

> *"Our company has commendable performance in carbon emission reduction, acknowledged by investors and endorsed by financial institutions. The local Industrial Bank has provided us with favorable interest rate loan support, thereby decreasing our financing costs."(P1)*

In accordance with prior research, the execution of the pilot ETS enhances the financial performance of companies and elevates their ROA by 0.01 units. The pilot ETS markedly enhances the financial performance of non-state-owned companies

while leaving state-owned companies unaffected. The enhancement in financial performance is more pronounced for non-energy sector companies compared to those in the energy sector (Yu et al., 2022). The carbon emissions trading system is significantly and positively related to the company performance of energy-intensive companies (Sun et al., 2022).

Participants from carbon trading pilot companies within the petrochemical sector subsequently assessed alterations in innovation performance. Innovation performance is defined by the impetus for technological innovation. Respondent P6 analyzed the correlation between carbon trading, green technology innovation, and company performance.

> *"Technological innovation is the primary catalyst for carbon neutrality, whereas carbon trading establishes a benchmark for companies to achieve. Innovations in green technology are essential for companies to surpass this level. This key enables the company to enhance compliance with environmental protection standards, optimize performance, and capture market share. Our company has allocated substantial human, material, and financial resources to the research and development of low-carbon transformation of coal power, cogeneration technology, and energy storage technology."(P6)*

This aligns with hypothesis H6a in Chapter 5 of this study, which posits that green technology innovation and carbon price regulations together enhance company performance. Green technology innovation helps companies enhance production efficiency, minimize expenses, and augment competitiveness. Consequently, company performance inherently improves. This aligns with other research indicating that the carbon price regime substantially enhances green technology innovation in Chinese A-share listed companies. The beneficial effect is more pronounced for companies with substantial capitalization and superior company governance, particularly within the mining and manufacturing sectors (Liu & Liu, 2023). Furthermore, carbon emissions trading policy significantly influences companies' green innovation, especially in non-state-owned companies, major companies, and clean industries. The influence of carbon emissions trading regimes on green innovation mostly manifests through internal incentives, with the cost compliance effect and the innovation compensation effect serving as the principal mechanisms that foster green innovation (Wu et al., 2023). In addition, ETS advances local green transformation by fostering green innovation,

optimizing industrial structures, and enhancing urban energy efficiency (Bian et al., 2024).

Participants from carbon trading pilot companies in the non-ferrous metals sector subsequently evaluated alterations in environmental performance. The environmental performance is quantified by diminished carbon emissions and enhanced efficiency in resource utilization. Carbon trading has resulted in a substantial decrease in the company's carbon emissions, allowing it to comply with the quotas set by the carbon market and fulfil its obligations within that market. As P13 shared:

> *"Our company enhances the production process, implements clean energy solutions, optimizes the utilization of solar, wind, and hydro energy, and boosts the efficiency of renewable energy usage. "(P13)*

P14 added:

> *"To comply with the carbon market criteria and retain the remaining quota, our company will reduce carbon emissions by 200,000 tons annually from 2021 to 2023. Despite technical revolution and enhancement, there remains potential for increased emission reduction capability. "(P14)*

This confirms hypothesis H3b in Chapter 5 of this study, which states that carbon trading policy promotes improved environmental performance. Bai and Ru (2022) analyzed the impact of ETS adoption on emissions reductions and renewable energy utilization using a sample of the 100 countries with the highest global Gross Domestic Product (GDP) in 2020. The analysis revealed that introducing the ETS across different countries considerably reduced greenhouse gas (CO_2) emissions by 12.1% (18.1%). The CETS resulted in an average decrease of 23.70% in fossil fuel use, including coal, while simultaneously increasing renewable energy usage by an average of 61.59%, reducing overall emissions.

P14 proceeded to add from the perspective of company carbon management and carbon disclosure:

> *"Carbon trading compels companies to enhance their carbon emission monitoring, reporting, and management systems, reveal their carbon emissions, emission reduction objectives and strategies, and timely fulfil social duties, thereby increasing the efficiency of carbon management."(P14)*

This supports previous findings in the literature where Tian et al. (2024) reported that market-based environmental regulatory tools ETS significantly enhance company ESG performance by constructing a time-varying DID model. Shen (2024) revealed that the ETS considerably affects several industries beyond the heavily polluting sector and notably enhances the ESG scores of agricultural companies.

Interviewees P1 and P2 from the carbon trading pilot in the power sector provided a comprehensive summary of the interconnections among carbon trading, green technology innovation, and company performance, elucidating the innovation effects, incentive effects, and punishment effects. P1 and P2 elucidated that.

> *"The innovation effect denotes a company's ability to lower emission reduction costs through enhanced technological innovation or the utilization of high-efficiency equipment, thereby facilitating its own emission reductions. The surplus carbon emission allowances are then sold in the carbon trading market, with the proceeds reinvested into further technological advancements, thereby perpetuating continuous innovation." (P1)*

> *"The incentive effect indicates that companies utilize the revenue from carbon allowance sales to enhance low-carbon technologies; the greater their investment, the higher their returns. Companies consistently achieve emission reductions at a marginal abatement cost lower than the carbon allowance price, thereby creating a virtuous cycle that exemplifies the incentive effect of carbon trading policy." (P2)*

> *"The penalty effect denotes that to evade sanctions from pertinent authorities due to heightened carbon emissions resulting from production expansion. A company will implement appropriate measures to mitigate emissions and offset the expenses incurred from purchasing allowances, thereby ensuring it does not forfeit developmental opportunities amidst elevated demand for carbon emissions." (P2)*

The aforementioned circumstances compelled the company to augment capital investment in technological innovation, enhance capital conversion efficiency, bolster competitiveness, and facilitate carbon emission reduction while simultaneously boosting operational efficiency.

The carbon emissions trading policy is a comprehensive emissions trading framework that commercializes carbon emissions and establishes a cap on the total CO_2 emissions for a specified future timeframe. The carbon emissions trading system is

government-led and market-operated. In contrast to the command-and-control mechanism, the carbon trading system encourages companies to achieve self-directed emission reductions based on their specific circumstances. These can be achieved by altering their strategies, modifying their company models, and acquiring carbon emission rights from the trading market through various methods to minimize carbon emission costs. Guided by the carbon emissions trading mechanism and governmental policy, investments will inherently gravitate towards low-carbon sectors. This fosters the advancement of green technologies within companies and facilitates the societal transition to a low-carbon economy.

The interconnection between carbon trading, green technology innovation, and company performance is significant. To maintain a strong position in a competitive market, companies must prioritise the interplay of these three elements, actively advocate for green technical innovation, and enhance company performance. The carbon trading market offers companies financial incentives to decrease emissions, encouraging enhanced carbon emission management and cost reduction in carbon emissions. Green technology innovation is essential for companies to achieve carbon emission reduction and sustainable development, enhancing energy efficiency, lowering manufacturing costs, and improving market competitiveness. Companies in heavily polluting industries must acknowledge the significance of carbon trading and the creation of green technologies, actively engage in the carbon trading market, and enhance their investment in green technology innovation.

Respondent P7 from a carbon trading pilot company in the paper industry examined the adverse effects of carbon trading concerning cash flow and short-term cost escalations. P7 confirmed and explained:

> *"When a company possesses surplus allowances exceeding its actual emissions, it can monetize this excess in the carbon market, resulting in a cash inflow. Conversely, companies utilizing obsolete production equipment and technology, which have allowances insufficient to cover actual emissions, must purchase additional allowances, leading to a cash outflow that adversely impacts the company's valuation."(P7)*

> *"To comply with carbon emission reduction standards, the company must invest significantly in technological transformation and equipment renewal during the initial phase of carbon trading, leading to increased short-term costs that adversely affect performance. However, in the long term, the*

positive effects of carbon trading on the company's performance will outweigh the negative impacts."(P7)

P9 and P10 from the chemical industry believe that the implementation of carbon trading has brought carbon asset management costs and compliance and certification costs to the company, as explained by the respondents:

"After the implementation of carbon trading, the operating costs of companies have increased significantly. The first and foremost is the cost of carbon asset management. Companies need to set up professional teams or hire external consultants to accurately monitor and analyze carbon emission data and plan for the use and trading of carbon allowances, which involves a number of expenditures such as manpower and consulting."(P9)

P10 added:

"The cost of compliance and certification should also not be underestimated. In order to meet the requirements of the carbon trading policy, the company has to accept strict verification by the third-party organization on a regular basis to ensure that the carbon emission data is true and accurate and that the operation process is compliant. The cost of verification and the labor and material resources invested in the preparation of information all add to the burden of the company and, to a certain extent, affect the allocation and turnover of funds." (P10)

This aligns with hypothesis H3a in Chapter 5 of this study, as the rise in cash flow and short-term expenses may result in an insignificant impact of carbon trading legislation on the company's economic performance. The company's acquisition of carbon credit allowances may impose further cost pressures. This may impact the company's cash flow, resulting in diminished profit margins. The company need substantial resources for R&D, has an extended timeline for R&D, and may incur risks and losses associated with R&D failures (Zhang et al., 2022). In the medium term, the substantial capital investment will affect the company's cash flow, perhaps exacerbating difficulties from significant cash outflows and R&D expenses. Furthermore, the prolonged technology investment cycle prevents the immediate technological impact from being realized, which may lead to the company's production failing to satisfy governmental mandates, hence incurring penalty costs. Consequently, in the short run, companies impacted by introducing carbon emissions trading may

experience a decline in profits and a reduction in value.

The conclusion is empirically corroborated by certain scholars. The establishment of the carbon emissions trading system elevates companies' operational expenses. Covered companies must incur both explicit and implicit costs to meet emission reduction objectives, encompassing MRV costs, compliance expenses, and investments in low-carbon technologies, all of which adversely affect their financial performance (Clarkson et al., 2015). Moreover, carbon price liquidity influences company performance, and the cash flow impact resulting from the sale of surplus allowances is contingent upon carbon market liquidity. In an illiquid market, carbon market volatility escalates, resulting in unpredictable carbon price. The company's cash flow is diminished, concurrently elevating the disclosure risk and adversely affecting its value (Zhang & Zhang, 2023).

Table 6.9 summarizes the results of the qualitative analysis of the relationship between carbon trading, green technology innovation and company performance.

Table 6.9
Qualitative Results of Carbon Trading, Green Technology Innovation and Company Performance

Deductive	**Codes**	**Categorizing**	**Final theme**	
Remaining quota	Surplus quota sold for extra profit Saves money Reduced cost of carbon emissions Support from financial institutions Loan support at favorable interest rates Reduced financing costs Attracting significant investment and resources Enhance market value	Quota trading benefits	Economic benefits	
New technology	Green technology innovation is the key Low-carbon transformation of coal power Cogeneration Technology Energy Storage Technology High-efficiency equipment Stimulating investment in innovation Low-carbon technology adoption accelerates	Technology innovation	Technical benefits	Positive impact
Abatement capacity	Improving the efficiency of new energy use Adoption of clean energy Reduce carbon emissions by	Energy saving and emission reduction	Environmental benefits	

	200,000 tonnes Emission reduction capacity has room to increase Decarbonization transition Improvement of environmental quality Promote optimization of energy structure			
Carbon emissions management	Carbon Emissions Monitoring, Reporting and Management System Disclosure of carbon emissions Improve carbon management efficiency Enhance brand value and social influence Increase public awareness and participation in environmental protection	Carbon management	Social benefits	
Cash outflow	Cash outflow due to purchase of shortfall quota Commitment of large amounts of capital Increase in short-term costs Technical modifications Equipment renewal Investment costs of abatement technologies Equipment Replacement and Retrofit Costs Carbon asset management costs Compliance and Certification Costs	Short-term costs	Cost pressure	Negative impact

Table 6.10 summarizes the PESTLE analysis of the relationship between carbon trading, green technology innovation and company performance in terms of economic benefits, technological benefits, environmental benefits, social benefits and cost pressures, respectively.

Table 6.10

PESTLE Analysis of the Relationship between Carbon Trading, Green Technology Innovation and Company Performance

		P	**E**	**S**	**T**	**L**	**E**
i	Quota trading benefits		/				
ii	Technology innovation				/		
iii	Energy saving and emission reduction						/
iv	Carbon management			/			
v	Short-term costs		/				

Note: F–Political, E–Economic, S–Social, T–Technological, L–Legal, E–Environmental.

6.5 Opportunities and Challenges

This study conducted and summarized interviews with personnel from carbon trading pilot companies and those from non-carbon trading pilot companies, addressing the potential and challenges involved.

6.5.1 Opportunities and Challenges for Carbon Trading Pilot Companies

6.5.1.1 Opportunities

Porter's effect theory posits that while environmental legislation may negatively impact the economy in the near term, it can foster technological innovation, enhance economic and environmental efficiency, and establish a virtuous cycle in the long run. Respondent P9 from the chemical sector examined the opportunities encountered by carbon trading pilot companies via the lens of policy impacts. The policy stipulates that carbon trading pilot companies will receive preferential policy advantages. This includes green credits, tax incentives, financial subsidies, and other company-friendly measures from the government to foster the growth of the carbon trading market (Zhao et al., 2022). As described by the interviewee:

> *"Our company secured a green loan with an interest rate below the market average and an extended repayment term, which expanded funding avenues, decreased operational expenses, and offered substantial financial backing for the company's growth." (P9)*

The policy impact is also evident in access to prioritized developmental opportunities. P9 added:

> *"Companies engaged in carbon trading are more likely to succeed in applications for environmental initiatives, thereby securing more development prospects and resource support for carbon trading companies." (P9)*

Subsequently, respondent P12 examined the economic impact standpoint. The economic impact is evident in the profitability of quota trading.

> *"Should a company's carbon emissions fall below the government-allocated credits, it can profit by selling the surplus emission credits in the carbon*

trading market. As the carbon market matures, the carbon price will progressively increase, enabling pilot companies to generate greater profits." (P12)

Consequently, corroborating prior research, carbon emissions pricing influences company financial performance, and its implementation markedly elevates the overall gearing and non-operating income levels of companies (Liu et al., 2021).

P13 argued that the economic effect is also manifested in the trading of carbon financial products.

"Alongside carbon quota trading, pilot companies may acquire various financial products, including carbon bonds, carbon futures, and carbon options, for purposes of hedging, risk management, profit generation, and expanding financing avenues." (P13)

As the demand for emission reduction intensifies, environmental laws will escalate. In this scenario, for companies to attain sustainable development, they must enhance existing pollution control technologies to accomplish technological innovation, optimization, and advancement. Moreover, engagement in carbon trading has compelled companies to priorities carbon emissions, incentivizing them to enhance investments in the R&D of low-carbon technology to reduce emissions and augment the value of their carbon assets. Respondent P4 from the iron and steel sector asserted that the carbon market mechanisms yield substantial technological impacts for companies. The impact of technology is evident in innovation and optimization. As described by the interviewee:

"We enhance the furnace architecture and optimize the charge distribution of the blast furnace to augment combustion efficiency and energy utilization. Utilize the captured CO_2 for the manufacture of carbonated drinks, dry ice, etc., or inject it into subterranean oil reserves, coal seams, etc., for sequestration, so preventing CO_2 emissions into the atmosphere." (P4)

P3 asserted that the technical impact is also evident in advancing energy structure transformation. It eradicates obsolete manufacturing capacity and fosters the advancement of the entire industry towards low carbon and environmental sustainability.

"The carbon trading mechanism has compelled the company to modernize

outdated motors, fans, and pump production equipment, implement new energy-efficient motors and furnaces, and install waste heat boilers to recuperate waste heat from high-temperature flue gases and slag produced during steel manufacturing for steam or electricity generation, thereby improving energy utilization efficiency." (P3)

"To attain full decarburization of significantly polluting industries, transforming the energy structure is vital, and utilizing clean energy to enhance this structure is a crucial strategy." (P3)

Companies must attain total decarburization of heavy industry, encompassing the power, steel, cement, and chemical sectors, via electrification, hydrogen energy, carbon capture and storage, and bioenergy (Zhao et al., 2022). Minimizing fossil fuel consumption is the primary method for decreasing carbon emissions, and the alteration of the energy mix poses a significant obstacle to the CET's long-term objective of carbon emission reduction (Li & Wang, 2022). Expediting the adoption of renewable energy alternatives, refining the energy framework, and establishing a clean, low-carbon, secure, and efficient energy system is a crucial measure for China to attain carbon neutrality (Kong & Wang, 2022).

Respondent P4 noted that carbon trading yields beneficial environmental outcomes essential for enhancing environmental quality and combating climate change. The environmental impact is mostly evidenced by facilitating greenhouse gas emission reduction.

"The primary objective of the company's involvement in carbon trading is to diminish carbon emissions. High-carbon-emitting sectors, such as the steel industry, possess a substantial carbon emission foundation and significant potential and pressure to mitigate emissions. In 2023, our CO_2 emissions were reduced by 68% compared to 2022." (P4)

This corroborates prior literature indicating that carbon emission reductions in the steel industry can be attained by phasing out obsolete production capacity, advancing novel technologies, and enhancing production frameworks (Zhang et al., 2021). In the iron and steel sector, enhancing energy and raw material efficiency, along with optimizing industrial production processes, can diminish carbon emissions by approximately 70%, while the non-metallic mining sector can achieve a reduction of over 90% (Zhao et al., 2022). The pilot towns in China for energy conservation and

emission reduction programs have demonstrated a relative decrease in carbon emissions after enacting these regulations, with a notable upward trend in this effect over time (Xu et al., 2022).

Engagement in carbon trading compels companies to seek cleaner alternatives to conventional high-carbon energy sources and encourages the optimization of the energy mix. P11 explained below:

> *"The company will augment its utilization of renewable energy sources, including solar and wind power, while diminishing its reliance on fossil fuels such as coal and oil, which is crucial for enhancing the energy consumption framework and mitigating carbon emission intensity." (P1)*

China's coal combustion emissions constitute over 80% of total carbon emissions, significantly above the global average. In 2023, China's consumption of coal, oil, and natural gas will constitute 55.3%, 28.3%, and 8.5% of the primary energy mix, respectively. This indicates a significant reconfiguration of China's energy composition and resource consolidation in pursuit of carbon neutrality (Hou et al., 2023). Fossil fuels continue to prevail in the global energy consumption framework. Thus, China must transition from an energy consumption model mostly reliant on coal, oil, and natural gas to one cent red on renewable energy sources (Zou et al., 2021). Xu et al. (2020) planned that by 2030, coal consumption should be limited to less than 50%, while non-fossil fuel consumption should exceed 20%. Presently, China's renewable energy sources primarily consist of wind energy, hydropower, nuclear energy, and biomass. To ensure energy supply security and mitigate carbon emissions, the advancement of clean energy is essential (Lu et al., 2023)

The growth of associated environmental sectors is fueled by participation in carbon trading. P13 added:

> *"Research and development of carbon emission reduction technologies, the production of carbon emission monitoring equipment, and other associated environmental protection sectors are all fueled by carbon trading. As these companies grow, environmental governance technology will also evolve, creating a positive feedback loop that will increase technical assistance and solutions for enhancing environmental quality." (P13)*

Zhao et al. (2022) believed that China should make the shift to a circular economy, increase the size of industries that protect the environment and save energy,

raise the standard of environmental protection technology, research and develop new products that save energy, encourage industrial energy conservation, and lower emissions.

Companies that perform well in the carbon market will also benefit indirectly from carbon emissions trading. For instance, they will be certified as green products, see an improvement in their ESG ratings, inspire a sense of honor and responsibility, establish a positive reputation, and indirectly increase economic efficiency. P13 stated:

> *"Companies that actively engage in carbon trading and address climate change show that they care about the environment and have a sense of social responsibility, which improves their reputation and influence in the community and builds a positive company brand image." (P13)*

This finding is consistent with Zhang et al. (2023), who stated that increased R&D investment and improved internal control and governance structure are encouraged by carbon emissions trading policy, which eventually raises a company's Bloomberg ESG score. The implementation of ETS in China as a quasi-natural experiment greatly enhances the company's capacity for sustainable development, eases external financial limitations, and improves its ESG performance (Shen, 2024).

The regulatory impacts, economic effects, technological effects, and environmental and social consequences can be used to summarize the prospects that carbon trading pilot companies face.

Table 6.11 provides the results of the qualitative analysis of the opportunities for carbon trading pilot companies.

Table 6.11
Qualitative Results of Opportunities for Carbon Trading Pilot Companies

Deductive	Codes	Categorizing	Final theme
Transaction fee and annual fee waiver	Broaden the company's financing channels Development opportunities and resource support Green transformation subsidy Quota allocation skew	Policy preferences	Policy benefits
Making money	Excess quota for sale Make more money Buy carbon finance products Profit from value-added carbon assets Adequate financial support	Profit from quota trading	Economic benefits
Technology optimization	Improvement of the furnace structure of the blast furnace	Technology upgrade	Technical benefits

	Optimization of charge distribution Use of new energy-saving motors and furnaces Improvement of energy efficiency Increase investment in energy-saving and emission reduction technologies Strengthen technical cooperation and exchange		
Reducing carbon intensity	Decrease in CO_2 emissions Improvement of energy consumption structure Development of environmental protection industry Advancement of Environmental Governance technology Improvement of environmental quality Promoting green transformation of the industry	Energy saving and emission reduction	Environmental benefits
Responsibility	Establish a good company brand image Responsibility for environmental protection Social responsibility Enhance the company's social reputation and influence Employment promotion and talent development Contributing to the National Carbon Peak Carbon Neutral Goal	Social responsibility	Social benefits

Table 6.12 summarizes the PESTLE analysis of opportunities for carbon trading pilot companies in terms of economic, technological, environmental and social benefits.

Table 6.12
PESTLE Analysis of Opportunities for Carbon Trading Pilot Companies

		P	E	S	T	L	E
i	Policy preferences	/					
ii	Profit from quota trading		/				
iii	Technology upgrade				/		
iv	Energy saving and emission reduction						/
v	Social responsibility			/			

Note: F–Political, E–Economic, S–Social, T–Technological, L–Legal, E–Environmental.

6.5.1.2 Challenges

The petrochemical industry interviewees P6 and P7 provided summaries of institutional and policy risk and market risk, respectively. Legal hazards and policy uncertainty are examples of how policy and institutional risks appear. As described by the interviewee:

"The market for carbon trading is still in its infancy, and the laws and policy governing the distribution of carbon emission limits and the regulations governing carbon trading are still in their infancy. The company will have to deal with the possibility of policy changes as a result." (P6)

"There are gaps and ambiguities in the legal characteristics of carbon emission rights and the legal consequences of trading contracts, and the current legal framework of the carbon market is not robust. Thus, the company can be at risk of legal issues." (P6)

Market risk manifests itself in the form of volatile carbon price and increased competition in the market. P7 stated:

"Policy changes, market supply and demand, energy prices, and other factors will all affect the price of carbon, which is more likely to fluctuate. This instability puts the company at risk of a transaction." (P7)

"There will be an increasing number of companies competing in the carbon market, and as the competition gets more intense, the pilot companies will need to keep improving their technology and carbon management capabilities to maintain a competitive edge." (P7)

The hazards were summed up by interviewees P11 and P13 from the non-ferrous metals industry and the building materials industry, respectively, in terms of internal company management risks and technology and data management concerns. The challenge of accounting for and monitoring carbon emissions and the risk of technological innovation are examples of how technology and data management risks are expressed. As described by the interviewee:

"Accurately tracking and accounting for a company's carbon emissions presents technical challenges. The regulator will penalize companies that submit false carbon accounting data." (P11)

"Problems like the failure of technical research and development and the challenges in transforming technological successes are characteristics of technological innovation, which is inherently marked by risk and uncertainty." (P11)

The primary sources of the company's internal management risk are its inadequate internal management structure and the dearth of carbon specialists. The foundation for ensuring the orderly conduct of carbon trading is a faultless internal management

system and professional carbon management staff. Supplement to P13:

> *"Carbon trading is a broad field that requires expertise in economics, finance, environmental science, and other fields. At the moment, China lacks these kinds of people with broad skills." (P13)*

> *"Carbon emission management, carbon asset accounting, and trading risk management are all part of the internal management system for carbon trading. In the process of carbon trading, management confusion and poor decision-making may result from an imperfect internal management system." (P13)*

Table 6.13 presents the results of the qualitative analysis of the challenges of the carbon trading pilot companies.

Table 6.13
Qualitative Results of Challenges for Carbon Trading Pilot Companies

Deductive	Codes	Categorizing	Final theme
Imperfect policy and regulations	Risk of policy change Inadequate legal system Risk of legal disputes Policy adjustment risk Risk of regulatory enhancement	Policy uncertainty	Policy & institutional risk
Unstable carbon price	More frequent fluctuations in carbon price Increased market competition Market liquidity risk	Carbon price volatility	Market risks
Technical difficulty	Inaccurate carbon accounting data Failure of technology research and development Difficulty in transforming technological achievements Inaccurate monitoring data Data security risks	Technology innovation risk	Technology and data management risk
Internal management	Lack of comprehensive ability talents Inadequate internal management system Confused management and poor decision-making	Carbon professionals	Internal management risks

Table 6.14 summarizes the PESTLE analysis of the challenges of carbon trading pilot companies in terms of economic, technological, environmental, and social benefits.

Table 6.14
PESTLE Analysis of the Challenges of Carbon Trading Pilot Companies

		P	E	S	T	L	E
i	Policy uncertainty	/					
ii	Carbon price volatility		/				
iii	Technology innovation risk				/		
iv	Carbon professionals			/			

Note: F–Political, E–Economic, S–Social, T–Technological, L–Legal, E–Environmental.

6.5.2 Opportunities and Challenges for Non-Carbon Trading Pilot Companies

6.5.2.1 Willingness of Non-Carbon Trading Pilot Companies to Participate in Carbon Trading

In response to the question, "Are non-carbon trading pilot companies willing to participate in carbon trading?" interviewees had inconsistent responses. A representative of a steel sector non-carbon trading pilot company examined the advantages of economic, technological, environmental, and social benefits. As P16 expressed:

> *"My company is open to taking part in carbon trading. First, the company can sell the extra carbon permits to generate revenue if it can effectively cut emissions. Second, engaging in carbon trading encourages the company to increase productivity and modernize its technology. Then, and perhaps most significantly, taking part in carbon trading helps to reduce CO_2 emissions and lessen the greenhouse effect. Lastly, a company's constructive attitude and social responsibility for environmental protection are demonstrated through involvement in carbon trading, which will ultimately benefit the environment more than it will harm it." (P16)*

In contrast, P23, a member of the chemical industry's non-carbon trading pilot company, provided the following response on drawbacks, including input costs and market penalties:

> *"Small companies are burdened by the expenditures associated with participating in carbon trading, which include sophisticated carbon monitoring technology and internal management systems. However, a company will be subject to fines and pressure to buy carbon allowances if it does not emit within the allowed limits." (P23)*

Ultimately, managers will base their decisions on the particular circumstances of their company, and there is no standard response to whether a pilot company that does not engage in carbon trading is willing to do so.

P27 from the non-ferrous metals industry responded to the question of whether the carbon market mechanisms will impact company performance if the company engages in carbon trading if it is not a carbon trading pilot company by citing benefits like improved technology and improved social image. P27 noted:

> *"If non-carbon trading pilot companies engage in carbon trading, their performance is significantly impacted by the carbon market mechanisms. On the one hand, companies are encouraged by the carbon market to enhance industrial technologies, boost energy efficiency, and lower carbon emissions. Active involvement in carbon trading, on the other hand, improves market competitiveness, boosts product market share, and improves the company's reputation with investors and consumers." (P27)*

P29 from the aviation industry gave answers in terms of negative aspects such as increased operating costs, the uncertainty of the carbon price, and environmental penalties. P29 explained below:

> *"Conversely, if a company fails to effectively reduce emissions, it must acquire carbon permits, thus elevating its operational expenses. Furthermore, the significant price fluctuation in the carbon market will introduce further uncertainty for the company. The company will incur environmental penalties if it does not comply with carbon market regulations. Hence, engaging in carbon trading may adversely affect its performance." (P29)*

Nonetheless, with the ongoing advancement of the carbon market, the involvement of non-carbon trading pilot companies in carbon trading could enhance long-term company performance, provided they respond constructively and strategies effectively.

Table 6.15 presents the results of the qualitative analysis of the willingness of non-carbon trading pilot companies to participate in carbon trading.

Table 6.15
Qualitative Results of Non-Carbon Trading Pilot Companies' Willingness to Participate in Carbon Trading

Deductive	Codes	Categorizing	Final theme

Making money	Excess carbon allowances sold for profit Increase in product market share Increase market competitiveness	Economic benefits	Positive influence
Technology optimization	Technology upgrades Improvement of production efficiency	Technical benefits	
Environmental protection	Improve energy efficiency Reduce carbon emissions	Environmental benefits	
Social responsibility	Positive attitude towards environmental protection Awareness of social responsibility	Social benefits	
Cost pressure	Fines Cost pressure to purchase carbon allowances Increased operating costs for the company	Cost pressure	Negative impact
Unstable carbon price	Carbon market prices are volatile	Carbon price volatility	
Fine	Facing environmental penalties	Environmental penalties	

Table 6.16 summarizes the PESTLE analysis of the willingness of non-carbon trading pilot companies to participate in carbon trading in terms of economic benefits, technological benefits, environmental benefits, social benefits, cost pressures, carbon price volatility and environmental fines.

Table 6.16
PESTLE Analysis of Non-Carbon Trading Pilot Companies' Willingness to Participate in Carbon Trading

		P	**E**	**S**	**T**	**L**	**E**
i	Economic benefits		/				
ii	Technical benefits				/		
iii	Environmental benefits						/
iv	Social benefits			/			
v	Cost pressure		/				
vi	Carbon price volatility		/				
vii	Environmental penalties					/	

Note: F–Political, E–Economic, S–Social, T–Technological, L–Legal, E–Environmental.

6.5.2.2 Opportunities

Employees from non-carbon trading pilot companies within the steel sector believed that despite their company's non-participation in carbon trading, it could concentrate its resources on its primary company activities. Interview participants remarked:

> *"Our company abstains from carbon trading, thereby eliminating the need to allocate resources towards comprehending the regulations and dynamics of carbon price. This allows us to redirect human, material, and financial resources towards our primary company objectives, including technological advancement, product innovation, and market expansion." (P18)*

Non-participation in carbon trading circumvents supplementary expenses, providing the company with a short-term cost benefit. P18 added:

> *"Engagement in carbon trading necessitates the acquisition of carbon monitoring apparatus, the training of personnel, and the accounting of carbon emissions data, so elevating the company's operational costs and incurring supplementary expenses, which can be entirely circumvented by companies not participating in carbon trading initiatives." (P18)*

Companies not involved in carbon trading can make flexible company decisions. Respondent P21 expressed:

> *"Companies are unbound by carbon emission limitations and can structure production based on their development objectives and market demand, such as increasing output to enhance market share and capitalize on commercial opportunities during peak demand periods." (P21)*

A non-carbon trading pilot company in the non-ferrous metals sector asserts that, despite its non-participation in carbon trading, it can collaborate with suppliers, customers, and other entities along the industry chain to investigate diverse emission reduction strategies. P27 explained below:

> *"The Company, while not engaged in carbon trading, collaborates with suppliers to enhance the procurement and transportation of raw materials, and with customers to improve recycling and reuse of products, thereby reducing carbon emissions in supply and distribution chains, and jointly investigates various methods for emission reductions." (P27)*

Even if a company does not engage in carbon trading, it can implement voluntary emission reductions and green marketing to improve its reputation and brand image. Companies can proactively implement voluntary emission reduction initiatives, establish explicit emission reduction objectives and strategies, and publicly disclose social responsibility reports and the outcomes of their emission reduction efforts to bolster consumer and investor recognition and trust in the company. As P23 shared:

"Our company exemplifies its commitment to environmental protection by efficiently handling wastewater, exhaust emissions, and solid waste while also advancing new biomass energy sources to achieve carbon offsetting." (P23)

"The Company can actively engage in the ISO 14001 environmental management system certification to demonstrate its commitment to effective environmental management and carbon emissions reduction, thereby augmenting its influence and visibility in the realm of environmental protection." (P23)

Companies are abstaining from carbon trading but may await more advantageous market conditions and contemplate participation when market dynamics and policy chances are favorable. Interviewee P30 remarked:

"China's carbon trading system remains in a nascent phase. Companies involved in non-carbon trading can defer participation until the market matures, regulations improve, and pricing becomes more equitable. Furthermore, to encourage greater company participation in carbon trading, the government will undoubtedly implement a range of favorable policies and incentives. Companies engaged in non-carbon trading pilots should closely monitor policy developments and select an opportune moment to engage in carbon trading." (P30)

Table 6.17 presents the results of the qualitative analysis of the opportunities for non-carbon trading pilot companies.

Table 6.17
Qualitative Results of Opportunities for Non-Carbon Trading Pilot Companies

Deductive	Codes	Categorizing	Final theme
Deepening professional strengths	Release more human, material and financial resources Avoid operational costs and additional expenses	Centralization of resources	Focus on core company development
Flexible decision-making	No restrictions on carbon emission allowances Freedom to organize production Freedom to reorient business Rapid response to the market	Freedom of production planning	Flexible company decisions
Company cooperation	Optimizing the procurement and transport of raw materials Recycling and reuse of products Reduce carbon emissions in supply and distribution chains Industry-university-research cooperation Participation in public welfare	Upstream and downstream cooperation	Multiple modes of cooperation for emission reduction

	programs		
Green Certification	Developing new biomass energy sources Carbon offsetting Active participation in ISO 14001 environmental management system Spreading the concept of environmental protection	Voluntary emission reduction	Enhanced reputation and brand image
Waiting for Opportunity	Observe policy changes Choose favorable timing Market access advantages Early preparation for low-carbon development	More favorable market timing	Policy opportunities

Table 6.18 summarizes the PESTLE analysis of the opportunities for non-carbon trading pilot companies in terms of economic, technological, environmental, and social benefits and waiting for favorable market timing.

Table 6.18
Qualitative Results of Opportunities for Non-Carbon Trading Pilot Companies

		P	**E**	**S**	**T**	**L**	**E**
i	Centralization of resources		/				
ii	Freedom of production planning		/				
iii	Upstream and downstream cooperation		/				
iv	Voluntary emission reduction						/
v	More favorable market timing					/	

Note: F–Political, E–Economic, S–Social, T–Technological, L–Legal, E–Environmental.

6.5.2.3 Challenges

P17, an officer of a non-carbon trading pilot company in the steel sector, perceives a policy risk regarding potential future regulatory pressures on companies. He stated:

> *"As the carbon trading market advances, an increasing number of companies will participate in carbon trading in the future. If non-pilot companies are compelled to engage in carbon trading in the future, they will encounter more regulatory pressure if they do not adequately prepare today." (P17)*

The iron and steel sector is characterized by significant energy consumption and substantial carbon emissions, requiring 113.5 kg of normal coal to produce 1 ton of iron and steel, resulting in emissions of 0.8 tons of CO_2 (Hou et al., 2023). Ultimately, the carbon market motivates companies to priorities energy conservation

and efficiency, decreasing carbon emissions and energy expenses per product unit. Moreover, non-pilot companies lacking market control will exhibit slowness in emission reductions, resulting in relatively high energy prices, which will increasingly highlight their cost disadvantage. Interviewee P26 from the construction materials sector articulated it as follows:

> *"The construction materials sector is characterized by high energy consumption, and the rise in carbon emission costs has resulted in diminished profitability and a drop in financial performance for the company." (P26)*

Heightened challenges in securing financing. Financial institutions, including banks, prefer companies with strong ESG performance, whereas those with poor environmental performance encounter elevated barriers and expenses in securing finance. P28 confirmed:

> *"Non-pilot companies who underperform in carbon emission reduction may struggle to secure preferential loan interest rates and other carbon financial product support, adversely impacting their capital turnover and investment strategies." (P28)*

Non-pilot companies who underperform in carbon emission reduction may struggle to secure preferential loan interest rates and other carbon financial product support, adversely impacting their capital turnover and investment strategies. As P29 expressed:

> *"As carbon trading becomes more prevalent and environmental consciousness grows, carbon emission regulations and industry environmental requirements will continue to escalate. Companies participating in non-carbon trading pilots will face market disadvantages if they fail to promptly align with trends and effectively manage their carbon emissions." (P29)*

Consumers and clients favor partnering with ecologically responsible companies that maintain minimal carbon emissions. Consequently, non-carbon trading pilot companies are at risk of losing clientele. P29 mentioned:

> *"One assessment criterion for certain large companies in supplier selection is the carbon emissions of the suppliers, and non-pilot companies with a*

detrimental environmental reputation will have greater customer attrition." (P29)

Employees from non-carbon trading pilot companies within the chemical sector identified problems for their companies, including the danger of technical obsolescence and the expenses associated with technological advancement. Carbon trading pilot companies can participate in significant technology exchanges and collaborations with other companies, research institutions, and governmental agencies, benefiting from enhanced platforms for experience sharing. In contrast, non-pilot companies have limited access to such opportunities. P24 noted:

"Pilot companies can stay informed about the newest emission reduction technology and policy advancements by engaging in technical workshops and collaborative project meetings, but non-pilot companies do not have access to such a platform." (P24)

P24 clarified:

"Non-pilot companies lack sufficient experience in the development and implementation of emission reduction technologies due to inadequate early-stage incentives, necessitating greater investment of funds and resources in technological transformation and enhancement subsequently." (P24)

Table 6.19 presents the results of the qualitative analysis of the challenges of the non-carbon trading pilot companies.

Table 6.19
Qualitative Results of Challenges for Non-Carbon Trading Pilot Companies

Deductive	Codes	Categorizing	Final theme
Environmental regulation	Forced to participate in carbon trading Greater regulatory pressure Policy uncertainty Policy tightening risk Changes in industry standards	Regulatory pressure	Policy risks
Carbon cost	Increased cost of carbon emissions Lack of carbon asset returns Rising cost of finance Hidden abatement costs	Carbon cost	Cost disadvantage
Concessionary loan	Difficulty in obtaining favorable loan rates Impact on liquidity and investment plans	Financing difficulties	Financial risk
Industry requirements	Rising industry standards Loss of more customers	Customer churn	Market competition pressure

	Green product competition Supply chain pressure		
Technology upgrades	Lack of technical exchange platform Difficulty in technological transformation and upgrading Difficulty in applying the technology Lagging technology upgrade	Technology upgrade costs	Risk of technological backwardness

Table 6.20 summarizes the PESTLE analysis of the challenges of non-carbon trading pilot companies in terms of economic, technological, environmental and social benefits.

Table 6.20
PESTLE Analysis of Challenges for Non-Carbon Trading Pilot Companies

		P	**E**	**S**	**T**	**L**	**E**
i	Regulatory pressure					/	
ii	Carbon cost		/				
iii	Financing difficulties		/				
iv	Customer churn		/				
v	Technology upgrade costs				/		

Note: F–Political, E–Economic, S–Social, T–Technological, L–Legal, E–Environmental.

Table 6.21 delineates the summarized outcomes of the primary possibilities and challenges encountered by both carbon trading pilot and non-carbon trading pilot companies.

Table 6.21

Summary of Key Opportunities and Challenges for Carbon Trading Pilot and Non-Carbon Trading Pilot Companies

Carbon Trading Pilot Companies		**Non-carbon trading pilot companies**	
Opportunities	**Challenges**	**Opportunities**	**Challenges**
Broaden the company's financing channels Development opportunities and resource support Green transformation subsidy Quota allocation skew	Risk of policy change Inadequate legal system Risk of legal disputes Policy adjustment risk Risk of regulatory enhancement	Release more human, material and financial resources Avoid operational costs and additional expenses	Forced to participate in carbon trading Greater regulatory pressure Policy uncertainty Policy tightening risk Changes in industry standards
Excess quota for sale Make more money Buy carbon finance products Profit from value-added carbon assets Adequate financial support	More frequent fluctuations in carbon price Increased market competition Market liquidity risk	No restrictions on carbon emission allowances Freedom to organize production Freedom to reorient business Rapid response to the market	Increased cost of carbon emissions Lack of carbon asset returns Rising cost of finance Hidden abatement costs
Improvement of the furnace structure of the blast furnace Optimization of charge distribution Use of new energy-saving motors and furnaces Improvement of energy efficiency Increase investment in energy-saving and emission reduction technologies Strengthen technical cooperation and exchange	Inaccurate carbon accounting data Failure of technology research and development Difficulty in transforming technological achievements Inaccurate monitoring data Data security risks	Optimizing the procurement and transport of raw materials Recycling and reuse of products Reduce carbon emissions in supply and distribution chains Industry-university-research cooperation Participation in public welfare programs	Difficulty in obtaining favorable loan rates Impact on liquidity and investment plans
Decrease in CO_2 emissions Improvement of energy consumption structure Development of environmental protection industry Advancement of Environmental Governance technology Improvement of environmental quality	Lack of comprehensive ability talents Inadequate internal management system Confused management and poor decision-making	Developing new biomass energy sources Carbon offsetting Active participation in ISO 14001 environmental management system Spreading the concept of environmental protection	Rising industry standards Loss of more customers Green product competition Supply chain pressure

Promoting green transformation of the industry		
Establish a good company brand image Responsibility for environmental protection Social responsibility Enhance the company's social reputation and influence Employment promotion and talent development Contributing to the National Carbon Peak Carbon Neutral Goal	Observe policy changes Choose favorable timing Market access advantages Early preparation for low-carbon development	Lack of technical exchange platform Difficulty in technological transformation and upgrading Difficulty in applying the technology Lagging technology upgrade

6.6 Problems and Countermeasures

This study conducted interviews to address the issues and solutions, summarizing the findings separately for individuals from carbon trading pilot companies and those from non-carbon trading pilot companies.

6.6.1 Problems and Countermeasures for Carbon Trading Pilot Companies

6.6.1.1 Problems

The expansion of China's carbon trading market is increasing the demand for financial services. Employees of carbon trading pilot companies within the power sector assert their companies have insufficient involvement and liquidity in carbon finance. The interviewee P1 commented:

> *"The current involvement of the financial sector in the carbon trading market is inadequate, resulting in an anomalous situation where trading activity is typically subdued. However, as the fulfilment period approaches, trading volume experiences a significant surge, leading to a sharp increase in the carbon price, which subsequently declines post-contract fulfilment. This creates a market akin to a dry pool, characterized by insufficient liquidity that fails to accurately represent the value of carbon quotas." (P1)*

The existing policy framework fails to offer sufficient incentives for financial product innovation, resulting in a lack of motivation among financial institutions to engage, consequently leading to inactivity in the carbon trading market. This is in line with previous studies. Zhou and Li (2019) argued that carbon emission rights have substantial financial attributes and that China lacks innovation in carbon financial products. The development of carbon financial derivatives, including carbon futures, options, bonds, funds, and insurance-linked to carbon emission rights trading, has emerged as a significant avenue for commercial innovation among financial institutions (Yuan, 2016).

The carbon market is plagued with diminished transaction prices for carbon permits and inadequate incentives for companies to mitigate emissions stemming from the carbon price. P3 commented:

> *"China's national carbon market operates as a singular entity, exhibiting an imperfect market mechanism. In comparison to other carbon markets, the carbon trading pilot in 2024 anticipates a price range of 30-80 yuan per ton, while transactions in the Beijing area may reach up to 110 yuan per ton. The carbon price experiences significant volatility, fluctuating dramatically between high and low values. Carbon price are comparatively low, and the company's emission reduction incentives are inadequate. Furthermore, a carbon price stabilization mechanism and associated risk prevention and control measures have yet to be implemented, resulting in swings in carbon price." (P3)*

On the relationship between carbon price and green technology innovation, P3 added:

> *"The influence of carbon emissions trading on company green technology innovation is limited by the carbon price; when the carbon price is comparatively elevated, the effect of green technology innovation among participating companies is more pronounced, and the carbon price is directly proportional to company green technology innovation." (P3)*

This validates previous research. Zhang et al. (2017), by comparing low-carbon technological innovation activities at the company level in pilot and non-pilot regions, reported that pilots with higher carbon price or higher cap-and-trade turnover had stronger incentives for low-carbon innovation and that market turnover was a stronger stimulus for innovation than carbon price.

Policymakers, when establishing carbon trading policy, should restrict carbon emission allowances to guarantee a consistent increase in carbon price. This approach will incentivize companies to engage in carbon trading, enhance trading activity, and optimize the potential of carbon price. The carbon price in China's carbon trading market remains comparatively low relative to other global markets, and such a low price may lead companies to overlook its significance. Consequently, anticipating a sustained rise in carbon price is essential to establish an effective price transmission effect, direct companies to integrate emission reduction into their decision-making processes, and motivate them to pursue technological innovation and engage in energy conservation and emission reduction initiatives.

The current surplus of free allowances in China's carbon trading market has resulted in supply surpassing demand, hence diminishing the market's incentive

function. P6 provided a comprehensive explanation.

> *"A substantial oversupply of carbon permits exists in the carbon trading policy. This not only augmented the supply of carbon allowances in the market but also resulted in a sustained decrease in prices, diminished market activity, and reduced market liquidity. For instance, the auction prices in Hubei and Guangdong have consistently been inferior to the public market transaction prices. This issue hinders companies from pursuing technological innovation in emission reduction and adversely impacts the robust development of the carbon market." (P6)*

> *"China's carbon market mostly relies on the free allocation of allowances, with a minimal percentage of auctions. Guangdong serves as the prototype zone with the largest percentage of auctions; for instance, in 2024, 96% of the total allowances will be granted gratuitously, while 4% will be auctioned for a fee." (P6)*

This aligns with other research indicating that the initial carbon allowances in China's existing carbon emissions trading market are excessively high, resulting in over-allocation that depresses carbon price (Ji et al., 2021). This does not promote companies' participation in the carbon emissions trading market or encourage technological innovation.

The poor state of implementation of the methodology for allocating allowances in the Chinese carbon market. The interviewee P8 commented:

> *"China primarily use the historical and baseline techniques for quota allocation, both of which have practical challenges. The historical technique may result in the phenomena of "whipping the cow," wherein high-emitting companies acquire additional carbon credits, hence disincentivising them from lowering emissions. Although the benchmarking method is more equitable, its adoption has been limited to a few sectors, such as the electric power industry, and has not been widely disseminated." (P8)*

The evolution of the EU ETS reveals a consistent annual reduction in the total quantity of carbon allowances. During the initial two phases, the aggregate quantity of carbon permits was established by a bottom-up approach based on the total allowances reported by member states. However, a scenario arose where supply surpassed demand, resulting in persistently low carbon price (Chung et al., 2018). In Stage 3, the total quantity of carbon allowances was modified to a top-down allocation, established uniformly at the EU level and allocated to the Member States, with the overall amount

diminishing linearly each year. During Phase 3, the overall quantity of carbon allowances diminishes at a rate of 1.73%. In Phase 4, the total quantity of carbon allowances for aviation and stationary sources declines by 2.2% annually (Dong et al., 2022).

The EU carbon market primarily comprises two methods of carbon quota allocation: free issuance and auction, with the distribution of carbon quotas varying from lenient to stringent (Sato et al., 2022). During the initial two phases, carbon allowances were allocated primarily through free issuance to effectively regulate the adaptation of emission control entities to the carbon market. In phases three and four, the allocation of carbon allowances was augmented by free distribution through auctions. This is with the auction proportion rising to 57% to underscore the market's function as a binding constraint for emission reduction (Bayer & Aklin, 2020). China's carbon market faces issues regarding the total quantity of allowances established and the allocation methods. It can benefit from the EU ETS's developmental experiences to enhance its strengths and mitigate its limitations.

Employees of a carbon trading pilot company in the building materials sector contend that the company possesses inadequate carbon management capabilities owing to the intricacies of carbon management tasks. P11 elucidated it in this manner:

> *"Carbon managers must effectively quantify carbon emissions across all production and operational facets, comprehend the carbon emission variables associated with various energy sources, analyse the carbon emission profiles of production processes, and anticipate future market trends. Identifying such extensive and proficient talents is challenging." (P11)*

P11 elaborated on the deficient talent development system and the scarcity of expertise in carbon management.

> *"The quantity of carbon management professionals trained by colleges is insufficient to satisfy the swiftly increasing market need. The training classes and certification systems focused on carbon management lack sufficient maturity in terms of on-the-job training. Furthermore, carbon management is an emerging discipline, characterized by a deficiency of practical case studies and forums for experiential exchange within the sector." (P11)*

Carbon managers must possess extensive expertise in environmental science,

energy management, sustainable development, and relevant legislation and regulations. Hence, companies must perform thorough monitoring, precise accounting, and detailed analysis of their carbon emissions, necessitating personnel with robust technological and data analysis expertise. In accordance with prior research, Zhou and Li (2019) believed that there is a lack of relevant professionals in the Chinese carbon market.

Employees of carbon trading pilot companies within the petrochemical sector contend they experience inadequacies in green investments, characterized by restricted investment volume, limited investment domains, and brief investment durations. The replies from P5 were as follows:

> *"Currently, our company allocates a greater portion of its investments to traditional energy, with green investments primarily focused on established sectors, such as energy-efficient renovation projects. Conversely, investments in nascent green technologies and sectors, including carbon capture and storage (CCS), solar energy, wind energy, hydro energy, and renewable energy sources like geothermal energy, remain minimal, resulting in a low percentage of renewable energy within the company's energy portfolio." (P5)*

Companies exhibit a greater propensity to engage in projects yielding short-term profits while demonstrating diminished motivation for green investment initiatives with long-term strategic importance but extended return periods. Lu et al. (2023) argued that companies should sequester carbon in ecosystems, maintain and enhance ecological carbon sinks, and realize the transition from a high-carbon economy to a low-carbon economy by planting trees and enhancing ecological protection and restoration. However, in practice, companies are not executing well. P5 continues to add:

> *"Companies typically invest cautiously in forest carbon sink projects due to the prolonged duration required to achieve substantial carbon emission reductions and economic rewards." (P5)*

Green investment projects are marked by substantial initial capital requirements, extended recovery periods, and elevated risk, leading companies to exercise caution in their green investments due to economic cost concerns and associated risks (Zhang et al., 2022). The government fails to provide policy incentives and advice, such as tax incentives and subsidy programs for green investment projects, leading to diminished motivation and confidence in company green investment decisions.

Employees from carbon trading pilot companies within the non-ferrous metals sector contend that their companies exhibit deficient green innovation skills characterized by limited innovative accomplishments, low innovation efficiency, and a scarcity of innovative talent. The interviewee P14 commented:

> *"There is a scarcity of advancements in green technology research and development, as well as in green product innovation. Issues such as resource wastage and project redundancy during the R&D process result in extended development cycles, preventing the timely application of innovative outcomes in production practices. Insufficient competent green innovation expertise results in technical bottlenecks and inadequate assistance for the company."*（*P14*）

Currently, most companies exhibit a poor ratio of R&D expenditure to operating income, which is insufficient to support green innovation initiatives. The internal innovation divisions of companies exhibit a deficiency in information interchange and technical collaboration with external entities, and partnerships with companies such as universities and research institutions are restricted.

P15, an employee of a carbon trading pilot company in the aviation sector, asserts that the company faces issues with inadequate carbon disclosure, including restricted disclosure material, inconsistent standards, and infrequent reporting.

Certain carbon trading pilot companies merely report aggregate carbon emissions without thorough disclosures regarding the precise sources of emissions and the emissions produced by various company segments. P15 noted:

> *"A manufacturing company disclosed just the total annual carbon emissions, omitting the specific contributions from energy usage, raw material acquisition, and transportation within the production process."*（*P15*）

There is an absence of a standardized format, indicators, and technique for carbon disclosure, resulting in a lack of comparability of the information. P15 has been added.

> *"Certain companies utilize tons of CO_2 equivalent as the metric for carbon emissions, whilst others employ alternative, less prevalent units, resulting in uncertainty for stakeholders such as investors and regulators."*（*P15*）

The absence of standardized criteria and procedures for carbon disclosure has

resulted in increased subjectivity in companies' selection of disclosures. Certain companies opt to reveal advantageous information while withholding detrimental details.

Most carbon trading pilot companies disclose carbon statistics just in their annual reports, missing regular and timely updates. The information's timeliness is inadequate to accurately represent changes in the company's carbon emissions promptly. As explained below:

> *"In certain industries, company carbon emissions fluctuate regularly due to modifications in manufacturing methods or variations in energy costs, and disclosures are rarely updated promptly, preventing consumers and clients from staying informed about these changes."*（*P15*）

The incomplete disclosure of carbon information primarily stems from insufficient regulatory mandates and the company's own lack of understanding. The state has yet to promulgate comprehensive carbon disclosure legislation and regulations, and regulatory bodies oversight and enforcement of carbon disclosure are inadequate. Moreover, companies lack a robust and independent awareness of carbon disclosure.

Employees of carbon trading pilot companies in the paper sector assert that their companies face challenges due to inadequate regulatory frameworks for carbon emissions data. Carbon emission data serves as the cornerstone of the carbon trading market, with accurate quantification of carbon emissions being a precondition for trade. In the absence of a rigorous Measuring, Reporting, and Verifying (MRV) process, the veracity and precision of carbon emission statistics cannot be assured. P7, confirmed by sharing:

> *"In 2021, the Department of Ecology and Environment of the Inner Mongolia Autonomous Region reported a case of carbon emission data fraud, marking it as the first instance of such a case in China. Inner Mongolia Erdos High-Tech Materials Co., Ltd. is an emission control entity that illicitly modified the test report to manipulate the data in the emission report and deliberately misrepresent the information." (P7)*

The purposeful fabrication of carbon emissions data is predominantly a minority occurrence. Nevertheless, the quality of carbon emissions data remains highly significant. The primary reason is that China's existing regulatory framework for carbon emissions data is neither complete nor fully developed.

P9 and P11 mentioned that the carbon trading pilot has problems, such as imperfect market policy and regulations.

> *"At present, China's laws and regulations on carbon trading are mainly based on departmental rules and local regulations, with a relatively low level of legislation and a lack of authority and stability. This makes the carbon trading pilot companies lack strong legal protection in the operation process, and the policy changes are large, which brings uncertainty to the long-term development of the companies." (P9)*

> *"The legal foundation of each pilot carbon trading program is devoid of a higher law, although there exists a distinction in the legislative format. Shenzhen and Beijing possess a superior legislative status, as legislation is enacted through local people's congresses. In contrast, regions such as Shanghai, Guangdong, and Hubei utilize governmental orders, resulting in a lower legislative status compared to people's congress documents. Consequently, the administrative binding authority in regions with inferior legislative status is weaker than that in regions with superior legislative status." (P11)*

This is consistent with previous studies, such as those by Yu and Zhang (2021), who argued that China's carbon market lacks a sound legal system. China's carbon emissions trading market is still in the early stages of construction, and there is a need to improve the supporting rules of the carbon emissions trading market further and implement relevant infrastructure construction. This includes clarifying the behavioral standards and norms of carbon trading-related parties and improving the national carbon emissions trading market system (Khan et al., 2021).

Table 6.22 summarizes the results of the qualitative analysis of the problems of the carbon trading pilot companies.

Table 6.22
Qualitative Results of Carbon Trading Pilot Company Problems

Deductive	Codes	Categorizing	Final theme
Lack of liquidity	A pool with no water It does not reflect the true value of carbon allowances The development of carbon futures, carbon options, carbon forwards and other derivatives is relatively lagging behind Uncertainty of returns is large Carbon financial products and services are single	Insufficient participation and liquidity in carbon finance	Carbon finance

	Insufficient regulation of the carbon finance market		
Carbon price fluctuation	Insufficient incentives for carbon price reduction Ride a roller coaster Carbon price stabilization mechanism Higher price volatility	Lower carbon price	Carbon price
Carbon quota surplus	Quotas are mainly allocated free of charge The proportion of auctions is lower Historical method and datum method Unscientific distribution methodology Lack of dynamic adjustment mechanism	Carbon quota allocation method	Carbon quota
Internal management	Lack of carbon management talent Carbon management training courses and certification systems are not mature enough Lack of carbon management practice cases and experience in the exchange platform Lack of whole process management of carbon emissions Incomplete management system	Weak carbon management capabilities	Carbon management capability
Lack of investment in renewable energy	The proportion of renewable energy in the company's energy mix is low Lack of investment in forest carbon sequestration projects Insufficient incentive to invest Concerns about investment risks and uncertainty of returns	Underinvestment in green	Green investment
Green technology research and development	Lack of green product innovation R&D cycle extension Innovation results cannot be applied to production practice in time Lack of professional green innovation talents Inadequate mechanisms for innovative cooperation	Weak green innovation ability	Green innovation capability
Detailed carbon disclosure data	The format, index and method of carbon information disclosure are not uniform Carbon disclosure is not timely Incomplete disclosure Poor quality of disclosure	Incomplete carbon disclosure	Carbon information disclosure
Malicious forgery	Carbon emissions data falsified Change emissions reporting data Inadequate regulatory system Outdated monitoring technology and means Insufficient punishment	Incomplete carbon emission data monitoring mechanism	Carbon regulation
Imperfect legislation	Lack of superior law There are differences in the form of legislation Lower level of legislation Incomplete content of the law Difficulty in enforcing the law	Imperfect policy and regulations	Carbon policy and regulation

Table 6.23 summarizes the PESTLE analysis of the problems of carbon trading pilot companies, which are expressed in terms of carbon finance, carbon price, carbon quota allocation, carbon management capacity, green investment, green technology innovation capacity, carbon disclosure, carbon data monitoring, and carbon policy and regulations.

Table 6.23
Qualitative Results of Carbon Trading Pilot Company Problems

		P	E	S	T	L	E
i	Insufficient participation and liquidity in carbon finance		/				
ii	Lower carbon price		/				
iii	Carbon quota allocation method		/				
iv	Weak carbon management capabilities			/			
v	Underinvestment in green				/		
vi	Weak green innovation ability				/		
vii	Incomplete carbon disclosure					/	
viii	Incomplete carbon emission data monitoring mechanism					/	
ix	Imperfect policy and regulations	/				/	

Note: F–Political, E–Economic, S–Social, T–Technological, L–Legal, E–Environmental.

6.6.1.2 Countermeasure

An advanced and optimal carbon financial system is a crucial representation of the robust growth of the carbon trading market (Zhao et al., 2022). To address the issue of inadequate carbon financial engagement and liquidity, representatives from carbon trading pilot companies within the power sector assert that companies ought to create a range of varied carbon financial products and pioneering climate financial instruments. This includes facilitating the inclusion of varied market participants and effectively directing financial institutions in creating carbon financial instruments. It encompasses but is not limited to, carbon futures, carbon options, carbon bonds, and more products (Lu et al., 2023; Zhang, 2022). P2, confirmed by expressing:

> *"At present, Beijing and Guangzhou are undertaking initiatives. Beijing is actively pursuing the creation of a national voluntary emission reduction trading center, while the newly established Guangzhou Futures Exchange serves as an innovative platform, with carbon emissions as its inaugural commodity, both of which will invigorate the carbon trading market." (P2)*

P2 added:

> *"To mitigate company funding constraints, the advancement of climate finance innovation should be expedited. It is advisable to consider the United States' experience in climate finance development to enhance and innovate climate finance products, such as Citibank's structured energy-saving collateral and Barclays Bank's green credit card. " (P2)*

Based on the maturity of the market mechanism, promote the advancement of voluntary emission reduction trading, investigate international green asset trading, and leverage the established expertise of carbon finance in the global carbon market to foster the development and application of innovative carbon financial instruments and carbon financial derivatives.

In light of diminished carbon quota transaction prices, representatives from carbon trading pilot companies within the iron and steel sector assert that companies had to manage the degree of carbon price fluctuations judiciously. To fulfil the guiding and regulatory function of carbon market risk signals, it is essential to construct a carbon price stabilization mechanism to prevent excessive volatility in carbon price. A suitable carbon price will be established, and a fair and stable carbon price system will be upheld. P4 elucidated it in the following manner:

> *"To enhance the mechanism for regulating the rate of increase and decrease in the short term, it is recommended to draw on the experience of Australia's carbon market, with the specific design delineated into two phases: the fixed price phase (2020 to 2022) and the floating price phase (2022 to 2024). During the fixed-price phase, the carbon price will be limited to $70, while in the floating-price phase, it will escalate at an annual rate of 5%." (P4)*

The impact of the carbon emissions trading mechanism on green technology innovation and company performance is contingent upon the carbon price level, where a higher carbon price incentivizes companies to innovate in green technologies (Tang et al., 2022b). The carbon price reflects the company's marginal abatement cost to some degree. Thus, profit-maximizing companies will compare the carbon price with their own abatement cost. When the carbon price exceeds the company's abatement cost, the emission control company will implement green technology innovation to reduce emissions and sell the surplus quotas in the carbon market, thereby incentivizing ongoing green technological advancements. Conversely, when the carbon price falls

below the company's abatement cost, the emission control company will purchase the necessary quotas in the carbon market to mitigate losses, resulting in insufficient motivation for technological innovation at that time. A higher carbon price can motivate companies to pursue green technology innovation. The carbon emissions trading mechanism's incentive effect on low-carbon technological innovation will be amplified by an increase in carbon price. This can be observed in Figure 6.1.

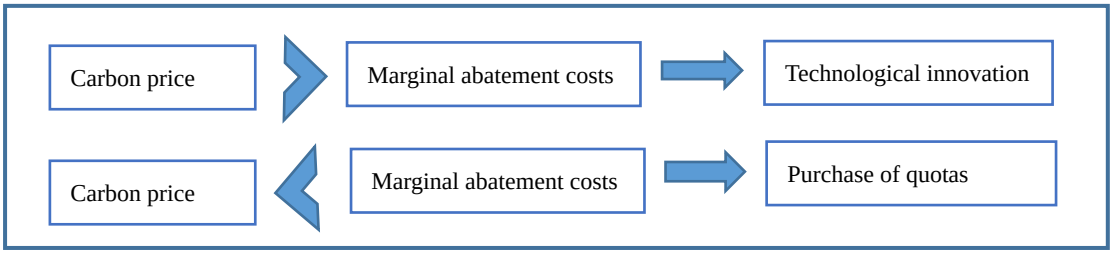


Figure 6.1 Carbon Price Signaling Mechanism

Governments can uphold an equitable carbon price by managing the supply and demand for carbon allowances. Two critical requirements must be met for the carbon market to effectively contribute to emission reduction: sustaining an appropriate carbon price and ensuring sufficient market liquidity. An overly low carbon price will significantly diminish the motivation of emission-control companies to invest in low-carbon technologies. The carbon price is determined by the interactions between the two market participants, and direct regulatory intervention is inappropriate. Thus, sustaining a reasonable carbon price level is essential.

In addressing the matter of carbon quota allocation, respondent P6 suggested an approach that integrates free allocation with competitive bidding. P6, confirmed by mentioning:

> *"While the distribution of quotas in China's pilot regions remains reliant on free issuance, the initiation of the national carbon market necessitates a gradual transition towards a hybrid model of quota allocation that Incorporates both free distribution and bidding, thereby progressively increasing the proportion of purchased quotas." (P6)*

Regarding the specific distribution methodology, P6 added:

> *"During the free allocation phase, the baseline method exerts a more significant incentive on companies' green innovation endeavors than the historical method; in contrast to free allocation, carbon trading, primarily utilizing auction as the allocation method, demonstrates a more pronounced impact on renewable energy technology innovation." (P6)*

The Regional Greenhouse Gas Reduction Initiative (RGGI) is the inaugural regional-mandated greenhouse gas emissions reduction agreement in the United States (US), exclusively encompassing the power sector. The issuing of RGGI carbon permits is rigorous, characterized by an annual reduction in the overall quantity of allowances (a reduction factor of 2.5% for 2014-2020, increasing to 3% for 2021-2030), and the auctioning of these allowances at a price (Rahman et al., 2023). Concerning the carbon market flexibility mechanism, a carbon allowance offset system has been established to regulate the supply of offset allowances by constricting the ratio and origin of offsets (Narassimhan et al., 2017).

China ought to expedite the R&D of a comprehensive methodological framework for total quantity determination and quota allocation, advocating that total quantity determination and quota issuance should follow the principle of moderate tightening to prevent total quantity excess. The initial stage of quota allocation for the power generation sector must integrate the production capacity attributes of the industry with emission reduction mandates. Specifically, differentiated quota allocation methodologies should be employed, thoroughly considering each region's historical emission profiles, economic development phase, industrial growth extent, demographic characteristics, and the degree of technological progress. Moreover, research on total amount setting and quota allocation methodologies should be expedited, and a systematic approach that incorporates regional and industry disparities and equity should be developed based on existing historical and industry benchmarking techniques. The development of a company's environmental information disclosure system should be expedited, and a transparent database for total amount determination and quota allocation should be constructed.

Considering the company's inadequate carbon management capabilities and shortage of skilled personnel in this area, P9 asserted that the company should improve its carbon management proficiency and develop expertise in carbon management. The company should implement internal training on carbon assets and carbon management

and engage external carbon management experts. P9, confirmed by stating:

> *"Encourage companies to engage in carbon asset management training, reduce the barriers to entry for such training, and develop a cadre of professionals proficient in carbon market policy and trading regulations. Secondly, enhance the substance of carbon asset training. Utilizing the current foundational data on the carbon market, incorporate content regarding carbon quota budget management, trading oversight, and accounting practices to assist companies in budgetary planning, standardize carbon assessment, and enhance carbon disclosure. The company should engage pertinent specialists and individuals in the carbon sector to enhance and fortify its carbon management talent team." (P9)*

Green investment is a crucial method for advancing a low-carbon economy. Green investment offers companies money for carbon emission reduction, facilitating their achievement of sustainable development. To address the issue of inadequate green investment, representatives from carbon trading pilot companies in the electricity sector assert that government agencies should provide incentives to motivate companies to enhance their green investments. P11 contended:

> *"Government agencies should actively acknowledge and promote the environmentally sustainable practices of exemplary companies, enabling them to serve as benchmarks within the sector and to assume a demonstrative and leadership role." (P11)*

The green investment significantly enhances the carbon market. It facilitates capital movement and the growth of the carbon market. Green investment offers significant financial backing for the carbon market by channeling substantial capital into low-carbon and environmental protection sectors. These funds are utilized to facilitate carbon emissions trading and implementing carbon reduction initiatives. It also fosters the creation and advancement of carbon financial products, enhances the flow of capital, and expands the carbon market. As green investments proliferate, the activity and impact of the carbon market will progressively escalate. Conversely, it facilitates the initiation and execution of carbon emission reduction efforts. Green investment is typically allocated to initiatives substantially reducing carbon emissions, including clean energy, energy efficiency, and emission reduction technologies. The execution of these initiatives not only mitigates carbon emissions but also stimulates the advancement of the associated industry chain, creating a virtuous cycle.

In addressing the challenge of inadequate green innovation capacity among companies, personnel from carbon trading pilot companies in the power industry assert that companies can develop their green innovation capabilities. P11 stated:

> *"Augment the company's green innovation initiatives, direct the company in executing green innovation activities, elevate the quantity of green patent applications and approvals, and recruit high-tech professionals." (P11)*

The significance of developing technologies in addressing climate change is increasingly evident, with technical innovation serving as a crucial mechanism for enhancing energy saving and reducing emissions (Xu et al., 2020). Porter's hypothesis posits that, in the long term, companies should initiate from the production source and augment their competitiveness via green innovation to achieve a mutually beneficial outcome for both the environment and the economy. The State Intellectual Property Office has the capacity to augment the volume of approved green patent applications. The advancement of green technology is inherently reliant on the help of skilled professionals. The company must integrate high-tech staff as a form of intellectual protection by enhancing collaboration with scientific research institutes to build a synergistic relationship among industry, academia, and research, thereby leveraging each other's assets. Moreover, the R&D of green technology is not instantaneous; despite the absence of major achievements at present, it necessitates the company's persistent efforts.

In the forthcoming 40 years, green technologies will be extensively implemented to pursue carbon neutrality. Negative emissions can be attained through two primary methods: nature-based solutions and carbon capture and storage. Afforestation serves as an economic strategy for the short-term mitigation of carbon emissions, yet zero- and negative-emission technologies will assume a more significant role in the future (Wenger et al., 2021). Consequently, the government sector must enhance energy technology and promote zero-carbon and carbon-negative innovations, including Carbon Capture, Utilization and Storage (CCUS) and hydrogen.

To address the issue of inadequate carbon disclosure, representatives from carbon trading pilot companies within the iron and steel sector assert that companies can take the initiative in company carbon transparency. Investors are increasingly focusing on company social responsibility reports. Through engagement in diverse

carbon reduction initiatives and the provision of carbon disclosures in company social responsibility reports, companies enhance environmental protection, cultivate a positive social image, and exhibit their impact (Tang et al., 2022b). P12 clarified:

> *"Currently, there is no cohesive standardization or guideline document for company carbon disclosure, resulting in inconsistent levels of disclosure that lack comparability. Consequently, government agencies must progressively establish and enhance a carbon disclosure system tailored to China's specific circumstances while enforcing regulations on the format and substance of company carbon disclosures." (P12)*

In light of the inadequacies in regulatory frameworks for carbon emissions data, representatives from carbon trading pilot companies within the non-ferrous metals sector assert that companies can rigorously validate data and enforce compliance oversight. P14 asserted:

> *"Expedite the enhancement of technical requirements pertaining to the MRV of carbon emission data and establish it as a national standard to standardize verification criteria countrywide and minimize data ambiguity. Enhance the admission qualification criteria for third-party verification companies and verifiers, implement various steps to elevate the quality of carbon emission data verification, and oversee and regulate the aspects susceptible to fraud." (P14)*

The efficacy of the carbon emissions market relies on a robust MRV system. Consequently, China's carbon market ought to implement a carbon emissions data monitoring system and a team of MRV professionals, refine the foundational database and information disclosure framework, augment the timeliness and transparency of information, and fortify the proceduralisation and standardization of carbon trading (Hua & Dong, 2019).

In light of the inadequacies in rules and regulations within the carbon trading market, representatives from carbon trading pilot companies in the aviation sector assert that companies must implement a stringent punishment mechanism. For individuals who do not comply with their obligations as per the regulations, the penalties will be escalated. P15 clarified:

> *"To enhance the incentive and punishment framework of carbon trading, it is recommended to leverage the experiences of the carbon markets in the*

United States and the European Union, with the following specific design: Establishing a reward system for the quota of the performing company; implementing a tiered progressive penalty mechanism for defaulting companies based on their size, whereby large defaulting companies incur fines ranging from three to five times the average market price of the quota in the year preceding the deadline for quota clearance, while small defaulting companies face fines of four to six times the quota, thereby enhancing the reward and punishment framework." (P15)

To optimize the market adjustment function of carbon trading, it is essential to ensure seamless operation through the coordination of incentives and penalties, together with a standardized MRV mechanism (Hao & Yang, 2022). Prior research indicates that enacting a carbon trading policy diminishes regional carbon emissions and curtails per capita CO_2 emissions, yielding a long-term impact. Furthermore, the effect of emission reductions is more pronounced in regions with higher carbon emission density and stricter legal regulations (Shi et al., 2022). To successfully limit the greenhouse effect, address climate change, and attain carbon neutrality, China must promptly enhance its climate change law framework and associated institutional development (Lu et al., 2023).

Table 6.24 presents the results of the qualitative analysis of the countermeasures of the carbon trading pilot companies.

Table 6.24
Qualitative Results of Carbon Trading Pilot Companies' Countermeasures

Deductive	Codes	Categorizing	Final theme
Climate finance products	Innovative futures exchange Accelerate innovative development of climate finance Diversify and improve climate finance products Structured energy-saving collateral Green credit card Enrichment of product types Improve the infrastructure of the carbon financial market Establish a sound carbon financial trading platform	Diversified carbon finance products	Carbon finance
Carbon price stabilization mechanism	Improvement of the upward and downward price limit mechanism Fixed price stage Floating price stage Establishment of price control mechanisms Setting a reasonable range for carbon price Balancing supply and demand in the carbon market	Fair and stable carbon price	Carbon price

Free distribution	Combination of free allocation and auction Expansion of paid access to quotas Benchmarking method Historical method Adoption of a scientific distribution model Improve the transparency and fairness of allocation Dynamic adjustment of carbon allowances	Rationalization of carbon allowance allocation methodology	Carbon allowance
Internal management	Enrich the content of carbon asset training Introducing experts and specialists in the carbon field Establishment of a professional carbon management team Improve the carbon management system Strengthen carbon management training and communication	Carbon management talents	Carbon management capability
Green behavior	Promoting green behaviors of advanced typical companies Demonstrate and lead the way Engaging social capital Setting up a green industry fund Improve green investment risk assessment and management system	Increasing Green Investment	Green investment
Green innovation dynamics	Launching green innovation activities Increase the number of green patent application approvals Establishment of specialized green innovation R&D funds Build innovation cooperation networks	Cultivate green innovation capacity	Green innovation capability
Carbon disclosure	A sound framework for carbon disclosure Binding the form and content of carbon disclosure Increasing transparency in carbon disclosure Enhance carbon disclosure training and communication	Guiding carbon disclosure	Carbon information disclosure
Carbon emissions data	Improve MRV technical specifications for carbon emissions data Harmonies verification standards nationwide Strengthening technical regulatory instruments Dynamic regulation of the whole process of carbon trading	Improving capacity for carbon regulation	Carbon regulation
Policy and regulations	Incentive quotas for performing companies Establishment of penalty mechanisms for non-compliance Refinement of the provisions of carbon-related laws and regulations Promote dynamic adjustment of laws and regulations	Improvement of policy and regulations	Carbon policy and regulation

Table 6.25 summarizes the PESTLE analysis of the responses of the carbon trading pilot companies, which are expressed in terms of carbon finance, carbon price,

carbon quota allocation, carbon management capacity, green investment, green technology innovation capacity, carbon disclosure, carbon data monitoring, and carbon policy and regulations.

Table 6.25
PESTLE Analysis of Countermeasures of Carbon Trading Pilot Companies

		P	E	S	T	L	E
i	Diversified carbon finance products		/				
ii	Fair and stable carbon price		/				
iii	Rationalization of carbon allowance allocation methodology		/				
iv	Carbon management talents			/			
v	Increasing Green Investment				/		
vi	Cultivate green innovation capacity				/		
vii	Guiding Carbon Disclosure					/	
viii	Supervision of company performance behavior					/	
ix	Improvement of policy and regulations	/				/	

Note: F–Political, E–Economic, S–Social, T–Technological, L–Legal, E–Environmental.

6.6.2 Problems and Countermeasures for Non-Carbon Trading Pilot Companies

6.6.2.1 Problems

Employees from non-carbon trading pilot companies in the iron and steel sector contend that their companies possess an inadequate understanding of the policy and exhibit limited low-carbon awareness. P17 asserted:

> *"Non-pilot companies may possess limited awareness of carbon trading policy and may not comprehend the significance of carbon trading and its future implications. This may result in companies being unable to implement timely adjustments, hence heightening compliance risks in response to future regulation changes." (P17)*

Companies participating in non-carbon trading pilots exhibit a deficient comprehension of the significance of carbon emissions management, fail to properly acknowledge the repercussions of climate change on their long-term viability, and demonstrate a lack of impetus to mitigate emissions and proactively engage in carbon management. P18 commented:

> *"The company refrains from engaging in carbon trading, and without external pressure or economic incentives to reduce emissions, it is likely to uphold the status quo. Its production processes remain excessively dependent on high-carbon energy, lacking the development and utilization of alternative energy sources, and it has not proactively implemented energy-saving or emission reduction measures." (P18)*

Insufficient policy awareness and a lack of motivation to reduce emissions will compel the company to invest substantial capital and time in emission reduction and renovation. This, in turn, elevates operating costs and company risks amid impending stringent environmental protection policy.

Employees of non-carbon trading pilot companies within the petrochemical sector observed an absence of sophisticated energy conservation and emissions mitigation solutions in their companies. As explained below:

> *"Non-pilot companies have overlooked the study, development, and implementation of low-carbon technology due to their non-participation in carbon trading and the absence of external pressure. This will result in companies trailing behind those engaged in carbon trading regarding technological innovation, hence diminishing their market competitiveness." (P20)*

The company's production technologies and equipment are comparatively obsolete, resulting in inefficient energy utilization and heightened carbon emissions. P21 asserted:

> *"Numerous traditional manufacturing companies possess obsolete production machinery and lack energy-efficient renovations and equipment enhancements, resulting in substantial energy consumption and significant carbon emissions during the manufacturing process." (P21)*

Employees from non-carbon trading pilot companies within the chemical sector evaluated the company's carbon data monitoring and accounting capabilities as insufficient. P24 noted:

> *"The Company lacks qualified staff and equipment for precise carbon data monitoring and accounting, leading to erroneous carbon emission data that adversely impacts the Company's carbon emission management and decision-making." (P24)*

P28 contends that there is presently a deficiency in project funding for non-carbon trading pilot companies. P28 shared:

> *"The company's execution of energy conservation and emission reduction initiatives necessitates substantial capital expenditure; yet, inadequate financing avenues have led to a funding shortfall for these projects, so compromising their effectiveness in reducing emissions." (P28)*

The aforementioned issues stem from companies' insufficient financial capacity. Numerous small and medium-sized companies exhibit insufficient financial robustness, hindering their ability to secure loan assistance from banks and other financial institutions and limiting their capacity to spend further resources on emission reduction initiatives.

Employees from non-carbon trading pilot companies in the aviation industry believe their companies are facing decreased market competitiveness. As P30 noted:

> *"As global apprehension regarding climate change escalates, people are more predisposed to select ecologically sustainable items and services offered by companies. Companies who do not engage in carbon reduction will face disadvantages regarding product image and market share." (P30)*

Table 6.26 summarizes the results of the qualitative analysis of the problems of the non-carbon trading pilot companies.

Table 6.26
Qualitative Results for Non-Carbon Trading Pilot Company Problems

Deductive	Codes	Categorizing	Final theme
Compliance risk	Inability to make timely adjustments Lack of development and utilization of new energy sources Low awareness of carbon reduction Lack of policy understanding	Policy awareness	Level of consciousness
Technology development	Neglecting R&D and application of low-carbon technologies Poor access to technology information High cost of technology adoption	Technology upgrades	Technical level
Carbon data monitoring and accounting	Lack of professional carbon data monitoring and accounting staff and equipment Inaccurate carbon emission data Inadequate carbon accounting systems	Internal management	Carbon management level
Funds	Shortage of funds for emission reduction projects Lack of policy funding support Limited access to financing	Shortage of funds	Financial level

Product image	Market share will be at a disadvantage Product Carbon Footprint Disadvantage Difficulty in meeting customers' green needs	Decreased market competitiveness	Market competitiveness level

Table 6.27 summarizes the PESTLE analysis of the problems of the non-carbon trading pilot companies, which are expressed in terms of policy awareness, technological upgrading, carbon management, availability of funds, and market competitiveness.

Table 6.27
PESTLE Analysis of Problems in Non-Carbon Trading Pilot Companies

		P	E	S	T	L	E
i	Policy awareness	/					
ii	Technology upgrades				/		
iii	Internal management			/			
iv	Shortage of funds		/				
v	Decreased market competitiveness			/			

Note: F–Political, E–Economic, S–Social, T–Technological, L–Legal, E–Environmental.

6.6.2.2 Countermeasures

In light of insufficient policy recognition and inadequate low-carbon awareness, employees from non-carbon trading pilot companies within the iron and steel sector assert that companies ought to enhance policy promotion and training and integrate low-carbon metrics into the company evaluation framework. P17 asserted:

> *"The Government should enhance awareness of low-carbon development and associated legislation and regulations, ensuring that company management and employees understand the significance of low-carbon initiatives. Fundamental understanding of carbon trading, rules and regulations, and market dynamics can be disseminated among companies through the company of training courses, seminars, and the distribution of promotional materials." (P17)*

P18 added:

> *"Low carbon indicators are incorporated into the assessment system to ensure that the company's management and personnel acknowledge the significance of carbon management." (P18)*

In light of the insufficient motivation to decrease emissions, representatives

from non-carbon trading pilot companies within the paper industry contended that companies have to implement internal strategies to mitigate emissions. As explained below:

> *"Non-pilot companies, while not engaged in carbon trading, can implement self-restraint, proactively develop internal emission reduction mechanisms, define targets and strategies for emission reductions, and enhance the management and control of carbon emissions." (P21)*

Implementing an internal emission reduction system enhances the company's environmental reputation, positions it for future engagement in carbon trading, and mitigates transition expenses.

In light of the issue of delayed technological advancement, employees from non-carbon trading pilot companies within the chemical sector assert that companies ought to augment their involvement in the R&D of low-carbon technologies. P24, confirmed by commenting:

> *"The company can collaborate with colleges, universities, and scientific research institutes to implement industry-university-research cooperation projects and collaboratively develop innovative emission reduction technologies. The company can actively adopt and integrate advanced foreign technological expertise to expedite its technological advancement." (P24)*

The government ought to enhance the green low-carbon science and technology innovation framework, establish a science and technology innovation consortium, promote collaborative research among industry, academia, and research applications, facilitate the integration of industry, academia, and research, refine the low-carbon technology standard system, and develop a low-carbon energy digital development data center (Du, 2023). Policymakers ought to promote collaboration between non-pilot companies and research institutions or universities to expedite the R&D of low-carbon technologies (Qi et al., 2021).

To address the issue of inadequate capacity for carbon data monitoring and accounting, staff from non-carbon trading pilot companies in the chemical sector assert that companies can recruit and train specialized technical professionals. As P25 mentioned:

"The company can attract and develop professional and technical talent through internal training and external recruitment to form a specialized carbon data monitoring and accounting team, thereby enhancing the accuracy and reliability of carbon data monitoring and accounting." (P25)

In light of the funding deficit for emission reduction initiatives, staff from non-carbon trading pilot companies within the building materials sector assert that companies had to diversify their financing avenues. P26 explained:

"The company may seek government grants for energy conservation and emission reduction or collaborate with banks to implement green credit initiatives and carbon asset pledge financing to secure funding for emission reduction projects." (P26)

To address the issue of diminishing market competitiveness, non-carbon trading pilot companies within the non-ferrous metals sector can improve their brand image and market position by intensifying environmental protection advocacy and engaging proactively in environmental certification and evaluation initiatives, as suggested by P28:

"A company can emblazon its product packaging with an environmental emblem to communicate its ecological philosophy and initiatives to consumers. Engage in environmental certification and rating initiatives, including ISO 14001 environmental management system certification and green company assessment, to enhance the company's environmental credibility." (P28)

Table 6.28 presents the results of the qualitative analysis of the countermeasures of the non-carbon trading pilot companies.

Table 6.28
Qualitative Results of Non-Carbon Trading Pilot Company Countermeasures

Deductive	Codes	Categorizing	Final theme
Policy training	Strengthen policy publicity and training Incorporate low-carbon indicators into the company's assessment system Taking the initiative to establish an internal mechanism to reduce emissions Strengthening of awareness-raising and education	Policy advocacy	Consciousness level
Emission reduction technologies	Industry-university-research co-operation projects Research and development of advanced emission reduction technologies	Low carbon technology	Technical level

	Increased investment in R&D Reduce technology costs		
Carbon data monitoring and accounting	Attract and develop professional and technical talents Establish a professional carbon data monitoring and accounting team Improving the carbon accounting system Developing a carbon management strategy	Internal management	Carbon management level
Earmarked funds	Apply for special funds for energy saving and emission reduction Carry out green credit company Expanding financing channels Increase return on investment	Financing channels	Financial level
Brand image	Active participation in environmental certification and rating activities Enhance environmental credibility Reduce product carbon footprint Satisfy customer needs	Enhancing market competitiveness	Market competitiveness level

Table 6.29 summarizes the PESTLE analysis of the countermeasures of the non-carbon trading pilot companies, which are expressed in terms of policy awareness, technological upgrading, carbon management, availability of funds, and market competitiveness.

Table 6.29
PESTLE Analysis of Responses of Non-Carbon Trading Pilot Companies

		P	**E**	**S**	**T**	**L**	**E**
i	Policy advocacy	/					
ii	Low carbon technology				/		
iii	Internal management			/			
iv	Financing channels		/				
v	Enhancing market competitiveness			/			

Note: F–Political, E–Economic, S–Social, T–Technological, L–Legal, E–Environmental.

Table 6.30 presents the summary results of the problems and countermeasures of the carbon trading pilot and non-carbon trading pilot companies. Table 6.31 summarizes the results of the qualitative analysis.

Table 6.30

Summary of Problems and Countermeasures for Carbon Trading Pilot and Non-Carbon Trading Pilot Companies

Carbon Trading Pilot Companies		Non-Carbon Trading Pilot Companies	
Problems	**Countermeasures**	**Problems**	**Countermeasures**
A pool with no water It does not reflect the true value of carbon allowances The development of carbon futures, carbon options, carbon forwards and other derivatives is relatively lagging behind. Uncertainty of returns is large Carbon financial products and services are single Insufficient regulation of the carbon finance market	Innovative futures exchange Accelerate innovative development of climate finance Diversify and improve climate finance products Structured energy-saving collateral Green credit card Enrichment of product types Improve the infrastructure of the carbon financial market Establish a sound carbon financial trading platform	Inability to make timely adjustments Lack of development and utilization of new energy sources Low awareness of carbon reduction Lack of policy understanding	Strengthen policy publicity and training
Insufficient incentives for carbon price reduction Ride a roller coaster Carbon price stabilization mechanism Higher price volatility	Improvement of the upward and downward price limit mechanism Fixed price stage Floating price stage Establishment of price control mechanisms Setting a reasonable range for carbon price Balancing supply and demand in the carbon market	Neglecting R&D and application of low-carbon technologies Poor access to technology information High cost of technology adoption	Incorporate low-carbon indicators into the company's assessment system
Quotas are mainly allocated free of charge The proportion of auctions is lower Historical method and datum method Unscientific distribution methodology Lack of dynamic adjustment mechanism	Combination of free allocation and auction Expansion of paid access to quotas Benchmarking method Historical method Adoption of a scientific distribution model Improve the transparency and fairness of allocation Dynamic adjustment of carbon allowances	Lack of professional carbon data monitoring and accounting staff and equipment Inaccurate carbon emission data Inadequate carbon accounting systems	Taking the initiative to establish an internal mechanism to reduce emissions
Lack of carbon management talent	Enrich the content of carbon asset training	Shortage of funds for emission	Strengthening of awareness-raising

Carbon management training courses and certification systems are not mature enough Lack of carbon management practice cases and experience in the exchange platform Lack of whole process management of carbon emissions Incomplete management system	Introducing experts and specialists in the carbon field Establishment of a professional carbon management team Improve the carbon management system Strengthen carbon management training and communication	reduction projects Lack of policy funding support Limited access to financing	and education
The proportion of renewable energy in the company's energy mix is low Lack of investment in forest carbon sequestration projects Insufficient incentive to invest Concerns about investment risks and uncertainty of returns	Promoting green behaviors of advanced typical companies Demonstrate and lead the way Engaging social capital Setting up a green industry fund Improve green investment risk assessment and management system	Market share will be at a disadvantage Product Carbon Footprint Disadvantage Difficulty in meeting customers' green needs	Industry-university-research co-operation projects
Lack of green product innovation R&D cycle extension Innovation results cannot be applied to production practice in time Lack of professional green innovation talents Inadequate mechanisms for innovative cooperation	Launching green innovation activities Increase the number of green patent application approvals Establishment of specialized green innovation R&D funds Build innovation cooperation networks		
The format, index and method of carbon information disclosure are not uniform Carbon disclosure is not timely Incomplete disclosure Poor quality of disclosure	A sound framework for carbon disclosure Binding the form and content of carbon disclosure Increasing transparency in carbon disclosure Enhance carbon disclosure training and communication		
Carbon emissions data falsified Change emissions reporting data Inadequate regulatory system Outdated monitoring technology and means Insufficient punishment	Improve MRV technical specifications for carbon emissions data Harmonies verification standards nationwide Strengthening technical regulatory instruments Dynamic regulation of the whole process of carbon trading		
Lack of superior law	Incentive quotas for performing companies		

There are differences in the form of legislation	Establishment of penalty mechanisms for non-compliance	
Lower level of legislation	Refinement of the provisions of carbon-related laws and regulations	
Incomplete content of the law		
Difficulty in enforcing the law	Promote dynamic adjustment of laws and regulations	

Table 6.31

Summary of Qualitative Findings

Research Questions	Research Objectives	Interview Topics	Categorizing	Final Theme
3. How does implementing carbon market policy affect the company performance of high-polluting industries - pilot and non-carbon trading pilot companies?	3. To investigate how implementing carbon market policy impacts the company performance in high-polluting industries, comparing pilot and non-carbon trading pilot companies.	1. Motivation to participate in carbon trading	Financial security New energy utilization Environmental image Carbon management Carbon regulation	(1) Economic benefits (2) Technology innovation (3) Carbon Emission reduction (4) Market competitiveness (5) Policy compliance and risk avoidance
		2. Carbon finance, green technology innovation and company performance	Financing support Technology upgrade Brand image Social responsibility Environmental compliance Financing costs	(1) Economic benefits (2) Technical benefits (3) Environmental benefits (4) Social benefits (5) Compliance costs (6) Financing constraints
		3. Carbon price, green technology innovation and company performance	Profit growth R&D investment Energy saving and emission reduction Social responsibility Cost of carbon Carbon price level	(1) Economic benefits (2) Technical benefits (3) Environmental benefits (4) Social benefits (5) Cost pressure (6) Reasonable carbon price
		4. Carbon trading, green technology innovation and company performance	Quota trading benefits Technology innovation Energy saving and emission reduction Carbon management Short-term costs	(1) Economic benefits (2) Technical benefits (3) Environmental benefits (4) Social benefits (5) Cost pressure
		5. Opportunities for carbon trading pilot companies	Policy preferences Profit from quota trading Technology upgrade Energy saving and emission reduction Social responsibility	(1) Policy benefits (2) Economic benefits (3) Technical benefits (4) Environmental benefits (5) Social benefits
		6. Challenges for carbon trading pilot companies	Policy uncertainty Carbon price volatility Technology innovation risk Carbon professionals	(1) Policy & institutional risk (2) Market risks (3) Technology and data management risk (4) Internal management risks
		7. Willingness of non-carbon trading pilot companies to participate in carbon trading	Economic benefits Technical benefits Environmental benefits Social benefits Cost pressure Carbon price volatility Environmental penalties	(1) Positive influence (2) Negative impact
		8. Opportunities for non-carbon trading pilot companies	Centralization of resources Freedom of production planning Upstream and downstream cooperation Voluntary emission reduction More favorable	(1) Focus on core company development (2) Flexible company decisions (3) Multiple modes of cooperation for emission reduction

			market timing	(4) Enhanced reputation and brand image (5) Policy opportunities
3. How does the implementation of carbon market policy impact the company's performance in high-polluting industries, comparing pilot and non-carbon trading pilot companies?	3. To investigate how implementing carbon market policy impacts the company performance in high-polluting industries, comparing pilot and non-carbon trading pilot companies.	9. Challenges for non-carbon trading pilot companies	Regulatory pressure Cost of carbon Financing difficulties Customer churn Technology upgrade costs	(1) Policy risks (2) Cost disadvantage (3) Financial risk (4) Market competition pressure (5)Risk of technological backwardness
		10. Problems of carbon trading pilot companies	Insufficient participation and liquidity in carbon finance Lower carbon price Carbon quota allocation method Weak carbon management capabilities Underinvestment in green Weak green innovation ability Incomplete carbon disclosure Incomplete carbon emission data monitoring mechanism Imperfect policy and regulations	(1) Carbon finance (2) Carbon price (3) Carbon quota (4) Carbon management capability (5) Green investment (6) Green innovation capability (7) Carbon information disclosure (8) Carbon regulation (9) Carbon policy and regulation
		11. Countermeasures of carbon trading pilot companies	Diversified carbon finance products Fair and stable carbon price Rationalization of carbon allowance allocation methodology Carbon management talents Increasing Green Investment Cultivate green innovation capacity Guiding Carbon Disclosure Supervision of company performance behavior Improvement of policy and regulations	(1) Carbon finance (2) Carbon price (3) Carbon allowance (4) Carbon management capability (5) Green investment (6) Green innovation capability (7) Carbon information disclosure (8) Carbon regulation (9) Carbon policy and regulation
		12. Problems of carbon non-carbon trading pilot companies	Policy awareness Technology upgrades Internal management Shortage of funds Decreased market competitiveness	(1) Level of consciousness (2) Technical level (3) Carbon management level (4) Financial level (5) Market competitiveness level
		13. Countermeasures of non-carbon trading pilot companies	Policy advocacy Low carbon technology Internal management Financing channels Enhancing market competitiveness	(1) Consciousness level (2) Technical level (3) Carbon management level (4) Financial level (5) Market competitiveness level

6.7 Chapter Summary

This chapter encapsulates the findings of the qualitative study. It initially presents the fundamental details of the interviewees. Secondly, it encapsulates the impetus for engaging in carbon trading, the influence of carbon market mechanisms and green technology innovation on company performance, as well as the possibilities, challenges, issues, and solutions encountered by both carbon trading pilot and non-carbon trading pilot companies. The chapter is ultimately summarized. The subsequent chapter encompasses the conclusion, research contributions, limitations of the article, and future research directions.

CHAPTER 7

DISCUSSION AND CONCLUSION

7.1 Introduction

This chapter encapsulates the findings of both the quantitative and qualitative research. It is structured as follows: Section 7.2 is the answer to the research question; Section 7.3 examines the significance and contributions of the study across conceptual, theoretical, methodological, empirical, and managerial dimensions; Section 7.4 outlines the limitations of the study; Section 7.5 proposes critical directions for future research; and it concludes with a summary.

7.2 Summary and Conclusion

The primary aim of this study is to investigate whether market-oriented environmental regulation, namely China's carbon market mechanisms, can provide a mutually beneficial outcome for environmental preservation and economic development. In particular, this paper analyses the multifaceted effects of carbon market mechanisms (carbon finance, carbon price, and carbon trading policy) on company performance (economic and sustainability performance). The moderating effect of green technology innovation on the relationship between carbon market mechanisms and company performance is also explored. The prospects, challenges, issues, and countermeasures confronting China's carbon market (both carbon trading pilot and non-carbon trading pilot) are analyzed.

This study employed a mixed research technique to address the research questions and objectives. This study seeks to fulfil the three research objectives using the quantitative and qualitative phases of the research design. The quantitative phase included the Difference-in-Differences (DID) model and multiple regression analysis to accomplish the initial two research objectives. Chapter 2 provides an overview of the backdrop of carbon market mechanisms. The theoretical framework and assumptions outlined in Chapter 3 have served as a fundamental guide to assure the attainment of all

study objectives. Chapter 4 examines the research process, namely the two phases of research design. Chapter 5 delineates the outcomes of the quantitative data analysis and provides a comprehensive discussion of the results. In Chapter 6's qualitative research phase, a semi-structured interview topic analysis was employed to substantiate the quantitative findings. Chapter 7 succinctly encapsulates the principal results and conclusions. The research objectives and the two-phase research design implemented are presented in Table 7.1.

Table 7.1

Research Objectives and the Summary of Two Phases of Research Design

Research Objectives	Phase of the Study	Sources of Data	Main Method of Analysis Used
1. To examine the differential impacts of carbon market mechanisms (carbon finance, carbon price and carbon trading policy) on company performance (economic and sustainability) of heavily polluting industries before and after carbon trading policy implementation, compared between pilot and non-carbon trading pilot companies.	Phase 1 (quantitative), supported by Phase 2 (qualitative)	CSMAR database, China carbon accounting database (CEADs), Bloomberg database, GPRD of China Research Data Service Platform (CNRDS)	DID model and multiple regression analysis
2. To analyse green technology innovation moderates the impacts of carbon market mechanisms (carbon finance, carbon price and carbon trading policy) on company performance (economic and sustainability) of heavily polluting industries, before and after carbon trading policy implementation, compared between pilot and non-carbon trading pilot companies.	Phase 1 (quantitative), supported by Phase 2 (qualitative)	CSMAR database, China carbon accounting database (CEADs), Bloomberg database, GPRD of China Research Data Service Platform (CNRDS)	DID model and multiple regression analysis
3. To investigate how implementing carbon market policy impacts the company performance in high-polluting industries, comparing pilot and non-carbon trading pilot companies.	Phase 2 (qualitative), to support Phase 1 (quantitative)	Semi-structured interviews with 30 persons selected from carbon trading pilot and non-carbon trading pilot listed companies	Thematic analysis of interviews related to Phase I findings, PESTLE analysis

7.2.1 Carbon Market Mechanisms and Company Performance

The initial research question investigates the varying effects of carbon market mechanisms (carbon finance, carbon price, and carbon trading policy) on company performance (economic and sustainable performance) in heavily polluting industries prior to and following the enactment of carbon trading policy.

Hypothesis H1a evaluated the influence of carbon financing on companies' economic performance, and the study's findings indicated a negative impact of carbon finance on companies' economic performance, hence refuting hypothesis H1a. The likely explanation for this is that carbon finance has resulted in a more rigorous compliance review of companies' loan disbursements by commercial banks, leading to financing penalties and disincentives for investment, thereby causing carbon finance to have an adverse effect on companies' performance.

Hypothesis H1b evaluates the influence of carbon finance on company sustainable performance (ESG), with study results indicating a positive effect of carbon finance on sustainable performance, fully supporting hypothesis H1b. Numerous investigations undertaken in China corroborate these concepts (Qian & Yu, 2024; Xue et al., 2023; Wu & Liew, 2023). These studies demonstrate that the adoption of the Green Finance policy enhances the ESG performance of significantly polluting companies and facilitates their sustainable development.

Hypothesis H2a evaluates the influence of carbon price on economic performance, and the study's findings indicate that carbon price positively affects the company's economic performance, fully supporting hypothesis H2a. The results of this study are consistent with Bolton et al. (2023), Guo and Gong (2023), and Bento et al. (2021). They suggested that carbon price affects companies' profitability through various paths, such as investment preferences, production costs and cost structure.

Hypothesis H2b evaluated the effect of the carbon price on sustainable performance (ESG), revealing that this effect is negligible and does not corroborate hypothesis H2b. Researchers, including Lin and Jia 2019, Venmans et al. 2020, and Flachsland et al. 2020, have contended that diminished carbon price adversely affect company value and competitiveness. Following the introduction of the pilot carbon emissions trading system in China, carbon price have remained low and erratic. Reduced carbon costs have not effectively enhanced the sustainable performance of

companies, and the potential of China's carbon price remains underexploited (Luo et al., 2021).

Hypothesis H3a evaluated the impact of carbon trading policy on the company's economic performance, and the study's findings indicated that this impact is negligible, thereby failing to substantiate hypothesis H3a. Potential explanations for this include the lax initial distribution of allowances in the Chinese carbon market (Guo & Gong, 2023), the illogical methodology of allowance allocation, and the disparity between abatement costs and benefits.

Hypothesis H3b evaluates the influence of carbon trading policy on sustainable performance (ESG), and the study's findings indicate that this influence is both positive and significant, fully supporting hypothesis H3b. The findings of this study align with those of Li et al. 2024, Han et al. 2023, and Shi et al. 2024. They demonstrated that enacting a carbon trading policy in China diminishes regional carbon emissions and curtails per capita CO_2 emissions with enduring effects while simultaneously reducing the carbon intensity of companies to varying extents. Research from the EU has revealed comparable outcomes, with the EU ETS prompting regulated manufacturing companies to decrease their CO_2 emissions by 14 to 16% (Wintr, 2021).

The quantitative data indicate that hypotheses H1a, H2b, and H3a align with compliance cost theory, suggesting that market-based environmental regulation elevates companies' compliance costs, hindering company performance. Consequently, Porter's hypothesis is invalid. The findings of hypotheses H1b, H2a, and H3b indicate that Porter's hypothesis is substantiated; specifically, stringent environmental regulations positively influence company performance. In summary, the findings from the initial phase of the study indicate that RQ1 has been addressed and RO1 has been fulfilled.

7.2.2 Carbon Market Mechanisms, Green Technology Innovation and Company Performance

The second research question examines the moderating effect of green technology innovation on carbon market mechanisms (carbon finance, carbon price, and carbon trading policy) and company performance (economic and sustainable performance) in heavily polluting industries, both prior to and following the

implementation of carbon trading policy.

Hypothesis H4a posits that the moderating effect of green technology innovation on the relationship between carbon finance and companies' economic performance is insignificant, potentially attributable to insufficient innovation capacity, challenges in implementing innovations, and the substantial costs and risks associated with green technology innovation (Zhang et al., 2022). The carbon financial market has issues, including restricted market size, a lack of diverse carbon financial products, and inadequate market liquidity.

Hypothesis H4b posits that green technology innovation significantly moderates the relationship between carbon finance and company sustainability performance, a notion corroborated by numerous research conducted in China (Xu et al., 2023; Zeng et al., 2022; Zhang & Li, 2022; Lee et al., 2023). The aforementioned research indicates that green funding enhances energy efficiency and hence diminishes carbon emissions by fostering green technology innovation and optimizing energy structures.

Hypothesis H5a posits that green technology innovation significantly moderates the relationship between carbon price and companies' economic success. The findings of this study align with those of Cui et al. (2018), Lim and Prakash (2023), and Cantone et al. (2023). It indicates that carbon price stimulate an increase in green patent applications and that elevated carbon price serve as a potent incentive for low-carbon innovation.

Hypothesis H5b indicates that the moderating influence of green technology innovation on the relationship between carbon price and sustainable performance is insignificant, likely attributable to carbon price volatility and the low carbon price in the Chinese carbon market (Yu et al., 2022). Inadequate liquidity in carbon markets and elevated initial Research and Development (R&D) expenses for green technology innovation (Sadawi et al., 2021).

Hypothesis H6a posits that green technology innovation positively moderates the relationship between carbon trading policy and economic performance. The findings of this study align with those of Fu et al. (2023), Sun et al. (2023), and Liu et al. (2022), indicating that carbon trading stimulates technological innovation and unleashes green innovation potential. Carbon trading enhances the efficiency of regional green innovation via energy substitution and structural upgrading impacts.

Hypothesis H6b posits that green technology innovation negatively moderates

the relationship between carbon trading policy and sustainable performance. This phenomenon may be ascribed to the irrational distribution of quotas within China's carbon market, excessive leniency, heightened company compliance and governance expenses (Sun et al., 2023), and the inherent characteristics of green technology innovation, which include substantial initial investment, elevated risk, and prolonged development cycles (Zhang et al., 2022).

The quantitative findings indicate that the results of hypotheses H4a, H5b, and H6b align with compliance cost theory, hence rendering Porter's hypothesis invalid. The results of hypotheses H4b, H5a, and H6a indicate the validity of Porter's hypothesis theory. In summary, the quantitative data suggest that RQ2 has been addressed and RO2 has been fulfilled.

The results of the quantitative study were mixed, indicating that the theory of Porter's hypothesis is very controversial. Hence, this study remains neutral. A summary of the quantitative findings is presented in Figure 7.1.

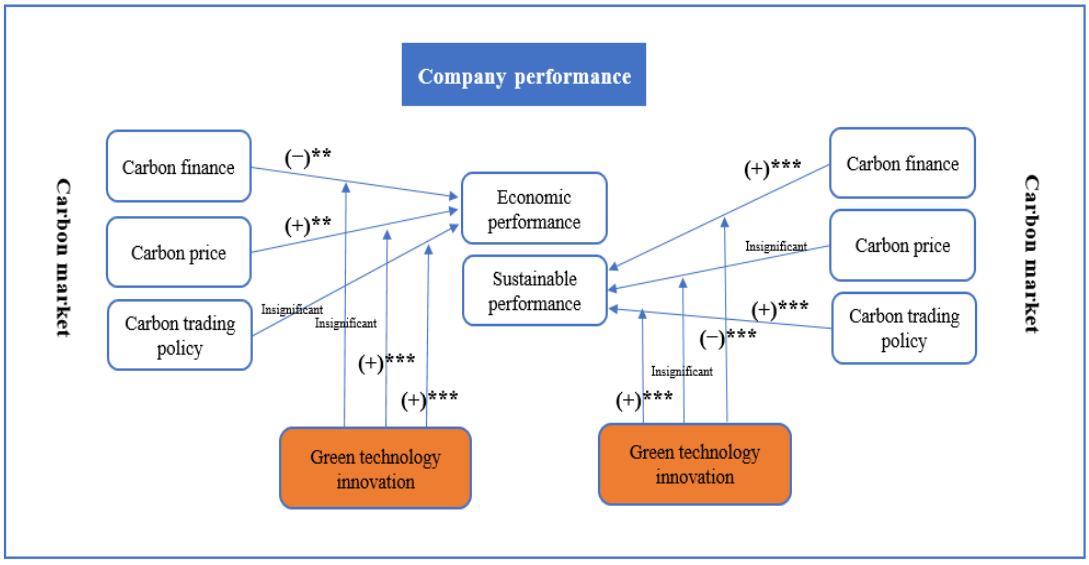


Figure 7.1 Summary of Quantitative Findings

7.2.3 Opportunities and Challenges, Problems and Countermeasures of Carbon Market Mechanisms

The qualitative study employed semi-structured interviews to reinforce the

quantitative results. The qualitative study performed PESTEL analyses for carbon trading pilots and non-carbon trading pilots (Figures 7.2 and 7.3), examining six dimensions: political, economic, social, technological, legal, and environmental. Carbon trading pilot companies face chances for advantageous policy alongside constraints posed by policy uncertainty and flawed rules. Economically, there exist prospects for lucrative quota trading alongside constraints, including fluctuating carbon price, depressed carbon price, and inadequate participation and liquidity in carbon finance. Socially, there are prospects for enhanced corporate social responsibility, alongside obstacles including insufficient carbon expertise, inadequate carbon management capabilities, and a scarcity of carbon management professionals. In the technological domain, there exist prospects for technological enhancement and augmented investment in R&D, alongside obstacles like inadequate green investment and feeble green innovation capabilities. Furthermore, legal challenges include heightened environmental compliance expenses, inadequate carbon disclosure, and flawed carbon emissions data monitoring systems. From an environmental perspective, there exists a chance for brand image development and the promotion of energy conservation and emission reduction.

Carbon Trading Pilot Companies PESTEL Analysis

P	E	S	T	L	E
Political	Economic	Social	Technological	Legal	Environmental
Policy preferences Policy uncertainty Imperfect policies and regulations Improvement of policies and regulations	Profit from quota trading Carbon price volatility Insufficient participation and liquidity in carbon finance Lower carbon prices Carbon quota allocation method Diversified carbon finance products Fair and stable carbon price Rationalization of carbon allowance allocation methodology	Social responsibility Carbon management Carbon professionals Weak carbon management capabilities Carbon management talents	Technology upgrade R&D investment Technology innovation Technology innovation risk Underinvestment in green Weak green innovation ability Increasing Green Investment Cultivate green innovation capacity	Environmental compliance Incomplete carbon disclosure Incomplete carbon emission data monitoring mechanism Guiding carbon disclosure Supervision of company performance behavior	Brand image Energy saving and emission reduction

Figure 7.2 Carbon Trading Pilot Companies PESTEL Analysis

For non-carbon trading pilot companies, the political dimensions encompass potential, such as anticipating more advantageous market conditions and problems, enhancing policy awareness, and bolstering policy lobbying. The economic factors encompass advantages like the aggregation of superior resources and autonomy in production planning alongside consumer attrition, capital scarcity, and diminished market competitiveness. Socially, there are issues, including a deficiency of carbon management personnel and inadequate internal carbon management. At the same time, technological issues include elevated expenses for technology updates and insufficient availability of low-carbon technology. In addition, there exists a challenge of regulatory pressure in the legal domain. Moreover, opportunities exist to enhance knowledge of voluntary emission reduction on the environmental front.

Non-Carbon Trading Pilot Companies PESTEL Analysis

P	E	S	T	L	E
Political	Economic	Social	Technological	Legal	Environmental
More favorable market timing Policy awareness Policy advocacy	Centralization of resources Freedom of production planning Upstream and downstream co-operation Carbon cost Customer churn Shortage of funds Decreased market competitiveness Financing channels	Carbon management	Technology upgrade costs Technology upgrades Low carbon technology	Regulatory pressure	Voluntary emission reduction

Figure 7.3 Non-Carbon Trading Pilot Companies PESTEL Analysis

The qualitative component of the study performed a PESTEL analysis of carbon trading and non-carbon trading pilots, which encapsulated the respondents' perspectives more thoroughly and offered greater support for the quantitative analysis. In summary, the qualitative research findings indicate that RQ3 has been addressed and RO3 has been achieved.

Figure 7.4 presents a comprehensive research framework employing the Strengths, Weaknesses, Opportunities, and Threats (SWOT) model to evaluate and contrast the opportunities and challenges alongside the issues and solutions encountered by carbon trading pilots and non-carbon trading pilots, yielding the following

significant implications from the comparative analysis.

Level of strategy development. Articulating the benefits of carbon trading pilots regarding policy preferences and profit models, alongside the advantages of non-carbon trading pilots regarding resource allocation and market timing, will enable them to devise a development strategy that leverages their unique strengths. For instance, carbon trading pilots may enhance their carbon finance operations, while non-carbon trading pilots can bolster upstream and downstream collaboration. Explicitly delineating the drawbacks of the two pilot types, including the insufficient carbon financial liquidity of carbon trading pilots and the funding deficits of non-carbon trading pilots. This necessitates the formulation of targeted remedial strategies to address their deficiencies and augment their overall competitiveness.

Level of risk management. It identifies perilous factors, including policy ambiguity and carbon price volatility encountered by carbon trading pilots, as well as regulatory pressures and financing challenges faced by non-carbon trading pilots, enabling relevant stakeholders to proactively prepare for risk alerts and responses, thereby mitigating potential losses. Moreover, leveraging opportunity factors, including the enhancement of policy and regulations for carbon trading pilots and the prospects for low-carbon technology advancement for non-carbon trading pilots, enables these initiatives to capitalize on opportunities promptly for swift development and breakthroughs.

Level of policy enhancement. It offers a basis for the government to design and modify pertinent policy, enabling the optimization of the carbon trading policy framework informed by analytical outcomes, enhancing policy support for non-carbon trading initiatives, and advancing comprehensive low-carbon economic growth. It also assists the government in allocating resources and delivers targeted support in capital, technology, and personnel to address the specific challenges and requirements of various pilots, thereby enhancing resource utilization efficiency.

Level of industry development. The two categories of pilots can benefit from one another’s expertise; carbon trading pilots can impart knowledge on carbon management, while non-carbon trading pilots can offer insights on internal management optimization to enhance the industry’s overall performance. By conducting comparative assessments, the researcher will facilitate the synergistic advancement of carbon trading pilots alongside non-carbon trading pilots, establishing

a framework of complementary advantages to collaboratively support low-carbon transformation and the attainment of sustainable development objectives.

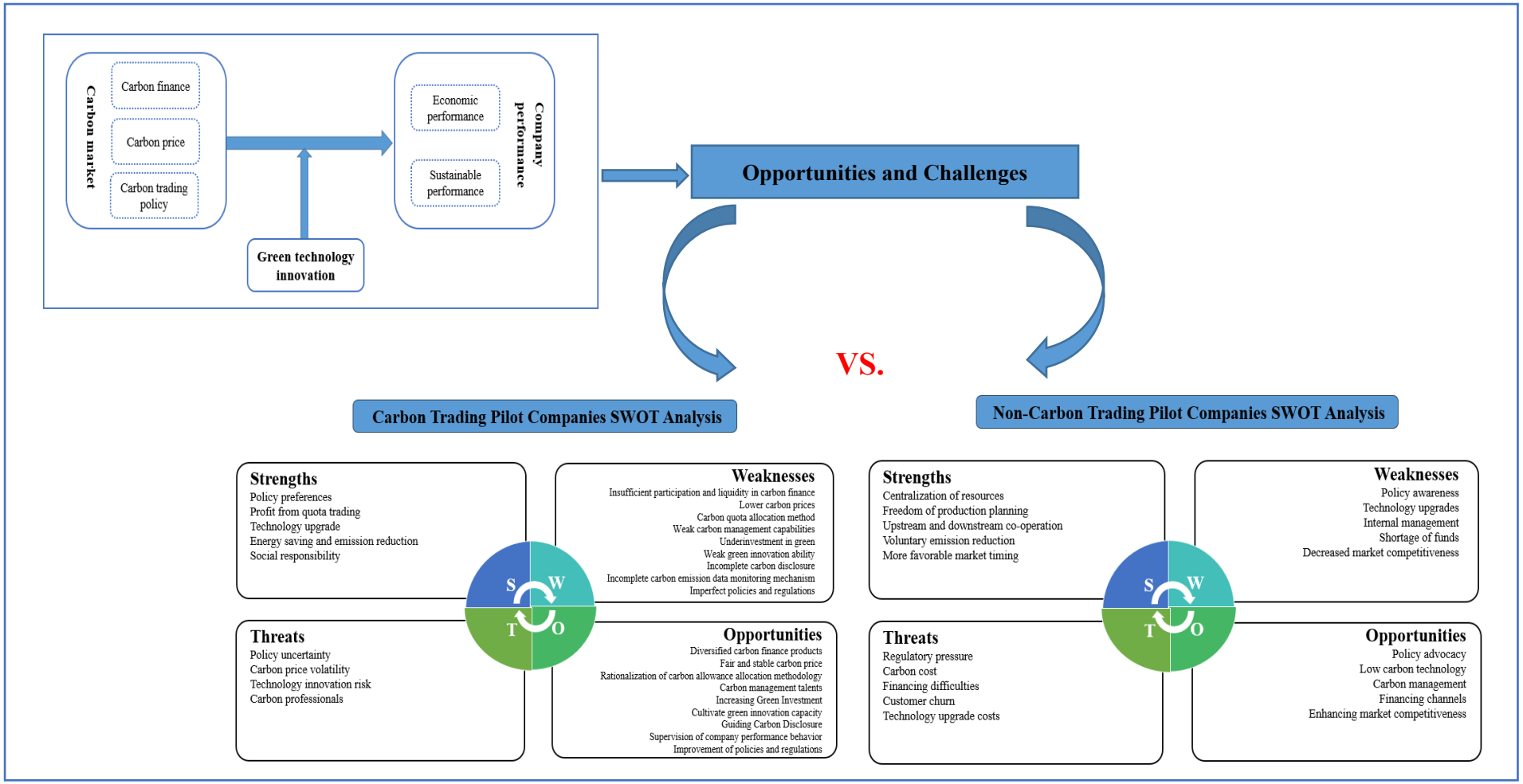


Figure 7.4 SWOT Analysis of Carbon Trading Pilots Companies and Non-Carbon Trading Pilots Companies

This study examines the influence of China's carbon market mechanisms on company performance within the framework of market-based environmental regulation. It employs both quantitative and qualitative research methodologies to analyse the interconnections among different components of the carbon market mechanisms, green technology innovation, and company performance. Additionally, it investigates the opportunities and challenges encountered by both carbon trading and non-carbon trading pilots, addressing associated issues and proposing countermeasures, ultimately leading to the following conclusive findings:

a) The complex relationship between carbon market mechanisms and company performance.

Carbon market mechanisms have positive and negative or insignificant effects on company performance. Some of the findings support Porter's hypothesis, and some are consistent with the compliance cost theory, suggesting that there is not a single trend in the impact of market-based environmental regulation on company performance. Nevertheless, Porter's hypothesis on the relationship between carbon market mechanisms and company performance is controversial.

b) Mixed moderating effects of green technology innovation

Green technology innovation has a positive moderating effect between the carbon market mechanisms and company performance. It also has a non-significant or negative moderating effect. This suggests that the moderating effect of green technology innovation in the relationship between carbon market mechanisms and company performance is constrained by various factors.

c) Porter's hypothesis theory is controversial

As some of the findings in the study support Porter's hypothesis and some contradict it, this study remains neutral on Porter's hypothesis, indicating that the hypothesis lacks consistent empirical support in the context of the relationship between carbon market mechanisms and company performance.

d) Opportunities and challenges exist for both carbon and non-carbon trading pilots

Government departments should pay attention to the challenges and problems and formulate positive coping strategies to better realize the win-win situation of economic development and environmental protection in the carbon market.

7.3 Implications and Contribution of the Study

This paper thoroughly evaluates the economic and sustainability impacts of the carbon market mechanisms concerning carbon finance, carbon price, and carbon trading policy, offering a detailed reference for the advancement of the carbon market mechanisms. This study offers a novel perspective on the correlation between carbon market mechanisms and company performance. This study provides original contributions in numerous significant domains, including conceptual, theoretical, methodological, empirical, and managerial.

7.3.1 Conceptual Implications

This paper thoroughly investigates the ideas of carbon market mechanisms, company performance, and green technology innovation. The carbon market mechanisms encompass three critical dimensions: carbon finance, carbon price, and carbon trading policy. Carbon finance is a novel and intricate domain encompassing primary and secondary markets. Carbon financial products consist of trading instruments, financing mechanisms, and market support systems. In particular, carbon finance encompasses a range of financial operations, and trading of carbon derivatives focused on carbon emission rights. It furnishes essential financial backing for the carbon market and establishes varied investment and risk management opportunities for participants.

Companies establish the carbon emissions trading price by purchasing and selling carbon allowances in the carbon emissions trading market. Similar to other trading markets, the carbon market facilitates price discovery, with the carbon price signal generated by market mechanisms serving as a significant characteristic of the carbon market. The establishment of the carbon price is affected by numerous elements, including macroeconomic conditions, energy prices, supply and demand dynamics, political influences, climate conditions, and the price of linked products. The volatility of carbon price mirrors the dynamics of the carbon market and significantly influences company decision-making, prompting companies to balance emission reductions with carbon trading considerations.

The carbon trading policy serves as the institutional framework for the systematic functioning of the carbon market, delineating the distribution of carbon emission rights, trading regulations, and oversight systems. The carbon trading policy

of many countries and regions differ based on their own development strategies and emission reduction objectives. However, all seek to motivate companies to decrease carbon emissions through market mechanisms.

This study examines two characteristics of company performance: economic performance and sustainable performance. Economic performance is primarily indicated by a company's Economic Value Added (EVA), whereas sustainable performance encompasses a more holistic approach that integrates economic, environmental, and social sustainability. This dimension of performance underscores the necessity for companies to seek immediate economic gains while prioritizing long-term sustainability to address escalating environmental and social challenges.

This study offers insights into the notion of green technology innovation. Green technical innovation is a crucial catalyst for carbon mitigation and sustainable development, encompassing the creation and implementation of many novel technologies, processes, and products designed to diminish environmental harm and enhance resource efficiency. In particular, green technology innovation offers companies and society technological avenues and solutions for achieving low-carbon transformation, significantly contributing to the efficient functioning of the carbon market mechanisms and improving company sustainability performance. As such, a comprehensive exposition of these notions establishes a robust theoretical framework for subsequent evaluations of their interconnections and effect processes.

7.3.2 Theoretical Implications

This study assesses the impact of the carbon emissions trading pilot on economic and sustainable performance characteristics via the lens of Porter's hypothesis theory. This research incorporates Porter's hypothesis theory into assessing carbon emissions trading pilots, enhancing the relevance and validity of Porter's hypothesis in China to some degree. Moreover, Porter's hypothesis posits that effective environmental regulation can yield environmental advantages while mitigating compliance costs by encouraging technical innovation among emitters, producing economic gains. Nevertheless, due to the disparities in research methodologies and objectives, no consensus exists regarding Porter's hypothesis within the academic community.

Porter's idea possesses a degree of rationality and positive importance, which accounts for its endorsement by certain experts. Nonetheless, Porter's concept

encounters numerous problems stemming from the substantial expenses associated with environmental regulation, the unpredictability of innovation remuneration, and the constraints of research methodologies and data. The empirical analyses in Chapter 5 of this study revealed both positive and negative effects of carbon market mechanisms on company performance, affirming the contentious character of Porter's premise; consequently, this study maintains a neutral stance.

Conversely, innovation theory constitutes a more expansive and intricate theoretical framework. Since Schumpeter introduced the concept of innovation, innovation theory has undergone constant development and refinement. In contrast to other forms of innovation, green technology innovation aligns with the low carbon economy and serves as a crucial component of green transformation and competitive enhancement for companies, and research on this innovation can directly validate Porter's hypothesis. This study examines carbon market mechanisms and company performance, revealing that green technology innovation has beneficial and detrimental effects. Consequently, it maintains a neutral stance on the regulatory framework of green technology innovation, affirming the contentious nature of Porter's hypothesis.

7.3.3 Methodological Implications

This study used a mixed research paradigm, leveraging the benefits of many research approaches to investigate the research issues more comprehensively and thoroughly. It includes both quantitative and qualitative research through semi-structured interviews.

This study employs the panel data DID model and continuous DID model for quantitative research on research questions RQ1 and RQ2. Panel data facilitates the observation of numerous individuals across various time points, thereby capturing information regarding changes in both individual and temporal dimensions. Panel data DID model efficiently adjusts for individual heterogeneity and temporal trends, allowing for precise evaluation of the causal impacts of policy or interventions on the variables of interest. This methodology possesses significant scientific validity and reliability in addressing issues typified by time series and cross-sectional data.

The continuous DID model enhances the depth and accuracy of the study by offering a more detailed representation of the dynamics of treatment effects in relation to continuous policy factors or variations in treatment intensity. The RQ1 and RQ2

investigations employ quantitative models utilizing extensive data samples, resulting in statistically significant and generalizable results that offer a robust empirical foundation for comprehending the phenomena and relationships involved.

Regarding the qualitative component of the study, for RQ3, semi-structured interviews were employed for the analysis. Semi-structured interviews integrate the systematic approach of structured interviews with the adaptability of open-ended interviews. Throughout the interview process, the researcher formulated essential questions beforehand, centered on the primary topics of RQ3, to ensure that the interview material aligned with the research questions. The interviews were semi-structured, permitting respondents to express their perspectives and experiences freely, hence facilitating the extraction of rich, in-depth, and contextualized material.

By conducting semi-structured interviews with various respondents, the researcher can elucidate the interplay between carbon market mechanisms, green technology innovation, and company performance from diverse viewpoints, thereby uncovering potential factors not captured by quantitative data. This approach facilitates a more thorough qualitative analysis of RQ3 and enriches the overall study with substantial qualitative insights. This mixed research paradigm allowed the study to leverage the capabilities of both quantitative and qualitative research in addressing various research topics, establishing a more robust foundation for the findings.

7.3.4 Empirical Implications

This study's quantitative findings in Chapter 5 indicate that the carbon market mechanisms exert both positive and negative effects on company performance, while the regulatory mechanism of green technology innovation also has facilitating and inhibiting impacts. The importance of the empirical findings is as follows:

a) Revelation of Multidimensional Impacts

The empirical findings indicate that the influence of carbon market mechanisms on company performance is multifaceted and not unidirectional. This challenges the potentially oversimplified view that carbon market mechanisms solely influence company performance in a favorable or negative manner. From a carbon finance standpoint, it may provide companies with novel financing avenues and cost

management instruments to enhance economic and sustainable performance. A company that secures funding to improve its environmental equipment via carbon financial products not only diminishes its carbon emissions (improving sustainable performance) but may also expand its market share due to heightened productivity or products that comply with environmental standards (improving economic performance). Nonetheless, the intricacy and market unpredictability of carbon financial instruments may expose companies to financial risks, including price volatility in carbon futures trading, which might result in losses and adversely affect economic performance.

The empirical analysis elucidates the distinct functions of carbon price and carbon trading programs across several performance metrics. A higher carbon price may incentivize companies to invest in energy conservation and emission reduction, hence improving long-term sustainable performance. In addition, a substantial carbon price enables companies to invest in more efficient energy recovery systems, thereby decreasing carbon emission intensity and enhancing their environmental reputation and performance. In the short run, this may elevate a company's production costs and adversely impact EVA, particularly for companies that face challenges and substantial expenses in mitigating emissions.

Concerning carbon trading policy, equitable quota distribution and trade regulations might motivate companies to engage in emission reduction initiatives and improve sustainable performance. A policy that incentivizes companies with supplementary carbon emission allowances for implementing innovative low-carbon technology would foster green technology innovation and enhance EVA. However, if the policy design is flawed, such as overly lenient quota allocation or inadequate trading regulations, it may result in market inefficiency. It may also fail to effectively incentivize companies to reduce emissions and adversely impact the sustainable improvement of the company's renewed performance.

b) Decision-Making Basis for Green Technology Innovation

The dual function of green technology innovation inside the regulatory framework serves as a significant reference for company technological innovation decisions. When green technical innovation enhances company performance, companies should allocate additional resources to this domain by advancing new renewable energy utilization technologies or more effective carbon reduction methods.

These technologies can assist companies in obtaining competitive advantages within the carbon market mechanisms by lowering production costs and enhancing the environmental features of products. When a disincentive to green technology innovation is identified, companies must thoroughly analyze the underlying reasons. This may result from elevated R&D expenses, challenges in technology transfer, or insufficient market acceptability of green technology products. Companies may modify their technological innovation strategy for several reasons, including collaborating with other companies or research institutes to mitigate R&D expenses or developing the market prior to the extensive promotion of green technology products.

c) Contribution to Academic Research

This empirical result enriches the research on the relationship between carbon market mechanisms and company performance. Prior research may concentrate predominantly on a singular facet of the influence of carbon market mechanisms on company performance or a unilateral perspective. This study elucidates the intricate multi-dimensional effect relationship, encompassing both positive promotion and negative inhibition, by quantitative analysis, thereby addressing the research vacuum in this domain and offering novel perspectives and concepts for future investigations.

7.3.5 Managerial Implications

This report examines the potential challenges, issues, and solutions encountered by carbon trading pilots and non-carbon trading pilot companies based on quantitative and qualitative data. The management implications are classified as follows:

a) Strategic Planning Level

For carbon trading pilot companies, recognizing the opportunities presented by carbon trading (e.g., supplementary revenue from the sale of carbon emission allowances, competitive edge in the market through the promotion of green technology innovation) will assist the company in devising a proactive development strategy to transition to a low-carbon economy and convert its environmental advantages into economic benefits. Simultaneously, comprehending the challenges (e.g., irrational

distribution of carbon allowances may result in elevated costs and the potential for price volatility in the carbon market) can motivate the company to develop a risk early warning and response mechanism to guarantee the stability of strategy implementation.

While not currently engaged in carbon trading, non-carbon trading pilot companies can benefit from comprehending industry trends, such as proactively implementing low-carbon technologies to address potential future policy developments. This understanding can inform their long-term strategic direction. Additionally, the challenges posed by the potential indirect effects of stricter regional carbon emission reduction policies compel these companies to monitor external environmental changes and prepare accordingly.

b) Resource Allocation Level

Pilot companies optimize their resource allocation in response to the opportunities and constraints presented by carbon trading. For instance, to capitalize on carbon emission reduction initiatives, they judiciously allocate financial and human resources for technological R&D, as well as the establishment of energy-efficient and emission-reducing infrastructure; in response to challenges, they mobilize resources to form a carbon asset management team to navigate the intricate regulations of carbon trading and market fluctuations. Non-pilot companies will determine their resource investment strategies, including clean and green energy, by analyzing potential possibilities and obstacles to align with the future trajectory of global decarburization.

c) Green Technology Innovation Level

Green technology innovation serves as a crucial connection between carbon market mechanisms and company performance. Consequently, companies can prioritise green technology innovation as a strategic imperative. In the energy sector, if a particular green technology innovation, such as high-efficiency solar cell technology, substantially impacts performance enhancement, the company can augment its R&D investment in this domain and redirect its strategic emphasis towards renewable energy technology innovation.

Green technology innovation entails risks, including potential technology development failures and elevated application costs resulting in diminished

performance, among others. Companies can strategically assess the risks and advantages of green technology innovation. In the chemical sector, a company can initially implement a small-scale trial of high-cost carbon capture equipment to evaluate its performance impact before committing to large-scale investment.

Companies are proactively engaging with the carbon market mechanisms and enhancing green technology innovation, mitigating greenhouse gas emissions and aiding in the battle against climate change. Energy companies are diminishing their reliance on fossil fuels by implementing sustainable energy technology, decreasing carbon emissions, and enhancing environmental quality.

d) Internal Management Optimization

Resolving the issues faced by pilot companies, such as imprecise carbon accounting and insufficient internal carbon management personnel, can enhance the internal management process. By implementing a precise carbon accounting system and training personnel, the company's operational efficiency and compliance in carbon trading can be enhanced. For non-pilot companies, addressing analogous challenges (e.g., inadequate policy comprehension, feeble low-carbon awareness) may result in advancements in internal management, augmentation of low-carbon knowledge and abilities, and elevation of overall management standards.

e) Competitiveness Enhancement and Sustainable Development

Resolving the challenges faced by pilot companies in carbon trading and executing effective strategies will improve their competitiveness in the low-carbon market. By optimizing carbon reduction strategies to decrease expenses and enhance the quality of carbon assets, companies can yield superior returns and reputation in carbon trading. Furthermore, by tackling their own issues (e.g., the elevated carbon footprint of products impacting brand reputation) and enacting enhancement strategies, non-pilot companies can more effectively satisfy consumer demand for low-carbon products, bolster market competitiveness, and ensure the sustainable advancement of their companies. The focus of both pilot and non-pilot companies on these issues and countermeasures will facilitate society's transition to a low-carbon economy, fulfil company social responsibility, improve the social image and reputation of companies,

and attain broader sustainable development objectives.

7.4 Research Limitations

This study presents some flaws and limitations compared to the existing literature on carbon market mechanisms and company performance, necessitating more exploration and comprehensive research. They primarily encompass the following aspects:

a) Availability of Data

The researcher could not acquire the precise price of each company's carbon trading and resorted to utilizing the CSMAR Carbon Emission Right Trading Information Statistical Report. It employs the average carbon trading price of each region as a substitute for the company's carbon trading price. This paper also omits consideration of carbon emissions.

b) Restricted Sample Size

This paper exclusively utilizes listed companies as research samples due to data availability, thereby excluding numerous non-listed companies from the key control ranking list of each carbon market. Consequently, the research conclusions possess inherent limitations.

Due to the limited sample of pilot-listed companies, this paper cannot thoroughly analyse the effects of carbon emissions trading on various industries, including building materials, non-ferrous metals, petrochemicals, paper, and aviation. Consequently, it is also unable to assess the differing impacts of quota issuance and penalty mechanisms on companies across various pilot regions within the carbon emissions trading framework and, therefore, cannot determine the optimal system design.

c) Narrowing of the Study Population

This paper primarily examines carbon emissions trading within the seven pilot regions and does not analyse the national carbon market or compare it with the international carbon market. Consequently, it lacks the capacity for a comprehensive study of the carbon emissions trading market mechanism, fails to encapsulate the successful experiences of foreign carbon emissions trading systems, and does not propose a carbon emissions trading framework tailored to China's market economy characteristics. As the national carbon market was officially started in 2021, its operational duration remains brief, resulting in the sample not encompassing all companies.

d) Limitations on the Number of Respondents

The qualitative research involved a restricted number of interviews with accountants and managers from both carbon trading and non-carbon trading pilots. Hence, the conclusions are confined to the subjective perspectives of the respondents. Although additional possible participants were found, only a limited number were interviewed due to time constraints.

7.5 Future Research

This research analyses the impact of China's carbon market mechanisms from two perspectives: economic and sustainable performance, acknowledging the presence of numerous unobservable factors in the evaluation of policy effects. In the future, the efficacy of carbon trading policy can be examined more comprehensively and diversely, exploring the impact of additional elements and prospective outcomes. Future research can contribute in four specific aspects.

a) Further Expansion of the Sample

The creation of a unified national market facilitates access to data about listed companies, hence allowing for a broader spectrum of research investigations. The ongoing enhancement of company data enables research on unlisted and small companies, rendering the study's conclusions more robust and precise.

The carbon trading system is intricate, encompassing various sectors like power and industry. The characteristics of carbon emissions and reduction trajectories differ significantly across industries, and companies within the same sector exhibit heterogeneity in technology, management proficiency, and market standing. In addition, future research will investigate the effects of industry variations and company heterogeneity on performance within the carbon market framework. This includes examining disparities in performance among high-carbon and low-carbon sectors, state-owned versus non-state-owned companies, and large versus small and medium-sized companies to inform more targeted policy and strategic development. In line with this, the relationship between implementing various environmental policies, including low-carbon and smart cities, and carbon trading policy must be enhanced, considering the diverse development aims and policy execution across different cities.

b) In-Depth Study of Carbon Market Elements

The components of the carbon market encompass quota allocation methods, carbon trading volumes, market liquidity, trade accounting standards, emission accounting management, and information disclosure. Despite the increasing adoption of carbon emissions trading across various countries and regions, discrepancies in internal standards among different carbon markets persist, particularly regarding quota methodology and accounting measurement. This lack of comparability in carbon information across regions adversely impacts investors' green investment decisions. In contrast, inadequate management of carbon accounting further influences company decision-making and the assessment of the economic benefits associated with emission reductions. The comprehensive analysis of carbon market components can be enhanced in the future.

c) Carbon Finance Product Research

In the future, further emphasis may be placed on the effective integration of carbon financial derivatives with carbon emission systems, alongside research focused on product design, supporting frameworks, and regulatory legislation. Carbon financial derivatives are crucial for stimulating the carbon market and fostering the advancement of a low-carbon economy. China's carbon financial derivatives are in the nascent phase,

and a forthcoming study may concentrate on the design and regulation of carbon financial instruments and the harmonization of policy across diverse carbon financial markets.

d) Expansion of Research Methods

This paper examines the policy impacts of the carbon market mechanisms by applying the DID model. Accordingly, future studies may incorporate the intermediary effect model and the regulating effect model and integrate the synthetic control method with the breakpoint regression model during the advanced stages of the development of the carbon emissions trading pilot region. This approach will enable a comprehensive analysis of the impact of environmental regulation from various perspectives, ultimately facilitating the establishment of a more refined evaluation system for policy effectiveness.

Table 7.2 presents a summary of the research limitations and future research directions.

Table 7.2
Research Limitations and Future Research

Research Limitations	Future Research
a) Availability of data	a) Further expansion of the sample
b) Restricted sample size	b) In-depth study of carbon market elements
c) Narrowing of the study population	c) Carbon finance product research
d) Limitations on the number of respondents	d) Expansion of research methods

7.6 Chapter Summary

This chapter encompasses a synopsis of the research problem, research contributions, study limitations, and prospects for future research. This study thoroughly examines the effects of various carbon market components on the multifaceted dimensions of company performance, employing both quantitative and qualitative research methodologies. However, the findings of this research yield mixed or neutral results. Nevertheless, this study offers a novel viewpoint on the evolution of carbon market mechanisms and company performance, serving as a significant reference for carbon market participants, governmental entities, and the advancement of carbon markets in other nations.

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APPENDICES

APPENDIX 1

Interview Protocol

SECTION I: Study Description

Principal Investigator: Zhang Xiaoping

PhD Research Title: Carbon Markets, Green Technology Innovation and Company Performance in China

You have been invited to take part in a study that investigates practical inquiries regarding carbon trading market procedures and the performance of companies in China. You have been invited to take part in a study that investigates practical inquiries regarding carbon trading market procedures and the performance of companies in China. The interview is expected to last for approximately 60 minutes. In order to preserve and accurately document the conversation, this interview will be audio-recorded and transcribed with your consent. Your personal identity will not be documented, and you will only be referred to by a pseudonym in all the information gathered.

The research will be carried out by Zhang Xiaoping, a doctoral candidate at Universiti Teknologi MARA (UiTM). The interviews will be scheduled at a mutually convenient time and location.

Risks and Benefits

This study aims to analyze the challenges, possibilities, and problems encountered by companies involved in carbon trading, as well as those not involved. Its objective is to contribute to the enhancement of China's Carbon market mechanisms and company performance. The risks associated with participating in this study are equivalent to those faced by individuals in their regular commercial endeavors. There is no monetary compensation for your involvement in this research.

Utilizing Data Storage for Ensuring Confidentiality

Your identity will not be disclosed by name at any point throughout this study or in any of its publications. The researcher shall exert utmost diligence to ensure that the information you supply remains entirely confidential. The data will be encrypted and securely maintained exclusively for professional purposes.

Purpose of Utilizing the Results

The interview results will be exclusively utilized for academic reasons and will contribute towards the fulfillment of the criteria for the Doctor of Philosophy (Accounting) degree at Universiti Teknologi MARA (Puncak Alam). The study's findings will be disseminated in the form of a scholarly publication.

SECTION 2: Rights of Participants

- I have thoroughly reviewed and engaged in discussions regarding the research inquiries and study synopsis with the researcher.
- I have been afforded the opportunity to inquire about the goal and methodologies employed in this study.
- I am participating in this study of my own volition. I retain the right to decline involvement or withdraw from participation at any given moment.
- The researcher has the authority to exclude me from the study based on their professional discretion.
- Any personally identifiable information gathered from the research will not be released or divulged without my explicit approval, unless legally mandated.
- If you have any inquiries regarding the research I am engaged in, I can reach out to the researcher Zhang Xiaoping, who will provide answers to my questions. The contact information for the researcher is +8615831202260. I can also reach out to the researcher's supervisor, Dr. Nur Syuhada Jasni, via the following phone number: 019-7305395.
- I request to be provided with a duplicate of the study description and the paper outlining the rights of participants.
- Audio recordings are included in this investigation. Written and recorded materials will only be accessible to the Principal Investigator and the study team members. Please select one of the options below.

  ( ) I consent to being recorded.

  ( ) I do not consent to being recorded.

  My signature signifies my consent to partake in this study.

  Participant's signature：

  Name：

  Date：

Investigator's Verification of Explanation

I, Zhang Xiaoping (researcher), confirm that I have thoroughly defined the objective and essence of this study to Mrs. Wang (participant's name). He has had the chance to thoroughly address this topic with me. I have responded to all of his inquiries and he has explicitly given approval to partake in this research.

Signature of researcher:

Date:

Interview Date:

Time:

Venue:

Basic information issues

Basic information of the respondents.

i. Name.

ii. Job Title.

iii. Years of working experience in current company.

Survey of personnel in carbon trading pilot companies

A. Background Questions - Conceptualization of Carbon market mechanisms

Research focus: Understanding

Objective: To assess the participants' comprehension of the main concepts mentioned in the question.

1. What is your interpretation of a carbon trading system?
2. What are the carbon market processes from a company standpoint?

B. Research focus: Current Practices in Information Retrieval

Objective: Assess the participant's ability to remember the necessary information.

1. What is the driving force behind your company's decision to engage in carbon trading?
2. What is the present state of your company's performance?

C. Research focus: Carbon market mechanisms and company performance

Objective: To investigate the methodologies employed by participants in responding to the questions.

1. What is your opinion on the impact of Carbon market mechanisms on company performance?

D (i). Research focus: the influence of response-company participation in carbon trading

Objective: To determine whether participants were capable of mentally mapping their responses to the available answer categories.

1. Prior to engaging in carbon trading, what was the efficacy of your company?
2. What has been the status of your company's performance following your involvement in carbon trading?
3. What are the financial obstacles that your company encounters while engaging in carbon trading?
4. What are the challenges associated with your company's involvement in carbon trading?
5. How can your company more effectively address the opportunities and challenges of transitioning to a low-carbon economy in order to achieve carbon neutrality?

D (ii). Impacts of companies' involvement in carbon trading

Objective: Analyze survey respondents' answers based on predefined categories.

1. What are the benefits and drawbacks of companies engaging in carbon trading?
2. What are the consequences of a company's involvement in carbon trading?

Survey of personnel in non-carbon trading pilot companies

A. Background questions - Conceptualization of Carbon market mechanisms

Research focus: Comprehension

Objective: To assess the participants' comprehension of the main concepts mentioned in the question.

1. Do you understand the carbon trading system?
2. What do you think the Carbon market mechanisms includes?

B. Research Focus: Current Practices in Information Retrieval

Objective: Assess the ability of participants to remember the necessary information.

1. Does your company have a willingness to engage in carbon trading?
2. What is the present state of your company's company performance?

C. Research focus: Carbon market mechanisms and their impact on company performance

Objective: To investigate the approaches employed by participants when responding to questions.

1. Will the Carbon market mechanisms have an impact on company performance when the company engages in carbon trading?

D (i): Research focus: Examining the consequences of company abstention from carbon trading.

Objective: To investigate the ability of participants to mentally associate their responses with the provided answer categories.

1. What are the present fiscal obstacles confronting your company?
2. What challenges are present in your company's move towards a low-carbon model?
3. How can your company effectively address the opportunities and challenges of transitioning to a low-carbon economy within the framework of carbon neutrality?

D (ii): Consequences of companies abstaining from carbon trading

Objective: Analyze the participants' responses in order to determine the answer categories.

1. What are the benefits and drawbacks of a company choosing not to engage in carbon trading?
2. What are the effects of a company not participating in carbon trading?

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List of Publications:

Zhang Xiaoping, Nur Syuhada Jasnib, Rina Fadhilah Ismail, Current Trends in Carbon Emission Trading: Theoretical Perspectives, Research Methods and Emerging Themes. Edelweiss Applied Science and Technology, Vol. 8, No. 4, 2024, p. 1658-1674. DOI: 10.55214/25768484.v8i4.1542 (Scopus, Q4)

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