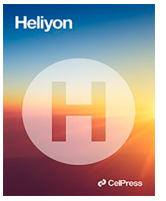
Heliyon 10 (2024) e26687

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

The impact of market-based environmental regulation on corporate ESG performance: A quasi-natural experiment based on China's carbon emission trading scheme

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ARTICLE INFO

Keywords:
Market-based environmental regulation
CETS
ESG
Green technology innovation
Agency cost
Analyst attention

ABSTRACT

At present, there are few studies exploring the impact of market-based environmental regulation on ESG performance based on the perspective of carbon emission trading scheme (CETS). This paper aims to supplement this research field through empirical analysis. Taking Shanghai-Shenzhen A-share listed companies from 2012 to 2022 as the research object, this paper studies the impact of CETS, a market-based environmental regulation tool, on the ESG performance of enterprises by constructing a time-varying DID model and examines the mediating roles of green technology innovation, agency cost and analyst attention. The results show that the implementation of CETS can significantly boost ESG performance, and green technology innovation, agency cost, and analyst attention play a partial intermediary role between the two, while the mediating effects of green total factor productivity and green total factor energy efficiency are not significant. In terms of heterogeneity analysis, the study shows that CETS implementation has a more substantial promotion effect on ESG performance in non-state-owned enterprises, non-politically connected enterprises and non-high-tech enterprises. In this paper, the robustness test was carried out through PSM-DID, placebo test and replacement of explained variables, and the test results further supported the hypothesis in this paper. This study enriched the research on the impact of market-based environmental regulation on ESG from the perspective of CETS. It provided enlightenment for enterprises to improve ESG performance to a strategic level, improve the level of green technology innovation, and the government to implement differentiated environmental governance policies.

1. Introduction

In 1987, the report of the World Commission on Environment and Development, Our Common Future, defined sustainable development as "development that meets the needs of the present generation without endangering the ability of future generations to meet their own needs". In an environment characterized by a globalized, dynamic and increasingly competitive economy, firms must confirm that they can earn higher profits than their competitors in order to survive. In this context, companies are pushing to

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https://doi.org/10.1016/j.heliyon.2024.e26687
Received 31 October 2023; Received in revised form 16 February 2024; Accepted 18 February 2024
Available online 20 February 2024
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incorporate sustainability into their business strategies as a potential source of competitive advantage [1]. In order to measure sustainability, the environmental, social and governance (ESG) performance of enterprises has been widely considered. ESG performance is an investment philosophy and corporate evaluation standard that focuses on corporate environmental, social, and governance performance rather than financial performance. With the increasing emphasis on sustainable development, companies are increasingly required to take responsibility for environmental protection, social performance and internal governance improvement. That is, the importance of disclosing and improving ESG performance has become increasingly prominent. However, companies in most emerging markets pay little attention to the disclosure of ESG performance because they focus more on capital accumulation than the potential gains from social investments.ESG performance represents a greener development model, a more responsible corporate image, and better corporate governance mechanisms, which largely depend on the efficiency of relevant policy formulation and implementation [2].As a critical ecological governance policy, it is of great practical significance to study its impact on ESG performance [3].

The so-called environmental regulation refers to various rules and measures formulated for environmental problems, which restrict the behaviour that destroys the environment and damages the public interest. Environmental regulation can be further divided into three types: command-and-control type, market-based type and voluntary type, among which command-and-control type and market-based type are the main ones [4–6]. Command-and-control environmental regulation policies, or direct control policies, are characterized by direct control of pollution behaviour by government environmental protection departments, including standards, orders and bans, and sometimes further divided into technical regulation and enforcement regulation. Market-based environmental regulation policies stimulate people's behavioural motivation through market signals, mainly including government subsidies, emission permit trading systems, carbon emission trading, and so on.

China's environmental regulation policy is relatively single, mainly command-and-control environmental regulation, and the previous research also mainly focuses on command-and-control environmental regulation [7]. In the early 21st century, China began to implement market-based environmental regulation policies gradually. Compared with command-and-control environmental regulation, which may cost enterprises a lot, market-based environmental regulation can improve the efficiency of resource allocation and encourage enterprise innovation [8–13]. Based on these advantages, more and more scholars pay attention to the ecological governance effect of this kind of environmental regulation.

Among many market-based environmental regulation tools, implementing a carbon emission trading scheme (CETS) is one of the most important tools. China designed CETS in 2011 and began to formally implement carbon emission trading in 2013 [14]. The pilot work of carbon emission trading has been carried out in Shenzhen, Shanghai, Beijing, Chongqing, Tianjin, Hubei, Guangdong, Fujian and so on. CETS is a typical application of the Coase theorem, which assumes that under clear property rights and zero or low transaction costs, the externalities are eliminated through market transactions, and environmental externalities are solved. The government allocates a certain number of "emission permits" to firms that can be freely traded like commodities. Therefore, under the market mechanism, the government can achieve the emission of the same amount of pollution at a lower economic cost [15].

This paper explores the impact of market-based environmental regulation on enterprises' ESG performance from the perspective of CETS. How does the implementation of CETS affect corporate ESG performance? What is the influence mechanism? Will there be different impacts depending on the nature of the enterprise? These are the issues that this paper focuses on. This paper takes China's A-share listed companies in Shanghai and Shenzhen stock exchanges from 2012 to 2022 as the research object and empirically studies whether and how CETS affects the ESG performance of enterprises by constructing a multi-time DID model. In addition, this paper discusses the heterogenous effects of CETS on the ESG performance of enterprises from three aspects: the nature of enterprise equity, political connection and technology attribute. At the same time, the robustness test is carried out through a placebo test, PSM-DID and replacement of explained variables.

This paper contributes to the related field in the following four aspects: First, the current research on ESG mainly focuses on developed countries, while the research on the environmental, social and governance performance of developing and emerging economies is still not exhaustive. In China, ESG-related research is still in its infancy. Secondly, as the concept of sustainable development has attracted more and more attention from governments and enterprises, more and more scholars have paid attention to the impact of environmental regulation on ESG performance. This study takes the implementation of CETS as the external policy impact, enriches the research on the impact of environmental regulation from the perspective of market-incentive-based environmental regulation, and improves the literature system of evaluating the effectiveness of CETS policy from the perspective of ESG. Thirdly, the existing research on the impact of environmental regulation on ESG often lacks a mechanism test. Fourthly, this study conducts heterogeneity analysis from three aspects of ownership nature, political connection and scientific and technological attributes, which is helpful to put forward targeted countermeasures and suggestions.

The structure of this paper is arranged as follows: The first part is the introduction, which introduces the research background, research content, research methods and research contributions of this paper. The second part is a literature review, which reviews the existing research on market-based environmental regulation, ESG and the relationship between market-based environmental regulation and ESG, summarizes their shortcomings and expounds the innovation points of this paper. In the third section, the four research hypotheses of this paper are proposed. The fourth part is the research design part, which expounds on the sample selection, data source, variable definition and DID model setting. The fifth part is the empirical analysis, which conducts variable descriptive statistics, correlation coefficient analysis, benchmark regression, GTE, agency cost and mediating effect analysis of analysts' attention, respectively. Finally, for further analysis, we explore the heterogeneity of the impact of CETS on corporate ESG performance from ownership nature, political connection and technology attribute. The sixth part summarizes the research conclusions of this paper, puts forward targeted suggestions, expounds on the limitations of this paper, and looks forward to future research.

2. Literature review

2.1. Review of relevant literature

2.1.1. Market-based environmental regulation

Current research on market-based environmental regulation mainly focuses on its impact on green technology innovation (GTI), green total factor energy efficiency (GTFEE) and green total factor productivity (GTFP) and its mechanism.

The research results of the impact of market-based environmental regulation on GTI show three views: the first view is that market-based environmental regulation promotes GTI, and the promotion effect on green utility model patents is slightly higher than that on green invention patents [16]. Other studies put forward the second view that the impact of market-based environmental regulation on GTI shows a trend of first promoting and then inhibiting [17]. The third view is that different market-based environmental regulations impact green technology innovation differently. For example, sulfur dioxide emission trading policy (SETP) can significantly promote green technology innovation, while carbon emission trading policy (CETP) has no promotion effect. The combination policy of SETP and CETP also cannot promote green technology innovation [18].

Most studies on the effect of market-based environmental regulation on green total factor energy efficiency show that market-based environmental regulation, especially the implementation of CETS, can significantly promote the improvement of GTFEE. CETS can improve GTFEE by improving enterprise technological innovation. A similar mediating variable is green technology innovation. Implementing CETS has less effect on improving GTFEE in non-old industrial-based and non-resource-based cities than in old industrial-based and resource-based cities. Compared with other pilot areas of carbon trading, the Beijing carbon market has a more prominent performance in improving GTFEE [19,20].

There are also two views on the impact of market-based environmental regulation on green TFP. One side believes that implementing a carbon trading pilot policy has a significant promotion effect on green TFP, and this promotion effect is getting stronger and stronger over time. The other side believes that in the short term, the implementation of CETS does not immediately improve green TFP but has a positive impact on technological progress after green TFP decomposition [21].

2.1.2. ESG

Currently, the research results on ESG are mainly concentrated in developed countries [22], while the research on ESG in developing countries and emerging economies is not mature, and the focus is scattered. The research fields that both of them focus on and are mentioned by a large number of scholars are mainly the economic consequences of ESG, including the impact of ESG on stock returns, financial performance and enterprise value.

In terms of research on ESG and stock returns, most research results report that companies with low ESG levels are proved to be able to achieve higher stock returns than companies with high ESG levels [23,24], while the stock price volatility of companies with good ESG performance is smaller than that of companies with poor ESG performance [25]. However, there are also a few studies that report that ESG level does not significantly positively affect stock returns. La Torre et al. (2020) studied how ESG affects stock returns based on the Eurostoxx50 index [26]. The study shows that the linear relationship between ESG index and stock returns is weak. The results of the random effects model show that the impact of the "ESG overall" index varies from company to company, and there is a significant correlation between the change of the "ESG overall" factor and stock returns for only 7 of the 46 companies included in the sample. These companies are in industries characterized by a strong correlation between ESG performance and company profitability, such as energy and utilities.

Research on the relationship between ESG and corporate financial performance (CFP) dates back to the early 1970s, and the number of ESG-CFP research publications has grown particularly large since the early 1990s [27]. Whelan et al. (2021) conducted a systematic study of more than 1000 papers from 2015 to 2020 and found that 58% of the studies reported a positive relationship between ESG and financial performance, 13% showed a neutral effect, 21% showed mixed results (the same study found positive, neutral, or negative results), and the same study found a positive, neutral, or negative result [28]. Only 8% of the studies showed a negative relationship. In recent years, most research results also show that ESG has a positive impact on corporate financial performance [29,30].

A large number of scholars have studied the impact of ESG performance on corporate value, and most of them have reported positive effects. Research on US commercial banks has shown that the market value of US commercial banks has an inverted U-shaped relationship with ESG and social pillar scores (SPS), while it has a U-shaped relationship with environmental pillar scores (EPS) [31]. In the context of M&A, if the ESG performance of the acquired enterprise is higher than the ESG performance of the acquirer before M&A, the environmental, social and corporate governance performance of the acquirer will also improve after M&A. After M&A, the market value of the acquirer will also increase with the improvement of ESG performance [32].

2.1.3. Market-based environmental regulation and ESG

The existing research rarely explores the relationship between market-based environmental regulation, a specific type of environmental regulation, and the ESG performance of enterprises, and the conclusions are not uniform. Some studies have shown that environmental regulation can significantly promote enterprise ESG performance. For example, Lu and Cheng (2023) used the revision of the Environmental Protection Law implemented in China as an exogenous impact event and found that the environmental protection law significantly improved the ESG performance of state-owned enterprises [2]. In addition, some studies have pointed out that environmental regulation will have a negative impact on the ESG performance of enterprises. A study based on a newly proposed environmental regulation policy in China, the Accountability Audit of Leading Officials on Natural Resources (AANR), points out that

the implementation of AANR pilot has a significantly negative impact on corporate ESG performance [33].

At present, few studies have included CETS and ESG performance in the same analytical framework. How does the implementation of CETS affect enterprise ESG performance? This is the central question of this paper. In some sporadic studies, some scholars believe that implementing CETS can promote enterprises to fulfil environmental or social responsibilities [34]. Although these studies involve one or two aspects of ESG responsibilities, they fail to consider the impact of CETS on ESG as a whole.

Based on the above literature review, it can be seen that in terms of the research on the economic consequences of market-based environmental regulation, studies are focusing on the impact of market-based environmental regulation on green technology innovation, green total factor energy efficiency and green total factor productivity. In terms of the ESG performance of enterprises, the existing research mainly focuses on the ESG performance of developed economies, while the relevant research on the ESG performance of emerging economies such as China is still insufficient. In terms of studies on the relationship between environmental regulation and ESG performance, as the importance of sustainable development has been increasingly emphasized, more and more literature has studied the impact of environmental regulation on ESG performance. However, existing studies mainly focus on the impact mechanism of command-and-control environmental regulation, while studies based on the perspective of market incentive environmental regulation are still insufficient. As one of the two primary policy tools for market-based environmental regulation, the impact of carbon emission trading scheme on the ESG performance of enterprises has rarely been studied, and the analysis of the impact mechanism and endogenous processing have been ignored in only a few relevant studies, which may reduce the reliability of the results.

To sum up, when studying the influencing factors of enterprise ESG performance, most of the existing studies examine the role of command-and-control environmental regulation, while this paper attempts to examine its impact on enterprise ESG performance from a new perspective of market-based environmental regulation. Secondly, this paper discusses the mechanism of the impact of CETS on corporate ESG from three aspects: green technology innovation, agency cost and analyst attention, which is conducive to enriching the relevant mechanism research. Third, we use PSM-DID to test the possible selection bias problem and further verify the hypothesis by replacing the explained variable. Fourth, we also examine the heterogeneous impact of CETS on individuals with different ownership natures, political connection backgrounds, and S&T attributes.

2.2. Hypothesis formulation

CETS is a quota trading mechanism [35]. Under this mechanism, the government issues carbon emission quota to enterprises through total volume control, stipulates the upper limit of carbon dioxide emission, requires enterprises to implement total volume management and emission reduction of greenhouse gas emissions, and sets punishment for emissions exceeding the quota [36]. CETS will prompt enterprises to strengthen the monitoring and control of the total amount of corporate greenhouse gas emissions, so that enterprises pay attention to their environmental responsibilities. At the same time, this mechanism will also encourage enterprises to reduce emissions in diversified ways, such as adjusting strategies, improving business models, low-carbon technology transformation, and optimizing product development, so that enterprises can fulfil their social responsibilities [37]. In addition, implementing CETS will bring more attention from analysts and investors, and these external supervisions will encourage enterprises to strengthen their corporate governance. Environmental responsibility, social responsibility and corporate governance are indicators that companies need to refer to when assessing their ESG performance. Therefore, the implementation of CETS will promote corporate ESG performance. Therefore, the first research hypothesis of this paper is put forward:

H1. The implementation of CETS will significantly promote the ESG performance of listed companies.

Green technology innovation is crucial for enterprises to balance environmental, economic and social benefits [38]. Under the pressure of CETS, enterprises choose environmental protection investment to achieve the purpose of reducing carbon dioxide emissions [39], and green technology innovation is a necessary condition to achieve this goal. On the one hand, non-environmental protection products with high pollution and high energy consumption are the main reasons for pollution emissions, and enterprises actively research and develop green and recyclable environmental protection products to achieve the goal of reducing pollution emissions. On the other hand, in order to reduce pollutant emissions in the production process, enterprises will tend to improve the pollutant treatment process through pollution control technology innovation, improve the efficiency of the waste disposal process, and transform the existing production process to create green production lines, which will bring higher environmental protection benefits to enterprises and make up for the environmental treatment costs of enterprises, so as to obtain the “process compensation effect”. To sum up, the implementation of CETS prompts enterprises to increase environmental protection investment, and the environmental protection investment of enterprises achieves the goal of energy conservation and emission reduction through green technology innovation, thus improving the environmental performance of enterprises. At the same time, GTI can reduce energy consumption, reduce waste disposal, provide safe workplaces, and improve corporate social responsibility performance by providing environmentally friendly products to the public, thus enhancing corporate ESG performance. The promotion effect of GTI on enterprise ESG performance is also supported by existing research [40]. Based on the above analysis, this paper puts forward the hypothesis:

H2. GTI plays a mediating role between CETS and corporate ESG performance.

Previous studies have shown that CETS can achieve the policy effect of improving GTFP by improving energy efficiency, promoting low-carbon innovation and adjusting industrial structure. Under the pressure of CETS policy, carbon emitting enterprises in the pilot cities will adopt decisions such as carbon emission quota trading, emission reduction innovation, and site selection and relocation to cope with the policy pressure. At the macro level, these decisions promote the gradual transfer of industrial capital and economic factors from high-carbon industries to low-carbon and clean industries, thus driving the improvement of energy efficiency, low-carbon innovation and industrial structure transformation, and realizing the improvement of multi-scale urban GTFP from micro to macro

[41]. The improvement of GTFP is usually accompanied by the improvement of resource utilization efficiency. By using resources more efficiently, companies can reduce environmental loads such as energy consumption, waste generation, and carbon emissions, which can help reduce their environmental impact and improve environmental sustainability. Secondly, improving GTFP may involve better social practices, such as providing safer and healthier work environments, fairer labor conditions, or positive contributions to the community. These practices of social responsibility reporting can improve a firm's social performance and enhance its relationships with employees, customers, communities and other stakeholders. In addition, achieving and maintaining a high level of GTFP typically requires strong governance structures and management practices. Companies need to develop and implement environmental policies to ensure compliance with relevant regulations, appropriate risk management, and transparent and accurate reporting. These good governance practices can improve a firm's governance performance and enhance its trust in external stakeholders. Based on the above analysis, this paper proposes the third hypothesis:

H3. GTFP plays a mediating role between CETS and corporate ESG performance.

According to the "Porter hypothesis," the emergence of the carbon emission trading system makes it necessary for enterprises to strengthen low-carbon technology innovation to reduce carbon emissions and improve energy efficiency. The implementation of the carbon emission trading system has strict standards in the primary market. However, in the long run, reasonable institutions will make enterprises take the cost of environmental regulation into account in business decisions. Even, this "innovation compensation effect" will be greater than the cost of responding to environmental regulation, thus improving green TFP. To sum up, a scientific and reasonable carbon emission trading system improves green total factor energy efficiency through low-carbon technology innovation effect. Green TFP usually involves reducing energy consumption and carbon emissions, which is a positive manifestation of environmental sustainability for enterprises and helps to reduce their negative impact on the environment, thus improving environmental performance (E) [42]. Secondly, by adopting cleaner energy sources and technologies, firms can improve the air quality of local communities, thereby enhancing their social reputation (S). Finally, the improvement of green TFP will also drive enterprises to build an effective governance structure and promote effective management practices. (G) Based on the above analysis, the fourth hypothesis of this paper is proposed:

H4. GTFEE plays a mediating role between CETS and corporate ESG performance.

Agency costs are one of the most prominent costs of corporate governance. There are mainly two types of agency problems in China, namely, the agency problems caused by information asymmetry between shareholders and managers (type I), and the agency problems between major shareholders and minority shareholders (type II). The cost mainly arises from the information asymmetry between shareholders and managers. That is, the first type of agency cost is the primary agency cost. Based on the principal-agent theory, the separation of corporate ownership and management rights leads to the self-interested behaviour of the management that damages the interests of corporate shareholders, leading to the first type of agency problem [43]. In the context of implementing market-based environmental regulation, enterprises are constrained by both external government and market mechanisms, which makes managers reduce self-interested behaviours, actively fulfil social and environmental responsibilities, and improve ESG performance. According to the information display theory, the implementation of CETS will force enterprises to provide greater information transparency in carbon quota trading, energy conservation and emission reduction measures, so as to alleviate the problem of information asymmetry between shareholders and internal management and reduce the agency cost of enterprises [44]. When the agency cost is high, managers will invest more funds in high-yield and high-return investment projects based on their own interests, while ignoring the improvement of ESG performance. In other words, high agency costs will inhibit the improvement of ESG performance, and the higher the agency cost is, the worse the ESG performance is. With the reduction of agency cost, the information barrier between shareholders and managers is broken, the self-interested behaviour of managers is reduced, and more funds are invested in ESG activities, thus improving the ESG performance of enterprises [45].Therefore, this paper puts forward the following hypothesis:

H5. Agency costs play a mediating role between CETS and corporate ESG performance.

Bhushan (1989) proposed that the demand and supply of analyst services determine analyst attention [46]. The Chinese government has long attached importance to the issue of carbon emissions, and in 2020 put forward a dual carbon strategy of "carbon peak" and "carbon neutrality" (CO2 emissions strive to peak by 2030 and carbon neutrality by 2060). One of the more successful and landmark policies of this period was CETS. In the context of "dual carbon", "energy conservation and emission reduction" has become a hot word. Public opinion media has the nature of tracking hot topics. In the context of advocating green environmental protection, public opinion media will focus on environmental protection topics to report. Since under the CETS policy, the government mainly includes high-carbon and high-polluting enterprises in the carbon emission trading system, as one of the most influential and promising carbon regulatory tools at present, the implementation effect of CETS will inevitably attract the attention of the market [44]. In order to meet the market demand, analysts mine, track and analyze the information of these CETS enterprises, so as to earn more income. Cao and Li (2022) conducted a comprehensive analysis of analysts' forecast reports and site visits based on text analysis, and also found that analysts were indeed very concerned about carbon emissions [47]. In summary, increased information demand from media and market investors requires more analysts to provide information intermediation services, so the demand curve for analyst services shifts to the right. From the supply perspective, the implementation of CETS will make enterprises face dual supervision from the government and the market, and enterprises will take the initiative to increase information disclosure under this regulatory pressure. The increase in public information in the market makes it easier for analysts to obtain information about enterprises implementing CETS, and the cost of information collection decreases, thus shifting the supply curve of analyst services to the right [48]. The simultaneous rightward shift of the demand and supply curves leads to an increase in the equilibrium number of analysts,

which means that analyst attention is enhanced.

Analyst attention affects ESG performance in two main ways. On the one hand, companies that analysts follow will pay more attention to improving ESG performance, so as to convey the information of actively fulfilling social responsibilities to the outside world and enhance corporate reputation. On the other hand, companies that are highly followed by analysts are given higher expectations, thus forming a kind of external supervision pressure, under which companies will pay more attention to fulfilling environmental and social responsibilities and improve corporate governance, thus enhancing ESG performance. In other words, analyst attention will promote companies to fulfill environmental and social responsibilities better, while strengthening corporate governance, thus improving ESG performance. Based on the above analysis, we propose the fourth research hypothesis of this paper:

H6. Analyst attention plays a mediating role between CETS and firm ESG performance.

3. Research design

3.1. Sample selection and data resource

In China, every year, the Ministry of Ecology and Environment organizes pilot areas to submit the list of key emitators to be included in the quota management of the carbon emission trading market. These pilot enterprises often belong to high energy consumption and high emission industries such as electricity, steel, cement and chemical industry, and their carbon dioxide emissions reach a certain standard. For example, key emitting units in the power generation industry in the national carbon Emission Trading market in 2019 need to meet greenhouse gas emissions of 26,000 tons of carbon dioxide equivalent (comprehensive energy consumption of about 10,000 tons of standard coal) or more in any year from 2013 to 2018. These selected pilot firms were required to report their GHG emissions and were assigned a certain carbon emission quota. Companies can sell excess emission rights if they can keep their emissions below the allocated quota for a certain period of time; Otherwise, additional emission rights need to be purchased. This mechanism encourages companies to take measures to reduce carbon emissions, prompting them to pay more attention to environmental sustainability and low-carbon development.

Since 2013, China has carried out carbon emission trading pilot projects in Shenzhen, Shanghai, Beijing, Guangdong, Tianjin, Hubei, Chongqing, Fujian and other places. At the end of 2017, the Plan for the Construction of a National Carbon Emission Trading Market was released and implemented, requiring the construction of a unified national carbon emission trading market. In 2021, the national carbon emission trading market was launched, gradually becoming the largest carbon emission trading market in the world. This paper takes A-share listed companies from 2012 to 2021 as the research sample, and according to the disclosure data of seven carbon trading markets including Shenzhen, Shanghai, Beijing, Guangdong, Tianjin, Hubei and Chongqing, manually collates the list of enterprises included in the carbon emission trading market, and conducts the following processing: (1) Eliminating the sample observations of ST and PT enterprises during the sample period; (2) Excluding financial enterprises; (3) In order to eliminate the influence of extreme values, all continuous variables are winsorized at the level of 1% and 99%; (4) The policy implementation time in Fujian Province is relatively short, so in order to ensure the accuracy of the results, the relevant samples in Fujian Province are eliminated. The list of enterprises included in carbon trading comes from the relevant documents of the National Development and Reform Commission or the Ministry of Ecology and Environment in each pilot region. After the above processing, 4863 listed enterprises are finally obtained, including 203 pilot enterprises. In order to reflect the technical specifications of this study, this study counted the sampling process of pilot enterprises, as shown in Table 1. All empirical operations in this paper are completed with Stata 17.0 software.

3.2. Variable definition

3.2.1. Explained variable

The explained variable in the empirical model is the ESG score of the listed company. At present, the famous ESG rating agencies in China mainly include Sino-Securities Index Information Service (Shanghai) Co., Ltd, SynTao Green Fiance, International Institute of Green Finance (CUFE), China Alliance of Social Value Investment (CASVI). Among them, Sino-Securities ESG rating is relatively the most comprehensive [49]. As can be seen from Table 2, Sino-Securities ESG rating has selected more than 300 underlying data indicators to build an ESG big data platform by integrating semantic analysis, NLP and other intelligent algorithms. Based on the big data platform, Sino-Securities ESG rating selected 17 environmental key indicators, 13 social key indicators and 14 governance key indicators as the evaluation criteria for each topic. At present, Sino-Securities ESG rating system has covered all A-share listed companies and investable Hong Kong listed companies, covering 95% of the market value of Hong Kong stocks. Therefore, this paper selects the

Table 1
Sample selection process.

Process	Shenzhen	Shanghai	Beijing	Guangdong	Tianjin	Hubei	Chongqing
Year of implementation of CETS	2013.6	2013.11	2013.11	2013.12	2013.12	2014.4	2014.6
Number of pilot enterprises	6390	2040	5674	1728	1013	2088	350
Number of listed enterprises	80	35	79	7	3	32	9
ST and PT enterprises were excluded	71	33	69	6	3	24	9
Financial firms were stripped out	71	31	59	6	3	24	9

Table 2
China Securities ESG rating system.

3 pillars	16 themes	44 key issues
Environment (E)	Climate Change	Greenhouse gas emissions, GHG emissions reduction roadmap, Response to climate change, Sponge city, Green finance
	Resource Utilization	Water consumption, Land use and biodiversity, Material consumption
	Environmental Pollution	Industrial emissions, Electronic waste, Hazardous waste
	Environmentally Friendly	Renewable energy, Green buildings, Green factories
	Environmental Management	Sustainable certification, Environment penalty, Supply chain management-E
Social (S)	Human Capital	Employee health and safety, Employee inspiration and development, Employee relations
	Product Liability	Quality certification, Recall, Complaints
	Supply Chain	Supplier risk and management, Supply chain relationship
	Community investment	Inclusion, Community investment, Employment, Technological innovation
	Data Security and Privacy	Data Security and Privacy
Governance (G)	Shareholders' interest	Protection of shareholder's interests
	Governance Structure	ESG governance, Risk control, Board structure, Executive turnover
	Information Disclosure Quality	ESG external assurance, Credibility of information disclosure
	Governance Risk	Major shareholder behaviour, Solvency, Litigation, Tax transparency
	External Punishment	Various external punishments
	Business Ethics	Business ethics, Anti-corruption

Note: Data from Sino-Securities ESG Index public official data (https://www.chindices.com/esg-ratings.html# esg-ratings-methodology (accessed on November 2022).

ESG rating data of Sino-Securities Index Information Service (Shanghai) Co., Ltd. as the explained variable, and assigns a total of 9 C-AAA grades 1–9 points in turn. Table 2 shows the details of Sino-Securities ESG rating system. Table 3 shows the definition of each variable.

3.2.2. *Explanatory variable*

The core explanatory variable in this paper is the dummy variable Policy. We manually collected and sorted out the list of listed enterprises included in the carbon emission trading pilot from each carbon market. If a firm joins carbon trading, Policy takes the value 1 for both the year from the beginning of the firm joining carbon trading and the following years; otherwise, policy takes the value 0.

3.2.3. *Mediating variables*

The first mediating variable in this paper is green technology innovation (lnGTI). The measurement of GTI is challenging due to its abstract nature. As patents are an essential indicator to measure innovation capability, most of the existing literature uses the number of green patents granted or the number of applications to measure GTI. Due to the lag of patent authorization, the number of patent applications can reflect the level of enterprise GTI in a more timely manner than the number of patent grants [50,51]. Therefore, we adopt the method of Zhou et al. (2018) to measure GTI by the sum of the number of invention patents and utility model patents applied in that year [52]. The second mediating variable in this paper is green total factor productivity (GTFP). Referring to the practice of Li and Chen (2021), we use the super efficiency SBM-ML model to measure the GTFP of enterprises [53].Among them, this paper uses the fixed capital stock at the prefecture level processed by the perpetual inventory method as the index to measure the capital input of GTFEE; Secondly, this paper uses the number of employees at the end of the year to measure labor input; In terms of energy input, we collected the energy consumption data of listed companies by searching the information of ESG reports and corporate social

Table 3
Variable definition table.

Categories	Symbols	Variable names	Variable definitions
Explained variable	ESG	Corporate ESG performance	Sino-Security ESG rating
Explanatory variable	Policy	Policy dummy variable	If the enterprise joins carbon trading, the value is 1 from the year in which the enterprise begins to join carbon trading and the following years; otherwise, the value is 0.
Mediating variables	Lngti	Enterprise green technology innovation	Ln (The number of green patents filed that year+1)
	Agency	Agency cost	Administrative expenses/Total sales
	Analyst	Analyst attention	Ln (The amount of attention received by analysts+1)
Control variables	Lev	Financial leverage level	Total liability/Total asset
	Size	Enterprise scale	Ln (Total asset)
	ROA	Profitability	Net profit/Total asset
	Growth	Enterprise growth	(Current operating income-Prior period income)/Prior period income
	Board	Internal governance	Ln (Number of directors)
	BM	Book-to-market ratio	Book value/Total market value
	FirmAge	Establishment years of enterprises	Ln (Current year-Year of establishment+1)

responsibility reports. The specific index is the annual comprehensive use equivalent of seven major energy sources of water, electricity, raw coal, natural gas, gasoline, diesel and district heating consumed by enterprises after the conversion of unified standard coal. The expected output is measured by the annual average main business income of the enterprise; This paper uses the data of three industrial wastes (sulfur dioxide emissions, industrial wastewater emissions, and dust emissions) at the prefecture level to measure the undesirable output of GTFP. The third mediating variable in this paper is green total factor energy efficiency (GTFEE). Referring to the practice of Ma et al. (2023), we use the EBM-GML model to calculate the GTFEE of enterprises [54].Considering that we use unbalanced panel data and the sample size is large, we use MAXDEA software to measure GTFP and GTFEE.

The fourth mediating variable in this paper is Agency cost. Referring to Fang et al. (2023), this paper measures agency costs by dividing administrative expenses by total sales [55]. In this paper, Analyst attention (Analyst) is also used as a mechanism variable, and the logarithm of the number of analyst attention plus one is used to measure analyst attention [56].

3.2.4. Control variables

Referring to the existing research on ESG performance, this paper selects the data of financial leverage level (Lev), enterprise Size (Size), enterprise Growth (Growth), profitability (ROA), Board size (Board), book-to-market ratio (BM), enterprise establishment Age (Firm Age) and other aspects as control variables.

Financial leverage level (Lev): Financial leverage, also known as financing leverage, reflects the extent to which a company uses debt financing instruments. For companies with different leverage levels, their business strategies and risk preferences will be different, so the performance of environmental and social responsibilities may also be different, leading to different ESG performance [57]. This paper uses the asset-liability ratio, that is, the ratio of total liabilities to total assets to measure the level of financial leverage.

Enterprise Size (Size): According to Drempetic et al. (2020), The size of an enterprise will affect the performance of ESG by affecting resources for providing ESG data (RPD) and ESG data availability (DA) [58]. Referring to the existing research, this paper uses the natural logarithm of total assets to measure the size of enterprises [59].

Enterprise Growth (Growth): Enterprise growth ability refers to the development trend and growth rate of the enterprise in the market in the future. Generally speaking, the stronger the growth ability of an enterprise is, the stronger the ability to undertake environmental and social responsibilities is. Referring to Endri and Fathony (2020), this paper uses the ratio of the difference between the current operating income and the previous operating income to the previous income to measure the growth of enterprises [60].

Profitability (ROA): The stronger the profitability is, the more resources the enterprise has to undertake environmental and social responsibilities, so the better the ESG performance will be. Referring to the method of Owolabi (2022), this paper uses the ratio of corporate net profit to total assets, namely ROA, to measure corporate profitability [61,62].

Board size (Board): Board size refers to the number of board members, which is measured by the natural logarithm of the number of board members [63]. Studies have shown that the size of the board of directors will positively and significantly affect the ESG performance of enterprises [64].

Book-to-market ratio (BM): The book-to-market ratio is the ratio of a company's book value to the total market value of the company's shares. The BM effect proposed by Fama and French (1992) believes that the average monthly return of companies with a high book-to-market ratio is higher than that of companies with low BM value. This also indicates that a higher BM may bring a higher income level, so that enterprises have more funds to improve ESG performance [65].

Firm age: To a certain extent, the establishment age of an enterprise reflects the development stage of the enterprise. Referring to Petruzzelli et al. (2018), this paper uses the natural logarithm of the difference between the year of establishment and the year of establishment plus one to measure the establishment years of an enterprise [66].

At the same time, two dummy variables, Industry fixed effect (Industry) and time fixed effect (Year), are added to the empirical model to exclude the influence of unobservable factors during the sample period.

3.3. Model specification

The following multi-period DID model is established:

$$ESG_{it} = \beta_0 + \beta Policy_{it} + \theta Control_{it} + \mu_c + \lambda_t + \varepsilon_{it} \quad (1)$$

In the above model, i denotes enterprise and t denotes year; ESG_{it} is the ESG score of the enterprise. $Policy_{it}$ is the core explanatory variable of this paper, and if the enterprise joins carbon trading, the value is 1 from the year in which the enterprise begins to join carbon trading and the following years; otherwise, the value is 0.This study focuses on the coefficient β. If its performance is significantly positive, it indicates that the carbon emission trading scheme can improve the ESG performance of enterprises. If the coefficient is significantly negative, it indicates that the carbon emission trading scheme is not conducive to the improvement of enterprises' ESG performance. $Control_{it}$ is a set of control variables, μ_c is industry fixed effect, λ_t is year fixed effect, and ε_{it} represents the random disturbance term. In order to alleviate the heteroscedasticity problem, this paper considers the robust standard errors clustered to individuals in each regression model.

In order to verify the mediating mechanism of green technology innovation, agency cost and analysts' attention in the impact of market-incentive-based environmental regulation on ESG performance of enterprises, this paper uses the stepwise method proposed by Baron and Kenny (1986) to test the mediating effect [67].

$$Mediator_{it} = \alpha + \beta_0 Policy_{it} + \theta Control_{it} + \mu_c + \lambda_t + \varepsilon_{it} \quad (2)$$

$$ESG_{it} = \alpha + \beta_1 Policy_{it} + \Phi Lngti_{it} + \theta Control_{it} + \mu_c + \lambda_t + \varepsilon_{it} \quad (3)$$

In the above equation, $Mediator_{it}$ represents the mechanism variables green technology innovation, agency cost and analyst attention, and the meanings of other variables are consistent with Model (1). The analysis idea is as follows: if the coefficient β in Model (1) is significant, and the coefficients of β_0, β_1 and Φ in Model (2) and Model (3) are also significant, the mediating effect is effective; otherwise, it is not.

4. Empirical analysis

4.1. Descriptive statistics of variables

Table 4 shows the sample size, mean, standard deviation, minimum and maximum values of each variable.

The descriptive statistics for main variables are shown in Table 4. Clearly, different variables have diverse effective observed values, but the number of missing values is small compared with the whole sample, which does not affect the empirical results. The average value of ESG performance of enterprises is 7.302, the standard deviation is 0.539, the minimum value is 5.727, and the maximum value is 8.422, showing that the ESG performance of enterprises varies greatly. The average value of Policy of carbon emission trading mechanism is 0.034, the standard deviation is 0.181, the minimum value is 0, and the maximum value is 1, indicating that there are large differences in the market-incentive environmental regulation of enterprises; The mean value of the control variable ROA is 0.039, the standard deviation is 0.066, the minimum value is −0.243, and the maximum value is 0.223, indicating that there are loss-making individuals in the sample enterprises, and the net profit margin of total assets of each enterprise varies greatly. The average value of the Growth rate of operating profit growth is 0.169, the standard deviation is 0.401, the minimum value is −0.570, and the maximum value is 2.430, indicating that there are enterprises with negative growth in the sample, and the growth rate of operating profit of each enterprise varies greatly.

4.2. Correlation coefficient analysis

The following correlation analysis is done for each variable, and the results are shown in Table 5:

It can be seen from Table 4 that the correlation coefficient between CETS and enterprises' ESG performance is 0.052, which is significantly positive at the level of 1%, indicating that the implementation of CETS has a positive role in promoting enterprises' ESG performance and can improve enterprises' ESG level. At the same time, the correlation coefficient between each control variable and the independent variable is low, which can rule out multicollinearity.

4.3. Baseline regression analysis

The benchmark regression adopts the model of Formula (1) to test the impact of CETS implementation on the ESG performance of enterprises, and the test results are shown in Table 6. Column (1) only adds the Policy dummy variable Policy, and its coefficient is significantly positive at the level of 1% with the value of 0.176, indicating that the implementation of CETS can significantly promote the ESG performance of enterprises, and the ESG performance of enterprises participating in carbon emission trading rights in the experimental group has increased by 17.6%. Column (2) controls the control variables on the basis of Column (1), and it can be seen that the variable Policy is significantly positive at 1%. Columns (3) and (4) control the time-fixed effect and industry-fixed effect on the basis of columns (1) and (2), and it can be seen that the variable Policy is significantly positive. Specifically, the ESG performance of enterprises participating in carbon emission trading rights is 12.2% higher than that of enterprises not participating in carbon emission trading rights, indicating that the market-based environmental regulation policy has a significantly positive effect on the ESG performance of enterprises, and H1 can be confirmed.In Column (4), Lev, Size, ROA and BM all play a significant positive role, Growth and FirmAge play a significant negative role, while the negative role of Board is not significant. It can be seen that enterprises with higher

Table 4
Descriptive statistics of variables.

Variable	Obs	Mean	Std.Dev.	Min	Max
ESG	29,905	7.313	0.539	5.727	8.422
Policy	29,905	0.034	0.181	0.000	1.000
lnGTI	25,685	0.318	0.683	0.000	3.401
lnGTFP	25,688	0.081	0.192	0.001	0.693
lnGTFEE	25,298	0.133	0.210	0.004	0.696
Lev	29,905	3.496	2.975	1.110	18.657
Size	29,905	22.205	1.298	19.90	26.277
ROA	28,436	0.039	0.066	−0.243	0.223
Growth	28,431	0.169	0.401	−0.570	2.430
Board	29,902	2.118	0.196	1.609	2.639
BM	29,355	0.617	0.250	0.115	1.190
FirmAge	29,905	2.912	0.319	1.946	3.526

Table 5
Correlation coefficient analysis.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
ESG	1											
Policy	0.052***	1										
lnGTI	0.146***	0.085***	1									
lnGTFP	0.054***	−0.046***	−0.021***	1								
lnGTFEE	0.103***	−0.020***	0.058***	0.916***	1							
Lev	0.022***	−0.043***	−0.085***	0.003	−0.088***	1						
Size	0.222***	0.113***	0.213***	0.024***	0.284***	−0.385***	1					
ROA	0.217***	0.000	0.049***	0.024***	0.029***	0.225***	0.002	1				
Growth	−0.004	−0.017**	0.007	−0.013*	0.001	−0.044***	0.033***	0.255***	1			
Board	0.048***	0.012*	0.048***	0.096***	0.149***	−0.122***	0.265***	0.018***	−0.025***	1		
BM	0.140***	0.026***	0.058***	0.176***	0.294***	−0.278***	0.574***	−0.186***	−0.046***	0.171***	1	
FirmAge	−0.032***	0.029***	−0.036***	−0.205***	−0.151***	−0.139***	0.162***	−0.086***	−0.055***	0.049***	0.101***	1

Table 6
Baseline regression analysis.

Variables	(1) ESG	(2) ESG	(3) ESG	(4) ESG
Policy	0.176***	0.111***	0.191***	0.122***
	(0.033)	(0.033)	(0.034)	(0.034)
Lev		0.012***		0.014***
		(0.002)		(0.002)
Size		0.087***		0.105***
		(0.006)		(0.006)
ROA		2.047***		2.010***
		(0.083)		(0.081)
Growth		−0.080***		−0.084***
		(0.009)		(0.009)
Board		−0.064**		−0.038
		(0.031)		(0.030)
BM		0.172***		0.100***
		(0.025)		(0.029)
FirmAge		−0.075***		−0.099***
		(0.019)		(0.021)
Constant	7.307***	5.508***	7.306***	5.164***
	(0.007)	(0.134)	(0.007)	(0.145)
Industry FE	No	No	Yes	Yes
Year FE	No	No	Yes	Yes
Observations	29905	27892	29905	27892
R^2	0.003	0.118	0.055	0.173

Notes:*, **, and *** indicate that the results are significant at the levels of 10%, 5%, and 1%, respectively.

financial leverage tend to have better ESG performance, which to a certain extent corroborates the debt constraint theory, that is, highly leveraged enterprises face greater debt pressure, and creditors' supervision and constraints on enterprises will be stricter, which will encourage enterprises to improve ESG performance more actively to reduce potential risks. Improve the reputation and investment attractiveness of the enterprise. Larger companies have been shown to have better corporate ESG performance, because the larger the company is, the more obvious the scale effect is, and the higher the sensitivity of the company to improve its financial performance and environmental performance through corporate governance and other means. The significant positive effect of ROA proves our discussion in 3.2.4 that enterprises with stronger profitability have stronger ability to undertake environmental and social responsibilities, and the significant negative effect of FirmAge indicates that enterprises in the early stage of development or growth may have stronger willingness to undertake social responsibilities. However, the negative and significant role of Growth is not consistent with our expectations, which is a point worth further investigation.

In addition, we separately conducted regression analysis on the three dimensions of E, S and G, and the results are shown in Table 7:

The results of the sub-dimension test show that CETS has a significant positive effect on the environmental (E) dimension and governance (G) dimension, while it has a negative effect on the social (S) dimension, but the effect is not significant. This suggests that

Table 7
ESG sub-dimension test.

Variables	(1) E	(2) S	(3) G
Policy	0.190***	−0.055	0.045**
	(0.052)	(0.053)	(0.023)
Lev	−0.016***	−0.007**	0.044***
	(0.003)	(0.003)	(0.002)
Size	0.166***	0.140***	0.071***
	(0.010)	(0.011)	(0.005)
ROA	0.304**	1.913***	3.159***
	(0.118)	(0.140)	(0.092)
Growth	−0.103***	−0.027	−0.111***
	(0.012)	(0.017)	(0.012)
Board	0.050	0.136***	−0.185***
	(0.048)	(0.053)	(0.023)
BM	0.075	−0.035	0.169***
	(0.046)	(0.052)	(0.024)
FirmAge	0.010	−0.253***	−0.053***
	(0.034)	(0.038)	(0.015)
Constant	2.191***	4.726***	6.468***
	(0.237)	(0.256)	(0.105)
Observations	27892	27892	27892
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
R^2	0.199	0.249	0.181

to a certain extent, an increase in overall ESG performance through increased environmental responsibility is partially offset by a reduction in focus on social indicators.

4.4. Testing the mediating effect of GTI, GTFP, GTFEE, agency cost and analysts' attention

Table 8 shows the test results of the parallel mediating effect. In Column (1), the impact of the explanatory variable Policy on the mediating variable lnGTI is 0.134, which passes the significance test of 1%, indicating that the explanatory variable has a positive and significant impact on the mediating variable lnGTI. In Column (6), after adding the mediating variable LnGTI, Policy has a significantly positive impact on ESG performance, and the mediating variable LnGTI also has a significantly positive impact on ESG performance, indicating that the mediating effect is established; In Column (2), the impact of the explanatory variable Policy on the mediating variable lnGTFP is 0.009, which passes the significance test of 1%, indicating that the explanatory variable has a positive and significant impact on the mediating variable lnGTFP. In Column (6), after adding the mediating variable lnGTFP, the impact of Policy on ESG performance is not significant, indicating that the mediating effect is not valid; In Column (3), the impact of the explanatory variable Policy on lnGTFEE for China and Russia for several times is 0.011, which passes the significance test of 1%, indicating that the explanatory variable has a positive and significant impact on the mediating variable lnGTFEE. In Column (6), after adding the mediating variable lnGTFEE, the impact of Policy on ESG performance is not significant, indicating that the mediating effect is not established; In Column (4), the impact of the explanatory variable Policy on Agency is −0.003, which passes the significance test at 10%, indicating that the explanatory variable has a significantly negative impact on the mediating variable Agency. In Column (6), after adding the mediating variable Agency, the influence coefficient of policy Poicy on ESG performance is −0.198, which passes the significance test of 1%, indicating the existence of mediating effect; In Column (5), the impact of the explanatory variable Policy on Analyst is 0.067, which passes the significance test at 5%, indicating that the explanatory variable has a significantly positive impact on the mediating variable Analyst. In Column (6), after adding the mediating variable Analyst, the influence coefficient of policy Poicy on ESG performance is 0.065, which passes the significance test of 1%, indicating the existence of mediating effect. Based on the above analysis, among our five mediating variables, green technology innovation, agency cost and analyst attention have mediating effects, while green total factor energy efficiency and green total factor productivity do not.Thefore,the hypotheses 2, 5, and 6 are valid, while hypotheses 3 and 4 are not.

Secondly, we tested the direct effect, the total mediating effect and the total effect, and the results are shown in Table 9.

According to Table 9, the direct effect reflects the direct effect of Policy on the performance of ESG; The total mediating effect (i.e., the indirect effect) represents the mediating effect of the three mediating variables of GTI, agency cost and analyst attention on the whole; The total effect is the sum of the direct and indirect effects. The results show that the direct effect is significant at the significance level of 5%, and both the total mediating effect and the total effect are significant at the significance level of 1%, indicating that the mediating effect of the model is valid on the whole.

4.5. Robustness test

4.5.1. Parallel trend test

The multi-period DID model was used in this study. The premise of the study was that there was no significant difference in ESG performance between the experimental group and the control group before the introduction of the carbon emission trading scheme in China, and there was a difference after the introduction. In this study, the earlier period of more than 6 years is combined into phase

Table 8
Mediating effect analysis.

Variables	(1) lnGTI	(2) lnGTFP	(3) lnGTFEE	(4) Agency	(5) Analyst	(6) ESG
Policy	0.134***	0.009***	0.011***	−0.003*	0.067**	0.047**
	(0.023)	(0.001)	(0.003)	(0.002)	(0.027)	(0.020)
lnGTI						0.067***
						(0.006)
lnGTFP						−0.186
						(0.156)
lnGTFEE						0.027
						(0.062)
Agency						−0.198***
						(0.070)
Analyst						0.065***
						(0.005)
Constant	−3.279***	−0.296***	−1.253***	0.292***	−6.799***	6.027***
	(0.106)	(0.006)	(0.015)	(0.009)	(0.133)	(0.121)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	23959	24359	23990	27883	19208	5333
R^2	0.183	0.969	0.831	0.349	0.396	0.170

Notes:*, **, and *** indicate that the results are significant at the levels of 10%, 5%, and 1%, respectively.

Table 9
The direct effect, total mediating effect and total effect.

Effect	Coefficient	Std.err.	z	P|z|
Direct effect	0.045	0.020	2.28	0.023
Total mediating effect	0.014	0.002	5.59	0.000
Total effect	0.058	0.020	2.97	0.003

−6, the later period of more than 6 years is combined into phase 6, and the −6 period is set as the base period. The test results are shown in Fig. 1. It can be seen that the estimated coefficients before the implementation of the policy are not significantly different from 0, indicating that enterprises in the experimental group and the control group have a parallel trend before the start of the experiment and meet the parallel trend test. It can be seen from Fig. 1 that the coefficient in the year when the policy was implemented changed from insignificant to positively significant, indicating that the policy played an effective role in the year when it was implemented, and there was no lag effect. In the following four years, the policy continued to play an effective role. However, in the fifth year after the implementation of the policy, the effect of the policy began to become insignificant. The possible reason is that from the perspective of enterprise operation and development, there is a ceiling level for the improvement of enterprise ESG level. For this group of enterprises implementing carbon emission trading mechanism, after about 5 years, enterprise ESG performance has been improved to a certain extent and gradually approaching its ceiling level. Every year, pilot cities will release a new round of carbon emission trading pilot policies, and the ESG performance of a new batch of enterprises will continue to be improved by the impact of the carbon emission trading mechanism, until they reach the cap level again five years later. By analogy, the ESG performance of listed companies in the pilot cities improved batch by batch.

4.5.2. PSM-DID test

This paper empirically studies the impact of CETS implementation on ESG performance by using a multi-time DID model. Using this model, the endogeneity problem caused by reverse causality is avoided. Furthermore, according to Hu et al. (2021), this paper adopts PSM-DID (propensity score matching DID) to solve the selection bias problem caused by observable and unobservable variables [68–70].

4.5.2.1. PSM process. Firstly, in order to test for possible sample bias, we used the propensity score matching (PSM) method to match the experimental group (CETS implemented) and the control group (CETS not implemented). We take financial leverage level (Lev), enterprise Size (Size), enterprise Growth (Growth), profitability (ROA), Board size (Board), book-to-market ratio (BM), and enterprise establishment years (FirmAge) as control variables. Referring to the practice of Wang et al. (2020), the nearest neighbour 1:1 matching method is selected for matching, which means that for each experimental group sample, the nearest control group sample will be selected for matching, and the Logit model is used to estimate the propensity score [71].

We used the common value test and the matching balance test to evaluate the impact of CETS implementation, and the results are shown in Fig. 2. As can be seen from Fig. 2(a), before matching, the value intervals of the experimental group and the control group overlap, indicating that the assumption of common value is satisfied.

It can be seen from Fig. 2(b) that after PSM, the distribution of samples with and without CETS tends to be significantly consistent. The absolute values of the standard deviations after PSM are all less than 10%, indicating that the matching results are valid and meet the requirements of the matching balance test. The p-values after matching in Table 10 all exceed 0.1, indicating that the two types of variables are irrelevant, which proves that the results of PSM are valid. Fig. 3 also shows that the standardization deviation of matching variables decreases significantly after matching, indicating that the matching results are reliable (see Table 11).

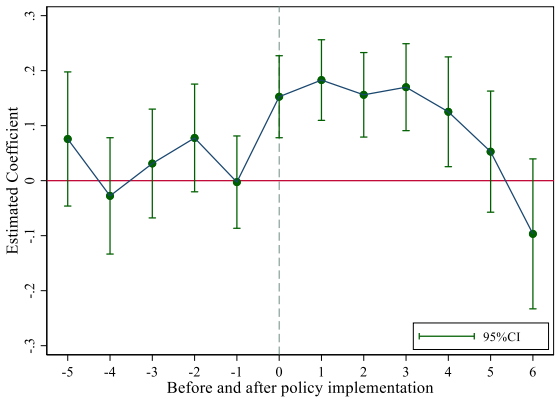

Fig. 1. Parallel trend test.

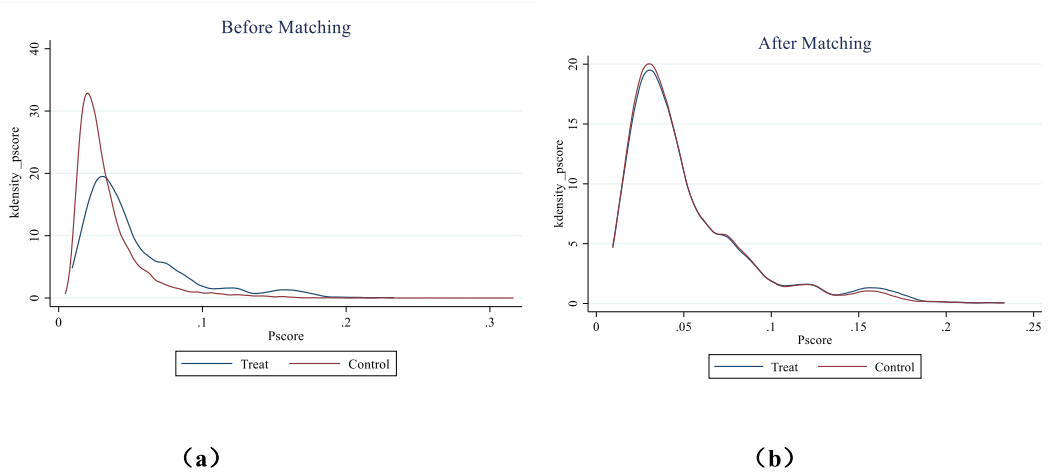

Fig. 2. Common values before and after PSM treatment (2015). (a) Kernel density before PSM, (b) Kernel density after PSM.

Table 10
Deviation and confidence level before and after PSM.

Variable	Unmatched	Mean			%reduct	*t*-test	
	Matched	Treated	Conrtol	%bias	| bias |	T	p>|t |
Lev	U	2.776	3.400	−25.0		−6.73	0.000
	M	2.776	2.672	4.2	83.2	1.14	0.255
Size	U	23.055	22.234	61.6		19.58	0.000
	M	23.055	23.051	0.3	99.5	0.06	0.952
ROA	U	0.0394	0.039	0.5		0.14	0.886
	M	0.0394	0.040	−0.7	−47.2	−0.16	0.874
Growth	U	0.148	0.169	−5.9		−1.65	0.098
	M	0.148	0.132	4.4	26.4	1.05	0.294
Board	U	2.140	2.119	10.1		3.27	0.001
	M	2.140	2.144	−1.9	81.3	−0.41	0.685
BM	U	0.656	0.616	16.0		4.95	0.000
	M	0.656	0.654	1.0	93.9	0.21	0.837
FirmAge	U	2.982	2.921	19.5		5.91	0.000
	M	2.982	2.968	4.4	77.3	1.01	0.314

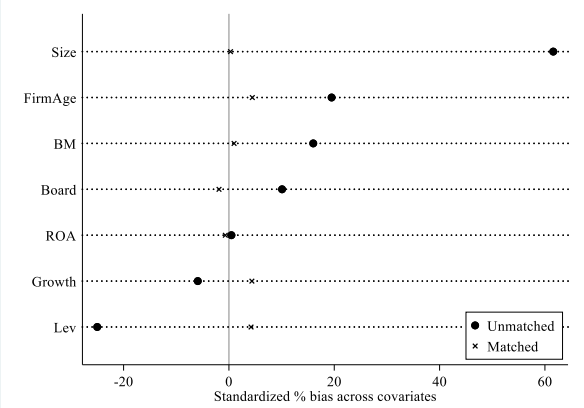

Fig. 3. Standardized deviation of variables before and after PSM treatment.

4.5.2.2. PSM-DID regression results. After using the propensity score matching (PSM) method to process the data, this study uses the difference-in-differences (DID) method for regression analysis, and the regression results are shown in Table 11 At the confidence level of 1%, the coefficients of the carbon emission trading mechanism is significantly positive, indicating that the implementation of the

Table 11
PSM-DID regression analysis.

	(1) ESG
Policy	0.093**
	(0.037)
Lev	0.014**
	(0.007)
Size	0.081***
	(0.017)
ROA	1.021***
	(0.229)
Growth	0.002
	(0.034)
Board	−0.085
	(0.078)
BM	0.033
	(0.077)
FirmAge	−0.113*
	(0.067)
Constant	5.940***
	(0.420)
Industry FE	Yes
Year FE	Yes
Observations	1892
R^2	0.191

policy does promote the ESG performance of enterprises, and there is no sample selection bias in the benchmark regression results. These results are consistent with the benchmark regression results, again supporting the results of this study.

4.5.3. Placebo test

This paper conducts the placebo test by constructing a false experimental group, and the result is shown in Fig. 4. Specifically, we conducted 500 times of random sampling. The results in the figure show that the mean value of the random regression coefficients is close to 0, and all regression coefficients significantly deviate from the actual estimated coefficients, indicating that in the random sampling of 500 times, CETS has no significant impact on the ESG performance of enterprises. Based on the above analysis, the placebo test is passed, and the impact of CETS on the ESG performance of enterprises is unlikely to be affected by other omitted variables, so the above conclusions are robust.

4.5.4. Replace the explained variable

In order to further test the robustness of the benchmark regression, this paper conducts regression on the model by replacing the explained variable. First of all, this paper uses the ESG rating of SynTao Green Fiance to reset the explained variable, and the regression results are shown in Column (1) of Table 12.

4.6. Further analysis

This paper conducts heterogeneity analysis based on the nature of the enterprise's equity, whether it has political connection and the attributes of science and technology. In addition, according to the Guidelines on Industry Classification of Listed Companies (2012 Revision), we determine the industry code of high-tech listed companies, assigning the value of 1 to high-tech listed companies and 0 to other companies. The results are shown in Table 13, and columns (1) and (2) of Table 13 show that the coefficient of non-state-owned enterprises (Non-SOEs) is significantly positive, while the coefficient of state-owned enterprises (SOEs) is insignificant. It can be seen that the implementation of CETS can have a favourable impact on the ESG performance of non-state-owned enterprises, while it also has a promotion effect on state-owned enterprises, but the effect is not significant. This may be because SOEs are obliged to undertake more environmental and social responsibilities in addition to achieving financial performance targets, so as to set an example for other enterprises so they will take the lead in responding to the public policy of CETS, rather than choosing profit maximization. Therefore, in the face of additional costs brought by market-based environmental regulation, the small cost elasticity of SOEs leads to a weak response to environmental regulation. In addition, SOEs are generally the pillar enterprises of the national economy, and the cost of production mode reform is high, the cycle is long, and they cannot timely respond to market-based environmental regulations in the short term. Non-SOEs, on the other hand, take profit maximization as the primary goal and will inevitably take effective measures to adjust production strategies and transform to green governance in the face of the costs brought by market-based environmental regulation. Therefore, under the market-based environmental regulation policy, non-SOEs are the main force for society to achieve emission reduction targets. From columns (3) and (4) of Table 13 and it can be seen that the implementation of CETS has a significantly positive impact on both politically connected and non-politically connected enterprises, but the impact on non-politically connected enterprises is more significant. On the one hand, government officials will protect politically connected enterprises from strict environmental regulation for personal gains. Previous studies have shown that political connections may, to a certain extent, encourage

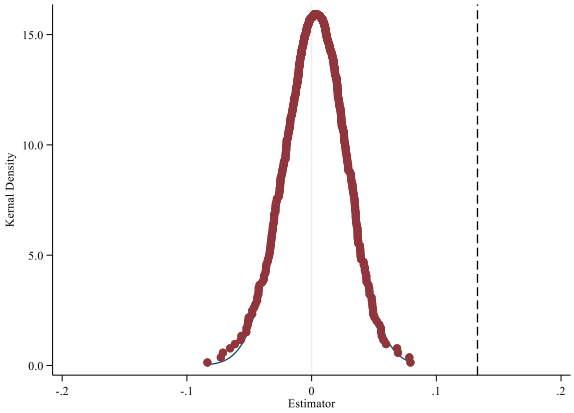

Fig. 4. Placebo test.

Table 12
Replace the explained variable.

	SynTao Green Fiance ESG
Policy	0.273***
	(0.104)
Constant	−0.760
	(0.947)
Controls	Yes
Industry FE	Yes
Year FE	Yes
Observations	3640
R^2	0.190

Notes:*, **, and *** indicate that the results are significant at the levels of 10%, 5%, and 1%, respectively.

Table 13
Heterogeneity analysis.

Variables	(1) SOEs	(2) Non-SOEs	(3) Politically connected	(4)Non-politically connected	(5)High-technology	(6)Non-high-technology
Policy	0.020	0.181***	0.064**	0.127***	0.113***	0.156***
	(0.023)	(0.019)	(0.028)	(0.019)	(0.017)	(0.026)
Constant	4.526***	5.988***	5.008**	5.237***	5.412***	4.869***
	(0.135)	(0.107)	(0.137)	(0.103)	(0.104)	(0.111)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9629	17786	7637	16322	14853	13039
R^2	0.247	0.149	0.194	0.163	0.131	0.223

Notes:*, **, and *** indicate that the results are significant at the levels of 10%, 5%, and 1%, respectively.

enterprises to avoid social responsibility, distort environmental performance, and produce a “shielding effect” on the punishment of enterprises for violations, thus making enterprises ignore the pressure caused by their own production on the social environment. However, enterprises that are not closely connected between government and enterprises will be subject to stricter environmental supervision under the pressure of market-based environmental regulation. On the other hand, Huang and He (2020) found that political connections weakened innovation investment, which may reduce the impact of CETS on enterprise ESG performance. The results in columns (5) and (6) of Table 13 show that the implementation of CETS has a significant positive impact on both high-tech and non-high-tech firms, but the impact is more significant for non-high-tech firms. According to Zhao (2019), the operating gross profit margin and total net asset ratio of high-tech industries are both higher than those of non-high-tech industries, which indicates that high-tech enterprises not only have high resource utilization efficiency, but also have more advantages in market competition. The disadvantage in resources encourages non-high-tech enterprises to win better social reputations by improving ESG performance and disclosing better ESG performance information. The social reputation brought by better ESG performance is one of the key resources required by enterprises, which can be converted into economic benefits in the future operation process of enterprises and promote them to achieve sustainable development. Therefore, in the face of the pressure of market-based environmental regulation, even if the current resource

strength of enterprises is at a disadvantage, managers of non-high-tech enterprises will still choose to invest resources to improve ESG performance for the consideration of sustainable development of enterprises.

5. Conclusions and suggestions

5.1. Conclusions and policy implictaions

The main contributions of this study are reflected in two aspects. Enterprise ESG performance is not only closely related to the global ecology, but also an important tool to promote high-quality and sustainable economic development. However, the existing research on ESG performance mainly focuses on developed economies, while the research on emerging economies is still relatively scarce. Secondly, existing studies focus on how command-and-control environmental regulation forces enterprises to reduce environmental pollution behavior, while the impact of market-incentive environmental regulation on enterprise ESG performance has not been fully explored. This paper takes the carbon emission trading mechanism gradually piloted in China as the breakthrough point to solve the above research questions, which not only expands the research on the policy effect of market-based environmental regulation in China, but also provides evidence and answers for whether the carbon market helps stimulate the ESG performance of Chinese enterprises. It also provides a reference for the government to improve the ESG information disclosure system, refine the requirements of ESG information disclosure, and improve the ESG performance level of Chinese enterprises. Second, it reveals the micro mechanism of the carbon emission trading mechanism more accurately. This paper empirically tests the impact mechanism of carbon emission mechanism on ESG performance from two aspects: internal governance and external supervision. It reveals that internal green technology innovation, agency cost management and external analyst attention may have significant impacts on the relationship between carbon emission mechanism and enterprise ESG performance, which provides strong support for enterprises to further strengthen green technology innovation and strengthen the top-level design of ESG construction. Our research also found that the implementation of CETS can improve ESG performance by reducing agency costs. In view of the great influence of analysts and institutional investors, enterprises can also build digital social responsibility platforms for analysts and institutional investors to supervise and inquire corporate social responsibility performance information, strengthen information communication and exchange between enterprises and analysts and institutional investors, so as to gain the trust and support of investors and other stakeholders, and obtain key resources. Promote sustainable development of enterprises. Finally, this paper discusses the different impacts of CETS on the promotion of ESG performance under different ownership nature, political connection attribute and technology attribute, and finds that the promotion effect is more significant in non-state-owned enterprises, non-political connection enterprises and non-high-tech enterprises, which provides some reference for the government to develop differentiated enterprise support policies. The research of this paper not only further deepens the related research of carbon market, but also puts forward some new thoughts on how to effectively drive the green and sustainable development of enterprises under the pattern of high-quality development.

5.2. Limitations and future research

There are still some shortcomings in this study: On the one hand, the sample of this study is the A-share listed companies in Shanghai and Shenzhen, and unlisted companies are not considered. Therefore, the coverage of the sample and the applicability of the research conclusions are still limited. Future studies can further expand the sample size to explore the corresponding situation of non-listed companies. On the other hand, since the results of this study are based on data sets in China, it is worth trying data sources from other emerging economies in future studies to confirm the validity and portability of the conclusions of this study.

Funding statement

This work was supported by Humanities and Social Sciences Research Project of Ministry of Education [grant number 22YJC790115], Central Universities Fundamental Research Operating Expenses Scientific Research Cultivation Project of Zhongnan University of Economics and Law [grant number 202411023] and the National Social Science Fund of China [grant number 21AZD026].

Data availability statement

Data will be made available on request.

Sharing research data helps other researchers evaluate your findings, build on your work and to increase trust in your article. We encourage all our authors to make as much of their data publicly available as reasonably possible. Please note that your response to the following questions regarding the public data availability and the reasons for potentially not making data available will be available alongside your article upon publication.Has data associated with your study been deposited into a publicly available repository?

No

Sharing research data helps other researchers evaluate your findings, build on your work and to increase trust in your article. We encourage all our authors to make as much of their data publicly available as reasonably possible. Please note that your response to the following questions regarding the public data availability and the reasons for potentially not making data available will be available alongside your article upon publication.Has data associated with your study been deposited into a publicly available repository?

Data will be made available on request

CRediT authorship contribution statement

Bowen Tian: Writing – review & editing, Validation, Supervision. **Jiayi Yu:** Writing – original draft, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Zhilong Tian:** Writing – review & editing, Validation, Supervision.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Bowen Tian reports financial support was provided by Humanities and Social Sciences Research Project of Ministry of Education [grant number 22YJC790115]. Jiayi Yu reports financial support was provided by Central Universities Fundamental Research Operating Expenses Scientific Research Cultivation Project of Zhongnan University of Economics and Law [grant number 202411023]. Zhilong Tian reports financial support was provided by National Social Science Fund of China [grant number 21AZD026]. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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