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How does Central Environmental Protection Inspection drive the green transformation of China's heavy-polluting enterprises from an ESG perspective?

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The green transformation of heavy-polluting enterprises under the carbon peaking and carbon neutrality goals needs the escort of command environmental regulation. This paper takes the first round of Central Environmental Protection Inspection as a natural experiment, reflecting the degree of green transformation through the environmental, social, and governance (ESG) level of enterprises. Taking Chinese A-share listed companies in Shanghai and Shenzhen from 2010 to 2022 as the research object, a dual machine learning model is used to determine whether this system can improve the ESG level of enterprises and promote their green transformation. Using a dual machine learning model, it is found that the system can enhance the ESG level of enterprises and promote their green transformation. Mechanism analyses show that the system promotes green transformation by enhancing green innovation capability, safeguarding the rights and interests of upstream and downstream supply chain actors, and enhancing governance diligence, thus encouraging enterprises to assume environmental, social, and governance responsibilities. It is also found that at the macro-policy level, with the migration of the inspection area to the west and the strengthening of local environmental governance, and at the micro-firm level, the higher the degree of digitization and the larger the size of assets, the deeper the system effect on the green transformation of heavy-polluting enterprises. It is further found that the spillover effect of green transformation within industries strengthens the positive effect of the Central Environmental Protection Inspection on the green transformation of enterprises compared to the inter-industry.

KEYWORDS

Central Environmental Protection Inspection, green transformation, double machine learning, ESG, heavy-polluting enterprises

1 Introduction

We now see international consensus for the promotion of green transformation of economic development. In 2020, the European Union allocated 37% of its economic recovery plan to the field of green transformation. In 2021, the United Kingdom government announced the "Net Zero Strategy." The United Arab Emirates has

released its 2050 energy strategy. Similarly, the Chinese government has deployed a series of policies to promote green transformation. The concept of "greening" was first proposed at the Central Political Bureau meeting in 2015, and the proposal of the dual-carbon target in 2020 raised the requirements for China's green economic development to a new height. The 2023 Government Work Report further emphasised the need to promote energy conservation and carbon reduction in key areas. Aniruddha Dasgupta, President and CEO of the World Resources Institute, pointed out in 2022 that as the world's second-largest economy and leader in renewable energy, China's green transformation will benefit the whole world (China Daily, 2022). China's green transformation can promote the development of its own green economy and contribute wisdom and strength to global sustainable development. Therefore, this study conducts research on green transformation from a Chinese perspective. At the same time, as the micro-subject of economic development, enterprises are the primary force for achieving green transformation. Studying how to promote green transformation enterprises is of great practical significance for achieving sustainable development.

Scholars have had many discussions on green transformation. First, from a conceptual point of view, some authors claim that this term should be associated primarily with environmental change (Borel-Saladin and Turok, 2013; Georgeson et al., 2017). The Nordic Council of Ministers proposed in 2021 that green transformation is a "hierarchical and comprehensive transition to a fossil-free, low-carbon society." The Institute of Industrial Economics CASS (2011) defines green transformation as a process in which the "industry moves toward the process of intensive use of energy and resources, reduction of pollutant emissions, reduction of environmental impact, improvement of labour productivity, and enhancement of sustainable development capacity." Many scholars have used this as a basis for the process of green transformation from different perspectives (Martínez-Zarzoso et al., 2019; Yu et al., 2019; Sarfraz et al., 2020) and have measured it separately from environmental and economic performance (Li et al., 2023; Yu and Zhou, 2023). Yang et al. (2023) comprehensively evaluated it at the environmental, social, and governance (ESG) level. Since ESG is closely related to China's new development concept of "innovation, coordination, greenness, openness, and sharing" and represents a greener development approach, it can fully reflect the degree of green transformation of enterprises. This paper draws on the study by Yang et al. (2023) to study the green transformation from the perspective of ESG. In addition, although existing studies have shown that environmental regulation is an important factor in promoting green transformation (Yu et al., 2019; Du et al., 2021; Chen et al., 2023), however, there are problems with local protection and market failure in China's environmental governance, and it is necessary to explore new paths of environmental governance to promote green transformation.

The Central Ecological Environmental Protection Inspection System (hereinafter referred to as the "Central Environmental Protection Inspection") is an innovative attempt to change China's command-type environmental regulation from the "supervision of enterprises" and "supervision of the government" to "joint responsibility of the Party and the government," which has been carried out for two rounds from 2016 to 2022. This system has the characteristics of campaign-style governance (Qi and Yu, 2018), which can effectively impact local pollution behaviour in the short term, but there is a risk of rebound in the later stage. It also gradually presents the characteristics of conventional governance, which can regularly inspect local governments and enterprises, but there may be problems such as agency relationships caused by institutional rigidity (Jin and Kong, 2022). So, based on these dual characteristics, how will the central environmental inspection affect the green transformation of enterprises?

Based on this, this paper focuses on environmental governance–heavy-polluting listed enterprises as the research samples, analyses the dual-environmental governance characteristics of the coexistence of the Central Environmental Protection Inspection campaign-style governance and conventional governance, and measures the degree of green transformation of enterprises at the ESG level, in an attempt to analyse and test the relationship between the Central Environmental Protection Inspection and the green transformation of heavy-polluting enterprises. The research contributions of this paper are as follows: (1) although scholars have demonstrated the positive impact of Central Environmental Protection Inspection on the ESG rating and performance of enterprises (Zheng and Xu, 2023; Chen and Li, 2023; Huang, 2024), their analysis and argumentation all start from the comprehensive ESG performance of enterprises, lacking theoretical analysis based on the three dimensions of environmental responsibility (E), social responsibility (S), and governance responsibility (G) and failing to analyse the mechanism of central environmental inspections with both campaign-style and conventional governance characteristics. Based on the unique perspective of macro-environmental regulation affecting micro-enterprise behaviour, the impact of Central Environmental Protection Inspection on the green transformation of heavy-polluting enterprises is examined for the first time using a dual machine learning approach, which not only provides evidence to support the role of Central Environmental Protection Inspection at the micro-level of corporate governance in improving the green transformation of enterprises but also enriches the research literature on the influencing factors of corporate green transformation; (2) the green transformation of heavy-polluting enterprises is taken as the object of investigation, and the green transformation governance effectiveness of the Central Environmental Protection Inspection is tested. This paper shows that the coexistence of campaign-style governance and conventional governance can promote the green transformation of enterprises, which not only effectively alleviates the short-term behaviour that may be triggered by the high-pressure situation under campaign-style governance but also circumvents the disadvantages of the decentralised system under conventional governance, promotes the convergence of the goals and interests of local and central governments, and provides empirical evidence for improving the environmental policy system; (3) examining the mechanism of Central Environmental Protection Inspection to promote the green transformation of heavy-polluting enterprises from the dimensions of E, S, and G, reveals a feasible way for the system to effectively promote the green transformation of heavy-polluting enterprises by enhancing the green innovation capability, safeguarding the rights and interests of upstream and downstream supply chain subjects, and improving the degree of diligence in governance, as well as assuming the environmental

responsibility, social responsibility, and governance responsibility. The applicability of Porter's hypothesis in China is verified at the level of the Central Environmental Protection Administration, which provides a guideline for Chinese enterprises to achieve green transformation through environmental policies, and (4) this paper develops the argument from the intensity of regional and local environmental regulations of Central Environmental Protection Inspection at the macro-policy implementation level, the degree of digitalisation and asset scale perspective at the micro-enterprise level, and the industry spillover effect level to clarify the differences in the promotion of the green transformation of heavy-polluting enterprises by Central Environmental Protection Inspection. It not only deepens the heterogeneity test of environmental regulation to promote the green transformation of enterprises but also provides a useful reference for the promotion of Central Environmental Protection Inspection, the promotion of the green transformation of enterprises, and the support of the environmental governance of the government in specific real-life situations.

2 Literature review

2.1 Research on the influencing factors of green transformation

Green transformation aims to transform the crude development mode of high emissions, high pollution, and environmental degradation and reconstruct the harmonious relationship between man and nature with low-emission, low-consumption green development to promote sustainable development (Zhou et al., 2022). In the post-epidemic era, green transformation is an important means to alleviate economic pressure (Kemfert et al., 2020). Pitkänen et al. (2016) reported that green transformation is related to a multiplicity of factors, and the implementation of green transformation requires a game between multiple stakeholders.

The influencing factors of existing green transformation can be distinguished based on the internal and external factors of the enterprise. The internal factors of enterprises are mainly in the scale of enterprises (Drempetic et al., 2019), the environmental attention of executives (Ding et al., 2023), and the non-economic factors related to the materials used during production (Declich et al., 2020). External influencing factors can be reviewed from both micro- and macro-perspectives.

From a micro-perspective, enterprises can achieve green transformation through various channels. Companies achieve green transformation by rapidly integrating environmental resources between themselves through green mergers and acquisitions (Pan et al., 2019). Green technology can effectively play a driving role in promoting green transformation (Terzi, 2020; Cheba et al., 2022). Green finance can provide sufficient financial support for green transformation (Ruzibaeva, 2022). However, an increase in the degree of shared ownership will reduce the motivation of companies to adopt green resources and inhibit green transformation (Hirose and Matumura, 2023).

From a macro-perspective, most studies discuss the role of formal institutions such as environmental regulations and legal systems. Studies have shown that green transformation is influenced by carbon pricing, renewable energy policies, and political pressure (Speck et al., 2017; Urban et al., 2018; Yuan et al., 2020); Garcia et al., 2017). Stricter environmental regulations may promote cleaner production and accelerate green transformation (Martínez-Zarzoso et al., 2019). Furthermore, environmental taxes can effectively incentivise the green transformation of enterprises (Yu et al., 2019). Some studies have also focused on the impact of changes in the financial system. Sustainable growth requires the support of ecological finance (Steblyanskaya et al., 2019). Green credit policies can promote the green transformation of the supply chain (Chen et al., 2024); after the implementation of the green credit policy, the emission reduction effectiveness of highly polluting enterprises improves, while the total factor productivity decreases (Yu and Zhou, 2023).

Scholars have also conducted research from other perspectives. Government spending on energy efficiency and R&D budgets contributes to green transformation (Caglar and Ulug, 2022). The environmental efficiency of domestic capital accumulation in countries with low emission levels is higher than that in countries with high emission levels (Destek et al., 2023). Rudneva et al. (2016) considered the influencing factors of the speed and process of green transformation.

2.2 Research on the impact of Central Environmental Protection Inspection on the behaviour of micro-enterprises

Most existing studies have demonstrated the validity of Porter's hypothesis from the perspective of corporate environmental behaviour, arguing that the policy can help enterprises achieve win–win development between economic growth and environmental protection, motivate enterprises to achieve performance growth based on innovation (Shen et al., 2019), and increase investment in green technology innovation (Lei et al., 2021). There are also studies from perspectives other than environmental behaviour. It is found that listed companies in provinces affected by environmental inspections are more likely to reduce information disclosure (Huang et al., 2021) and that the announcement of the Central Environmental Protection Inspection's "looking back" leads to a decrease in the return of listed companies in highly polluting industries (Chen et al., 2020) and in the share price (Tian et al., 2019). In addition, the Central Environmental Protection Inspection increases audit fees by increasing the time investment and risk premium of the auditor (Li et al., 2022).

2.3 Research on the impact of the Central Environmental Protection Inspection on the ESG performance of micro-enterprises

Given that this paper measures the degree of green transformation based on the ESG performance of enterprises, relevant research on the Central Environmental Protection Inspection and ESG performance is summarised. Zheng and Xu (2023) found that the Central Environmental Protection Inspection enhances the ESG responsibility rating of family businesses at the

macro-level through constraint and supervision effects and at the micro-level through reputation value and social capital. Chen and Li (2023) found that the Central Environmental Protection Inspection policy significantly improved the ESG performance of enterprises, with government environmental governance and enterprise green technology innovation as the pathways. Huang (2024) drew similar conclusions and explored the inherent paths of the proactive risk-taking level and green technology innovation momentum.

2.4 Summary of the literature

In summary, the following three conclusions can be drawn: (1) although there have been many studies on the impact of environmental regulation on the green transformation of enterprises, there is little literature on the impact of the Central Environmental Protection Inspection, which is extremely important at present, and there is a need to thoroughly analyse the impact of command-type environmental regulation on the green transformation based on China's national conditions; (2) the existing literature on the impact of the Central Environmental Protection Inspection mostly focuses on the individual environmental behaviour of enterprises and less on other perspectives, but in China's promotion of environmental regulation to create a good atmosphere for the transformation and development of enterprises, it is more important to start from this comprehensive perspective of green transformation and to analyse in depth the role of Central Environmental Protection Inspection as the representative of environmental regulation on the green transformation of enterprises; (3) meanwhile, although some literature studies have examined the relationship between Central Environmental Inspection and ESG performance, they all start from the comprehensive performance of corporate ESG, lacking evidence and intrinsic path testing for individual dimensions of environmental responsibility (E), social responsibility (S), and governance responsibility (G); and (4) finally, existing studies have not yet clarified the internal path and contextual changes of the Central Environmental Protection Inspection to promote the green transformation of enterprises, and this paper builds a solid analytical framework for the argumentation of the effect of environmental regulation by comprehensively analysing the institutional characteristics of the Central Environmental Protection Inspection and deeply exploring the mechanism of its effect on green transformation.

3 Research hypothesis

3.1 Central Environmental Protection Inspection and green transformation

The theory of economic externalities holds that ecological environment resources, as a public good with unclear property rights, cannot be completely solved by market mechanisms but require government intervention and regulation (Coase, 1960). Although companies understand that environmental pollution can lead to an overall decrease in social welfare, they are often unwilling to carry out green transformation actions due to the high risks, high investment, and low short-term returns caused by green transformation. Therefore, in order to address the negative externalities caused by environmental pollution, it is necessary to rely on environmental regulations from government departments. According to the theory of legitimacy, enterprises will adjust their behaviour in order to conform to the norms, values, beliefs, and regulations constructed by society (Suchman, 1995). The government will decide whether to impose administrative penalties such as closure and fines on enterprises by evaluating their compliance with environmental legality. At this point, command-type environmental regulations can play a guiding role in corporate environmental behaviour based on administrative power. However, in China, command-type environmental regulations follow the system of superior instructions and subordinate execution. In order to achieve the expected results under this environmental regulatory system, it is necessary to stimulate the enthusiasm of the local government to implement environmental regulations and effectively limit the power of the local government. As a command-type environmental regulation, the Central Environmental Protection Inspection can strengthen the local government's control over the environmental behaviour of enterprises based on the vertical governance system (Shen et al., 2019) and is a means to "correct" local environmental protection behaviour. The Central Environmental Protection Inspection is characterised by both campaign-style governance and conventional governance (Shen et al., 2019). The characteristics of campaign-style governance are reflected in the system's ability to understand the situation at the grassroots level through short periods of resident inspection and multiple ways of identifying and feeding back problems so that pressure is generated at the local level and transmitted through the layers to achieve the objectives of governance (Ma and Zhao, 2023). Conventional governance refers to work based on traditional hierarchical government institutions, which is reflected in the fact that the Central Environmental Protection Inspection has nationwide institutional support, the implementation process is full of emergencies and comprehensiveness, and there is a post-guarantee mechanism of "looking back" (Shen et al., 2019).

This paper argues that campaign-style governance can usefully complement conventional governance tools and that these two features of Central Environmental Protection Inspection will work together to produce better environmental governance. On one hand, campaign-style governance features can cope with the failure of conventional governance (Qi and Yu, 2018). In the practice of environmental governance, when the local party and government environmental protection agencies have insufficient motivation or capacity, the phenomena of environmental policy failure, environmental problems left behind, and environmental inaction often occur (Yang, 2015). Conventional governance is prone to the problems of institutional rigidity, heavy bureaucracy, information asymmetry between the central and local governments, and chaotic principal–agent relationships (Jin and Kong, 2022). Campaign-style governance can play a more active role in the practice of local environmental governance by improving the legitimacy authorisation and performance accountability system of local environmental governance, which plays the role of mobilisation, motivation, and control (Ni and Yuan, 2014), and the Central Environmental Protection Inspection has effectively improved the

local protection behaviour of local environmental governance based on this feature. On the other hand, conventional governance features can effectively guarantee the governance effect of campaign-style governance. The Central Environmental Protection Inspection is gradually reflecting the key features of conventional governance. In terms of duration, following the conclusion of the first round of the Central Environmental Protection Inspection in 2018, the second round was also completed between 2019 and 2022 and will continue in the future. In terms of administrative institutional support, inspectorates have been established nationwide, and a sound network of environmental inspectors has begun to be established at the sub-provincial level. Although the Central Environmental Protection Inspection exhibits campaign-style characteristics, it may lead to enterprises relying on high-pressure environmental governance to conduct short-term inspections of environmental governance indicators rather than substantive green transformation (Yang, 2015). These features can ensure that local inspection targets are subject to long-term central supervision, and the space for speculation is greatly compressed, prolonging the "shelf life" of the good effects of campaign-style environmental governance. The unique mechanism of synergy between the campaign-style and conventional environmental governance features of the Central Environmental Protection Inspection provides strong institutional support for the green transformation of heavy-polluting enterprises.

In addition, the Central Environmental Protection Inspection can demonstrate critical and constructive governance functions in the process of stationing, sinking, and looking back. On one hand, the critical function can be used to station enterprises on the spot using administrative power; find out the current state of environmental governance of enterprises through evidence collection, interviews, and public contacts in parallel; dig out internal problems; and exert pressure on local governments and enterprises through severe punishments such as flexible treatment or referral to the judiciary. On the other hand, it can play a constructive role by providing feedback on the problems found during the inspection process based on the implementation of "party and government shared responsibility" and environmental governance and make valuable suggestions to enterprises. These two functions have successfully reversed the problem of information asymmetry between the central and local governments, effectively restraining local governments from hiding the true information, selective implementation, and even evading central inspections due to their advantage of local environmental information (Shen et al., 2019).

The critical and constructive functions of the Central Environmental Protection Inspection can be maximised in a sustainable manner in the context of the synergy between its campaign-style and conventional governance characteristics. First, as a campaign-style environmental regulation, the Central Environmental Protection Inspection can motivate enterprises in their regions to be environmentally responsible, which greatly facilitates the incentives of local party governments to strengthen environmental enforcement against enterprises in response to ecological accountability (Lei et al., 2022). Relying on the conventional governance characteristics of the Central Environmental Protection Inspection, local officials will urge enterprises to optimise their environmental management systems, reform their production processes to permanently reduce pollution emissions, strengthen cleaner production, and achieve real environmental governance in their jurisdictions. At the same time, according to the theory of resource dependence, enterprises and the surrounding environment are interdependent, and enterprises, in order to achieve their own better development, not only need to obtain the resources of the surrounding environment but can also adjust the degree of dependence on the environment to achieve interdependence with the surrounding environment. Based on the above functions and governance characteristics, the Central Environmental Protection Inspection forces enterprises to fundamentally improve their pollution control technology and environmental protection behaviour, which makes them assume their environmental responsibilities while influencing stakeholders in society and also requires them to continuously innovate their internal systems to improve their efficiency, thus fulfilling their social and governance responsibilities and ultimately realising an all-round green transformation. The environmental responsibility, social responsibility, and governance responsibility of enterprises are interrelated and affect the whole body (Huang, 2021). The implementation of the Central Environmental Protection Inspection has changed the external environment in which enterprises were originally located; in order to cope with the gradually normalised inspection mechanism, in addition to the fulfilment of environmental responsibility, enterprises have the incentive to improve their own fulfilment of social responsibility and governance responsibility so that when the inspection team is stationed in the enterprise to play a critical function and when the inspection team is stationed in the enterprise after the end of playing a constructive function, the enterprise can present a good state of operation to cope with the situation in a calm manner. On one hand, social responsibility helps enterprises establish a good social image, build a solid foundation of social trust, and minimise the negative impact of reports and complaints at the social level during the inspection period. On the other hand, corporate governance responsibility helps enterprises improve their self-monitoring system, strengthen performance evaluation in terms of environmental and social responsibility, improve information disclosure, etc. so that they can effectively respond to inspections and rectify the situation in a timely manner.

Based on the above analysis, this paper argues that Central Environmental Protection Inspection can effectively regulate the environmental behaviour of enterprises and, at the same time, have governance spillover effects on the social and governance responsibilities of enterprises. This is precisely the all-round development of enterprises at the overall level of ESG, which is an important process for the ultimate realisation of green transformation.

Hypothesis 1. Central Environmental Protection Inspection can promote the green transformation of heavy-polluting enterprises.

3.2 Mediating factors in the promotion of green transformation by the Central Environmental Protection Inspection

In this process, this paper argues that the Central Environmental Protection Inspection can encourage heavy-polluting enterprises to

strengthen their green innovation capability; maintain supply chain stability; improve corporate governance to assume environmental, social, and governance responsibilities; and ultimately achieve green transformation. Specific analyses and arguments are as follows:

Strengthening green innovation capability is a must for enterprises to respond to central environmental protection controls and achieve green transformation. Based on Porter's hypothesis, well-designed environmental regulations can encourage enterprises to invest in reducing compliance costs and even improve production processes and product design to enhance competitiveness, resulting in an "innovation compensation" effect (Porter and Linde, 1995). As a highly authoritative environmental supervision system, the Central Environmental Protection Inspection can push enterprises to respond to the fundamental path of green innovation by facing higher-intensity environmental protection requirements and more severe environmental penalties. In terms of critical function, the inspection team will understand the current status of the environmental protection equipment and wastewater discharge of enterprises after being stationed in the country. In terms of constructive function, the policy requires enterprises to provide feedback, design treatment programmes, and make public the results of rectification in response to problems identified by inspectors. In order to meet the requirements of the Central Environmental Protection Inspection and avoid the possible penalties imposed by the inspectors, the enterprises will accept the relevant recommendations of the inspection working group and transfer the external costs of environmental pollution to the enterprises (Zhao and Li, 2021). Accordingly, it analyses the shortcomings of its own environmental management mechanism; increases green innovation investment; reduces pollution emissions; improves environmental management efficiency by purchasing pollution-treatment equipment, improving clean production technology, and introducing green innovation talents; and effectively fulfils its environmental responsibility by improving its green innovation capability.

Maintaining the rights and interests of upstream and downstream stakeholders in the supply chain is a powerful guarantee for enterprises to respond to the Central Environmental Protection Inspection and achieve green transformation. According to stakeholder theory, the management of a company should not only be the responsibility of shareholders but also of other stakeholders such as factor providers and product consumers (Freeman, 1984). Suppliers and customers are important subjects of enterprises at the social relationship level, and implementing green innovation helps maintain relationships between businesses and consumers, as well as between businesses and supply chain partners (Stock et al., 2002). Enterprises can only maintain the rights and interests of upstream and downstream stakeholders in the supply chain and establish a stable cooperative relationship so that they can allocate resources within the entire supply chain to help themselves cope with the Central Environmental Protection Inspection. This is mainly because, on one hand, although the Central Environmental Protection Inspection is for the supervision of the environmental protection behaviour of the enterprises, the environmental protection behaviour of the enterprises cannot be separated from the strong financial support that the enterprises need to achieve through good performance. Supply chain stability can provide enterprises with sufficient raw material supply and sale channels (Kulp, 2002), reduce decision-making costs, improve the speed of resource adjustment of enterprises, and ensure internal cash flow. On the other hand, while promoting green innovation to assume environmental responsibility, it is also necessary to create an environmentally friendly atmosphere from upstream to downstream of the supply chain; enhance environmental awareness; show its positive and good image to society; win more trust from local people, regulators, and investors; and avoid more bad feedback from the public in the next inspection. Based on this requirement, the company will take more social responsibility to protect the rights and interests of suppliers, consumers, and customers.

Strengthening governance diligence is an internal institutional support for enterprises to respond to the Central Environmental Protection Inspection to achieve green transformation. Based on the agency theory, the management accepts the commission of the shareholder to operate the enterprise (Jensen and Meckling, 1976). In order to obtain the expected compensation, the management needs to maintain high-quality environmental behaviour of the enterprise and pass inspections by the environmental protection department, which relies on a sound internal governance mechanism. The presence of the Central Environmental Protection Inspection in enterprises will have a spillover effect on internal governance. With the authority and permanence of the inspectors, enterprises have the incentive to innovate internally to achieve sustainable development. In order to better fulfil their environmental responsibilities, enterprises need to fulfil their own governance responsibilities to support them. On one hand, it is necessary for the relevant managers and cadres of the enterprise to clearly define their powers and responsibilities and to equip specialised staff so they may contact the inspectors promptly, provide them with the required information in an efficient and complete manner, and show them the production and wastewater discharge processes that comply with the prescribed standards and demonstrate the enterprise operational capabilities. On the other hand, there is also the need to issue corrective action plans in a timely and efficient manner, demonstrate to the inspectors the appropriate business and organisational capabilities, gain the inspectors' trust, meet the requirements of regional environmental governance, and meet the environmental performance evaluation of local government officials. These requirements have prompted the management to strengthen its own corporate governance initiative, and it will inevitably make great efforts to optimise the existing corporate mechanisms, build a better incentive and constraint system, and improve governance efficiency. Figure 1 illustrates the research approach of the paper. Therefore, we propose the following hypotheses:

Hypothesis 2a. Central Environmental Protection Inspection can promote the green transformation of heavy-polluting enterprises by prompting them to enhance their green innovation capabilities.

Hypothesis 2b. Central Environmental Protection Inspection can promote the green transformation of heavy-polluting enterprises by prompting them to safeguard the rights and interests of upstream and downstream supply chains.

Hypothesis 2c. Central Environmental Protection Inspection can promote the green transformation of heavy-polluting enterprises by prompting them to enhance their governance diligence.

4 Research design

4.1 Sample selection and data sources

The Central Environmental Protection Inspection started in 2016 with Hebei as a pilot; the first round ended in 2018, and the second round started in 2019 and ended in 2022. In order to have the longest possible research period, this paper takes the time of the first round of the Central Environmental Protection Inspection as the start of the shock of the quasi-natural experiment and defines the study period as 2010–2022, which can include the start and end of the two rounds of the Environmental Protection Inspection, and the samples are the heavy-polluting listed enterprises in Shanghai and Shenzhen A-shares. This paper excludes missing data samples and ST samples. After the above data screening, a total of 4,370 firm-year observations are obtained. To reduce the effect of extreme values, all continuous variables are Winsorized at 1% and 99% quantile levels. The Central Environmental Protection Inspection data are obtained from the official website of the Central Department of Ecology and Environmental Protection. ESG data are obtained from the Bloomberg ESG ratings database, and financial data are obtained from the CSMAR database. Green patent applications are from the CNRDS database. Supplier, customer, and consumer rights and responsibilities data are from the Hexun.com social responsibility rating scores. The Economic Policy Uncertainty Index is from the monthly China Economic Policy Uncertainty Index jointly published by Stanford University and the University of Chicago. The classification of heavy-pollution industries is based on the Guidelines for Environmental Information Disclosure of Listed Companies (2010) implemented by the Ministry of Environmental Protection of China.

4.2 Definition and measurement of variables

4.2.1 Independent variable: CEPI

The explanatory variable CEPI is a dummy variable that measures whether heavy-polluting enterprises are subject to the Central Environmental Protection Inspection. As the time when provinces are inspected is not uniform, inspections end at the beginning of the year, in the middle of the year, and at the end of the year. Considering that it takes time for inspections to take effect, and in order to more accurately test the governance effectiveness of CEPI, we define the CEPI variable based on the month in which the CEPI ends. When the end month of the inspection is at the beginning of the year, the CEPI variable takes the value of 1 for the inspection year and the year after that and 0 otherwise. When the end month of the inspection is in the middle of the year and at the end of the year, the CEPI variable takes the value of 1 for the second year of the inspection and the year after that and 0 otherwise.

4.2.2 Dependent variable: green transformation

ESG focuses on stakeholder rights and interests, which can not only fully reflect the efforts made by enterprises at the environmental level but also comprehensively reflect the social responsibility and governance responsibility of enterprises in order to achieve environmental goals. Green transformation emphasises the transformation and upgrading of enterprises in terms of systems, technologies, and outputs with environmental and economic objectives, which is in line with the ESG concept. Therefore, the ESG level is used to reflect the degree of green transformation of enterprises, with reference to the study by Yang et al. (2023). Meanwhile, as the Bloomberg ESG score is a specific value, and there are 120 three-level indicators under each dimension as the basis for scoring, it can measure the ESG performance of enterprises in a more comprehensive and scientific way and has been widely used in academic research and practical activities at home and abroad. Therefore, the natural log of Bloomberg ESG score is used to measure the level of corporate ESG with reference to the study by Saini et al. (2022).

4.2.3 Moderating variable: green innovation capabilities, the rights and interests of upstream and downstream supply chains, and governance diligence

The previous theoretical analysis shows that the Central Environmental Protection Inspection can promote the green transformation of enterprises by stimulating them to enhance their green innovation ability, safeguarding the rights and interests of upstream and downstream subjects in the supply chain, and enhancing the diligence of governance, in which the three path variables are selected as follows: (1) the number of green invention patent applications is used to measure the green innovation ability of enterprises (GIP). Referring to Valero-Gil et al. (2023), we use the number of green patents to measure corporate green innovation, which is seen as a robust indicator of innovation activities (Berrone et al., 2013); (2) the "Supplier, Customer, and Consumer Rights and Responsibilities" (SCCR) score in Hexun.com's Social Responsibility Rating is used to measure the strength of the enterprise defence of the rights and interests of upstream and downstream stakeholders in the supply chain. This is mainly in consideration of the fact that enterprises need to maintain the stability of the supply chain in order to obtain the support of stakeholders. Enterprises are bound to bundle their own interests with the rights and interests of suppliers, customers, and consumers in the supply chain and actively safeguard the rights and interests of supply chain subjects. Therefore, the degree of responsibility for the rights and interests of suppliers, customers, and consumers can be a good reflection of the efforts of the enterprise to safeguard stakeholders; (3) in this paper, the sum of "the number of strategy committee meetings," "the number of audit committee meetings," "the number of remuneration and appraisal committee meetings," and "the number of nomination committee meetings" is used to measure corporate governance diligence (CGD). The convening of meetings of board of directors often implies that enterprises make decisions on matters related to internal mechanisms, which can fully reflect the diligence and importance of corporate governance, and the corporate governance mechanism of the enterprise is thus improved.

4.2.4 Control variables

Control variables are selected with reference to the study Saini et al. (2022). $Controls_{i,t}$ is a vector of all control variables: $Size_{i,t}$, $Lev_{i,t}$, $Roa_{i,t}$, $Dual_{i,t}$, $Board_{i,t}$, $Ind_{i,t}$, $Growth_{i,t}$, $Top_{i,t}$, $Pay_{i,t}$, $Eps_{i,t}$, $Mb_{i,t}$, $Tbq_{i,t}$, $Cost_{i,t}$, $Tat_{i,t}$, $Sa_{i,t}$, and $Epu_{i,t}$. In addition, this paper introduces enterprise individual- and time-fixed effects in the form of individual and year dummy variables. Specifically, $Size_{i,t}$ denotes the natural log of total assets; $Lev_{i,t}$ denotes the total debt divided by the total assets; $Roa_{i,t}$ denotes the net profit divided by the total assets; $Dual_{i,t}$ is a dummy variable that equals 1 when the managing director is also the chairman of the board and otherwise equals 0; $Board_{i,t}$ denotes the natural log of the number of board members; $Ind_{i,t}$ denotes the number of independent directors divided by the number of board members; $Growth_{i,t}$ represents the ratio of increase in the operating income for the year to the total operating income for the previous year; $Top_{i,t}$ represents the sum of the squares of the shareholdings of the top 10 shareholders; $Pay_{i,t}$ denotes the natural log of the total remuneration of the top three senior executives; $Eps_{i,t}$ denotes the net profit after tax divided by the equity; $Mb_{i,t}$ denotes the shareholders' equity divided by the market value; $Tbq_{i,t}$ denotes the market value divided by the net assets; $Cost_{i,t}$ denotes the financial expense divided by the net assets; $Tat_{i,t}$ denotes the sales revenue divided by the average assets; $Sa_{i,t}$ indicates the degree of financing constraints of the enterprise, which can be calculated using the formula "(-0.737* Size) + (0.043* $Size^2$) - (0.040*A)", and Age is the enterprise age; $Epu_{i,t}$ indicates the economic policy uncertainties, and it is weighted by a monthly economic policy uncertainty index.

4.3 Model setting

4.3.1 Benchmark model

The purpose of this paper is to investigate the driving effect of environmental command regulation on green transformation from an ESG perspective based on the Central Environmental Protection Inspection. Currently, related studies mostly use multi-period multiplicative difference models to evaluate policy effects, but such models require more demanding conditional constraints such as parallel trend tests, and the data used for the study are often difficult to meet the standard. To overcome the shortcomings of traditional models, many scholars have begun to pay attention to the application of dual machine learning in the field of causal inference (Chernozhukov et al., 2018; Knittel and Stolper, 2021). Dual machine learning has a unique advantage in variable selection and model estimation and is also more applicable to the research problem of this paper. On one hand, green transition is a comprehensive indicator of sustainable development, which is influenced by many factors in the economy and society; to ensure the accuracy of policy impact estimation, the influence of other factors on green transition should be controlled as much as possible. However, when dealing with high-dimensional control variables, traditional regression models may face the "curse of dimensionality" and multicollinearity, and the accuracy of the estimates is questionable. Dual machine learning uses many machine learning and regularisation algorithms to automatically filter the pre-selected high-dimensional control variables to obtain an effective set of control variables with high prediction accuracy, which not only avoids the "curse of dimensionality" caused by redundant control variables but also alleviates the biased estimation problem caused by limited main control variables. On the other hand, in economic transition and growth, nonlinear relationships between variables are the norm, and traditional linear regression may cause bias in the model setting, and estimates are not robust enough. Dual machine learning, with the advantage of machine learning algorithms in dealing with nonlinear data, can effectively avoid the problem of model misspecification (Yang et al., 2020) and can also mitigate the "regularity bias" in machine learning estimation, ensuring the unbiased estimation of disposition coefficients in small samples. Based on this, this paper adopts a dual machine learning model to assess the impact of the Central Environmental Protection Inspection on green transformation. Specifically, partly linear dual machine learning regression Equations 1, 2 are established to examine the effect of the Central Environmental Protection Inspection on green transformation.

$$ESG_{i,t} = \beta_0 CEPI_{i,t} + \beta_2 g\left(X_{i,t}\right) + \varepsilon_{i,t}, \tag{1}$$

$$E\left(U_{i,t} \middle| CEPI_{i,t}, X_{i,t}\right) = 0. \tag{2}$$

The variable subscripts i and t represent company i in year t. $ESG_{i,t}$ represents the degree of green transformation of enterprises; i is the enterprise; and t is the year. CEPI is a dummy variable for the disposition variable "Central Environmental Protection Inspectorate," which equals 1 in the year after the province where the enterprise is located is being inspected; otherwise, 0. The disposal coefficient β_0 indicates the policy effect of the Central Environmental Protection Inspectorate on the effect of green transformation. $X_{i,t}$ is a set of high-dimensional control variables that affect the explanatory variables through the form of the function g (X), the specific form is unknown, and the estimator g (X) is obtained by the method of machine learning. $U_{i,t}$ is the error term that satisfies the assumption of zero mean. To alleviate the misleading results of omitted variables, we add a series of control variables related to financial performance, represented by the vector $Controls_{it}$. $Firm_i$ and $Year_t$ represent the firm-fixed effect and year-fixed effect, respectively. Given the small sample nature of the data sample, the construction of the auxiliary regression was continued so that the estimates of the disposal coefficients satisfy the unbiasedness assumption:

$$CEPI_{i,t} = m\left(X_{i,t}\right) + V_{i,t}, \tag{3}$$

$$E\left(V_{i,t} \middle| X_{i,t}\right) = 0\,. \tag{4}$$

On Equations 3, 4 $m(X_{i,t})$ represents the regression function of the disposition variable on the high-dimensional control variable, which also needs to be estimated using a machine learning algorithm in the specific form $\hat{m}$ $(X_{i,t})$, with $V_{i,t}$ as the error term and a conditional mean of 0. Based on Equations 1, 2, an unbiased estimation of the coefficients θ_0 is obtained by a three-step method.

4.3.2 Moderating effect model

In this paper, we refer to the study by Farbmacher et al. (2022) for the causal mediation effect analysis of dual machine learning based on the machine learning algorithm to test the transmission mechanism of the Central Environmental Protection Inspection

TABLE 1 Descriptive statistics for primary variables.

Variable	Observation	Mean	Min	Max	SD
ESG	4,370	3.319	3.344	3.531	0.335
CEPI	4,370	0.457	0	1	0.498
Size	4,370	23.020	22.960	23.850	1.1950
Lev	4,370	0.439	0.446	0.589	0.196
Roa	4,370	0.055	0.046	0.088	0.066
Dual	4,370	0.186	0	0	0.389
Growth	4,370	0.142	0.091	0.193	0.256
Top	4,370	0.191	0.163	0.263	0.127
Pay	4,370	14.600	14.570	15.050	0.743
Eps	4,370	0.615	0.413	0.851	0.821
Mb	4,370	0.604	0.588	0.833	0.292
Board	4,370	2.349	2.303	2.485	0.248
Tbq	4,370	2.069	1.532	2.349	1.506
Cost	4,370	0.020	0.012	0.028	0.038
Tat	4,370	0.174	0.147	0.215	0.127
Ind	4,370	0.377	0.364	0.429	0.074
SA	4,370	−3.820	−3.828	−3.660	0.235
EPU	4,370	375.238	339.572	72.900	244.365

to promote the green transformation of heavy-polluting enterprises.

5 Empirical results

5.1 Descriptive statistics

Table 1 reports the descriptive statistical analysis of the main variables, including explained, explanatory, and control variables. The maximum ESG is 3.531, the minimum is 3.344, and the mean value is 3.319, indicating that there is some difference in the degree of green transformation of heavy polluters. The maximum of the Central Environmental Protection Inspection is 1, the minimum is 0, and the mean is 0.457, indicating that the data before and after the inspections in the sample are more balanced. The statistical values of other variables are in line with those in the current relevant studies and are all within a reasonable range.

5.2 Benchmark results

Table 2 reports the benchmark results for green transformation and Central Environmental Protection Inspection based on Equation 1. A dual machine learning model is used to estimate the policy effect of the Central Environmental Protection Inspection on green transformation, in which the sample split ratio is 1:4, and a random forest algorithm is used to predict and solve the main

TABLE 2 Effect of CEPI on green transformation.

Variable	ESG		
	(1)	(2)	(3)
CEPI	0.41976***	0.01913*	0.02602**
	(66.66)	(1.72)	(2.22)
Constant	−0.00389	−0.00037	0.00096
	(-1.19)	(-0.14)	(0.39)
Controls		√	√
Firm-fixed effects	√	√	√
Year-fixed effects			√
Obs	4,370	4,370	4,370

regression and auxiliary regression, and the regression results are shown in Table 2. Column (1) adds firm-fixed effects with no control variables and year-fixed effects. The regression coefficient of the Central Environmental Protection Inspection (T = 66.66) is significantly positive at the 1% level. Column (2) adds firm-fixed effects and control variables with no year-fixed effects. The regression coefficient of the Central Environmental Protection Inspection (T = 1.72) is significantly positive at the 10% level. Column (3) adds firm-fixed effects, control variables, and year-fixed effects. The regression coefficient of the Central Environmental Protection Inspection (T = 2.22) is significantly positive at the 5% level. The above results show that the positive relationship between the Central Environmental Protection Inspection and green transformation of heavy-polluting enterprises is established regardless of controlling the individual-fixed effects, year-fixed effects, and control variables of enterprises. Furthermore, the Central Environmental Protection Inspection can effectively promote the green transformation of heavy-polluting enterprises, and the heavy-polluting enterprises can not only satisfactorily deliver a satisfactory answer to the Central Environmental Protection Inspection team and the local government in terms of environmental governance after the Central Environmental Protection Inspection but can also practically improve their fulfilment of their own social and governance responsibilities and promote the green transformation of the enterprises, which verifies the correctness of hypothesis H1.

5.3 Robustness analysis

5.3.1 Excluding the effects of other policies

Heavy-polluting enterprises will be affected by other policies related to environmental governance at the same time as they are subject to the Central Environmental Protection Inspection from 2016. Therefore, we separately consider the potential biases that may arise from the “overcapacity reduction policy” and the “pilot program for energy-use rights trading” in the research. (1) Considering that the 2016–2017“de-capacity” policy may have a greater impact on some heavy polluters, the de-capacity key industries are divided (according to the list of de-capacity key industries released by the State Council in 2016, six industries,

TABLE 3 Robustness test regression results.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Exclude "de-capacity" policy	Exclude "energy-use rights" trading	Kfolds = 6	Kfolds = 8	Interactive model	IV	Province–time interaction-fixed effects
CEPI	0.01956*	0.03119***	0.01954*	0.02201**	0.14615***	2.65556*	0.02602**
	(1.72)	(2.88)	(1.80)	(2.05)	(18.14)	(1.75)	(2.22)
Constant	0.00121	0.00087	0.00131	−0.00027		−0.00076	0.00096
	(0.47)	(0.32)	(0.53)	(-0.11)		(-0.11)	(0.39)
Controls	√	√	√	√	√	√	√
Firm-fixed effects	√	√	√	√	√	√	√
Year-fixed effects	√	√	√	√	√	√	√
Obs	4,152	3,379	4,370	4,370	4,370	4,023	4,370

namely, iron and steel, coal, cement, ships, electrolytic aluminium, and glass are the de-capacity key industries) with reference to the study by Zhao and Li (2021), and regressions are carried out by deleting this type of enterprises in the sample. Column (1) of Table 3 reports the regression results. The Central Environmental Protection Inspection regression coefficient of 0.019556 (T = 1.72) is significantly positive at the 10% level, consistent with the baseline regression results. (2) The pilot program for energy-use rights indicators began in 2016. At that time, the National Development and Reform Commission proposed to carry out pilot programs for energy-use rights in Zhejiang, Fujian, Henan, and Sichuan, fully utilising market-oriented means to force enterprises to save energy; reduce emissions; and transform, upgrade, and promote green and high-quality development of society. In order to eliminate the impact of the pilot program of energy trading, we removed the sample of enterprises located in the four major provinces of Zhejiang, Fujian, Henan, and Sichuan and re-regressed Equation 1. Column (2) of Table 3 reports the regression results. The Central Environmental Protection Inspection regression coefficient of 0.03119 (T = 2.88) is significantly positive at the 5% level, consistent with the baseline regression results.

5.3.2 Change in the sample segmentation ratio

We change the sample split ratio in the baseline regression. The sample split is changed from 1:4 to 1:5 and 1:7. The results of the above robustness tests are presented in column (3) and column (4) of Table 3, which show that after changing the sample split ratio from 1:4 in the baseline regression to 1:5 (Kfolds = 6) and 1:7 (Kfolds = 8), the regression coefficients of the Central Environmental Protection Inspection are 0.01954 (T-value = 1.80) and 0.02201 (T-value = 2.05), which are significantly positive at the 10% and 5% levels, respectively.

5.3.3 Replacement of the interactive model

In benchmark regression, a partial linear model was constructed based on dual machine learning for analysis, and there is certain subjectivity in the model form setting. We use dual machine learning to construct a more general interactive model and explore the impact of model settings on the conclusions of this paper. Based on Equations 5, 6, the changes in the main regression and auxiliary regression used for analysis are as follows:

$$ESG_{i,t} = g\left(CEPI_{i,t}, X_{i,t}\right) + \varepsilon_{i,t}, \tag{5}$$

$$CEPI_{i,t} = m\left(X_{i,t}\right) + V_{i,t}. \tag{6}$$

The results of the above robustness tests are presented in column (5) of Table 3, which shows that after replacing the research model *i* with an interactive model, the regression coefficient of the Central Environmental Protection Inspection is 0.14615 (T-value = 18.14), which is significantly positive at the 1% level.

5.3.4 Instrumental variable method

We attempt to take into account the factors affecting the green transition as much as possible, but due to data limitations, there are inevitably omitted variables. Regression encounters endogeneity problems, which can be effectively mitigated by the instrumental variable approach. We construct a partially linear instrumental variable model for dual machine learning referring to the study by Chernozhukov et al. (2018). Based on Equations 7, 8, the specific setup is as follows:

$$ESG_{i,t} = \beta_0 CEPI_{i,t} + g\left(X_{i,t}\right) + \varepsilon_{i,t}, \tag{7}$$

$$IV_{i,t} = m\left(X_{i,t}\right) + V_{i,t}. \tag{8}$$

IV is the instrumental variable for the Central Environmental Protection Inspection. To mitigate the endogeneity problem, we need to find instrumental variables that do not directly affect the explained variable (green transition) but are highly correlated with the endogenous variable (CEPI). We use the global 0.75° × 0.75° raster meteorological data from the ERA-Interim database to construct province-level air mobility coefficient indicators as instrumental variables for the Central Environmental Protection Inspection referring to the study by Hering and Poncet (2014), the air flow coefficient is a determinant of the pollution diffusion rate,

and the smaller the ventilation coefficient of two places with the same level of pollution, the more serious the air pollution and the more inclined to adopt a stricter level of environmental regulation, thus fulfilling the assumption that the instrumental variables are highly correlated with the endogenous variables. In addition, both wind speed and the height of the atmospheric boundary layer are determined by complex meteorological systems and geographic conditions, satisfying the assumption of exogeneity of instrumental variables (Chen and Chen, 2018). The results of the above robustness tests are given in Table 3. The regression coefficient of the Central Environmental Protection Inspection after double machine learning regression using the instrumental variable in column (6) of Table 3 is 2.65556 (T-value = 1.75), which is significantly positive at the 10% level. All of the above results are consistent with the benchmark regression results, indicating that the promotion effect of the Central Environmental Protection Inspection on the green transformation of heavy polluters still holds after changing the sample splitting ratio, replacing the machine learning model and solving the endogeneity problem distress.

5.3.5 Province–time interaction-fixed effects

Provinces are very important administrative nodes in the governance structure of the Chinese government, and firms under the same province tend to be similar in terms of the policy environment, location characteristics, and history and culture. Therefore, we add province–time interaction-fixed effects to the baseline regression to control for the effects of different provinces over time. The regression results are shown in column (7) of Table 3. According to the regression results, after considering the correlation between the characteristics of enterprises in the same province, the effect of the Central Environmental Protection Inspection on the green transformation of heavy polluters is still significantly positive at the 10% level, and the original conclusion is still valid.

5.3.6 Event study

Running overlapping difference in differences (DIDs) based on TWFE may result in significant estimation errors (Goodman-Bacon, 2021). Sun and Abraham (2021) proposed correcting the dynamic effect estimation bias of DID by calculating the group period average treatment effect. This method is suitable for situations where the sample size is sufficient, there is no policy of "withdrawal," and there are no "individuals who have never received processing." Due to the fact that the central environmental inspection covers all provinces, it is not applicable to traditional DID. Therefore, this study adopts the event study method proposed by Sun and Abraham (2021), taking the first inspection as the research event, selecting the year before the inspection as the base period, and selecting the sample of enterprises that received inspection in the last year before the inspection as the control group. Based on annual data, the dynamic impact of inspections in different years is identified and estimated. Figure 2 shows the above estimation results, with the horizontal axis ranging from −5 to −2, representing the fifth, fourth, third, and second years before the first inspection, respectively; 0 representing the year of inspection; and 1–5 representing the first, second, third, fourth, and fifth years after the first inspection, respectively. As shown in Figure 2, there was no significant difference in ESG performance between the treatment group and the control group companies before the inspection. After the inspection, the ESG performance began to gradually improve. The above empirical results indicate that the Central Environmental Inspection can effectively improve the ESG performance of heavy-polluting enterprises, further supporting the reliability of the research conclusions in this study.

5.3.7 Placebo test

To verify whether the research conclusions in the previous section are random, this study randomly assigns a year of first inspection to each company and conducts DID testing based on this. Under the assumption of placebo testing, the Central Environmental Protection Inspection should not have a significant impact on the ESG performance of heavy-polluting enterprises. We conducted 500 random samplings using the above method and obtained the estimated coefficients and p-values of the Central Environmental Protection Inspection through regression analysis, which are given in Figure 3. Figure 3 shows the sampling results of randomly assigning the first inspection time. It can be observed that after randomly assigning the first inspection year, the regression coefficient follows a normal distribution with a mean of 0. However, the estimated coefficient of the Central Environmental Protection Inspection in column (3) of Table 2 is 0.02602, which is significantly different from the mean. Moreover, in the placebo test, the majority of p-values were greater than 0.100, indicating that supervision did not have a significant impact on ESG performance.

5.4 Moderating mechanism analysis

The above results have already proved that the Central Environmental Protection Inspection can significantly promote the green transformation of heavy-polluting enterprises, and we are more concerned about how the Central Environmental Protection Inspection can promote heavy-polluting enterprises to realise all-round green transformation based on the ESG perspective. According to the previous argument, under the ESG perspective, heavy polluters need to take environmental responsibility, social responsibility, and governance responsibility to realise green transformation and mainly implement the transformation through the paths of improving the green innovation capability, safeguarding the rights and interests of the upstream and downstream supply chain, and enhancing the diligence of governance.

For this reason, we use the causal mediation effect of double machine learning to analyse referring to the study by Farbmacher et al. (2022). The specific test results are shown in Table 4. It can be found that the total effect is significantly positive under different mediating paths, which does not change the conclusion that the Central Environmental Protection Inspection can promote the green transformation of heavy-polluting enterprises.

5.4.1 Improving the green innovation capability

The total effect of the mediation effect test for green invention patents is significantly positive, and the indirect effect is positive in both the treatment and the control groups. In addition, after removing the indirect path of green innovation, the direct effect of the treatment and control groups is still positive, indicating that

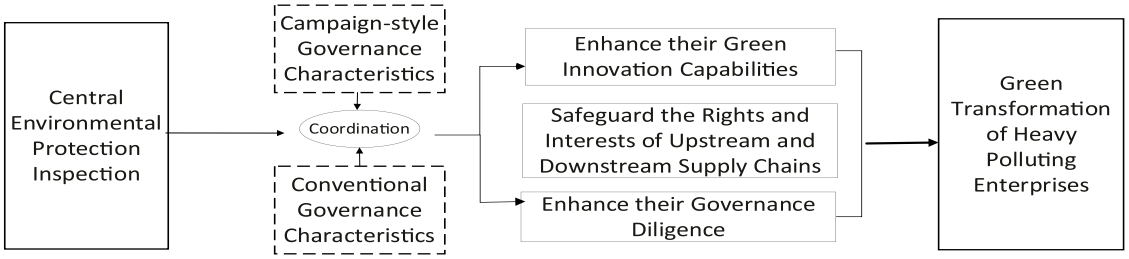

FIGURE 1
Role mechanism of the Central Environmental Protection Inspection in promoting the green transformation of heavy-polluting enterprises.

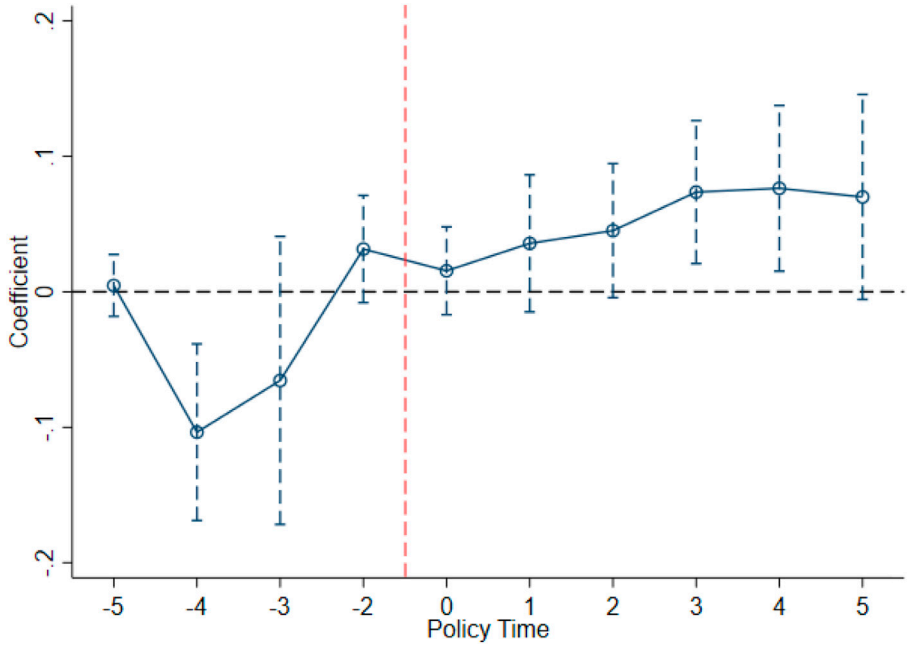

FIGURE 2
Dynamic impact of the Central Environmental Protection Inspection.

the Central Environmental Protection Inspection prompts enterprises to improve the level of green innovation to promote green transformation, which verifies hypothesis H2a. In the face of increasing pressure on environmental governance, enterprises must rely on green innovation to reform clean technology, improve production equipment, and improve the means of sewage disposal in order to achieve environmental protection from the source. In this way, they can realise environmental protection management from the source, improve the efficiency of the end discharge, reduce environmental pollution, and promote the sustainable development of heavy-polluting enterprises.

5.4.2 Safeguarding the rights and interests of upstream and downstream supply chains

The total effect of the mediation effect test for green invention patents is significantly positive, and the indirect effect is positive in both the treatment and control groups. In addition, after removing the indirect path of safeguarding the rights and interests of upstream and downstream supply chains, the direct effect of the treatment group and the control group is still positive, indicating that the Central Environmental Protection Inspection encourages enterprises to safeguard the rights and interests of upstream and downstream supply chains to promote the green transformation, which verifies hypothesis H2b. The Central Environmental Protection Inspection encourages the public to participate in environmental protection governance by providing information about the environmental governance of enterprises to the inspection team through phone calls or letters. Based on this, heavy-polluting enterprises need to gain the trust of the public by assuming social responsibility, maintain their good social image, and avoid as much as possible being subjected to bad reports that trigger stricter environmental inspections. Maintaining the rights and interests of the supply chain and establishing good relationships with suppliers and customers can not only provide economic support for the sustainable development of enterprises but also beautify the corporate image and play a solid role in guaranteeing the green transformation of enterprises.

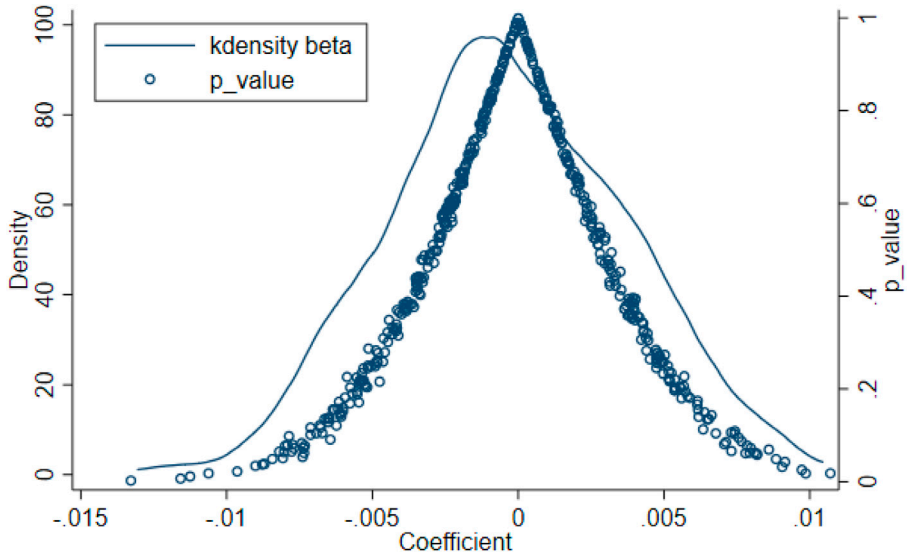

FIGURE 3
Placebo test.

TABLE 4 Moderating mechanism test regression results.

Variable	Total effect	Treat group		Control group	
		Direct effect	Indirect effect	Direct effect	Indirect effect
GIP	0.15823***	0.15198***	0.00328***	0.15495***	0.00624***
SCCR	0.10851***	0.12238***	−0.00639	0.11490***	−0.01387***
COMM	0.15680***	0.13800***	0.14000***	0.01680***	0.01880***

5.4.3 Enhancing the diligence of governance

The total effect of the mediation effect test for governance diligence is significantly positive, and the indirect effect in both the treatment group and the control group is positive. In addition, after removing the indirect path of enhancing governance diligence, the direct effect in the treatment group and the control group is still positive, indicating that the Central Environmental Protection Inspection prompts enterprises to enhance governance diligence to promote the green transformation, which verifies hypothesis H2c. The Central Environmental Protection Inspection promotes the green transformation of the heavy-polluting enterprises. The process of promoting the green transformation of heavy-polluting enterprises by the Central Environmental Protection Inspection requires enterprises to increase the investment in governance, improve the efficiency of governance, and provide internal institutional support to cope with the normalised Central Environmental Protection Inspection.

5.5 Heterogeneity analysis

In the above section, we verify the effect of the Central Environmental Protection Inspection on green transformation in various ways. Here, we analyse whether the Central Environmental Protection Inspection has heterogeneous effects on the green transformation of different firms. We analyse heterogeneity at the macro-level and micro-level. The macro-level perspective encompasses the geographic area of the Central Environmental Protection Inspection and the intensity of environmental regulation in the province where the firm is located. The micro-level perspective encompasses the enterprise asset size and degree of digital transformation. Table 5 shows that most variables have significant differences between groups, indicating that a comparison between groups is feasible.

5.5.1 Macro-level heterogeneity analysis: geographic area of the CEPI

There is a phenomenon of unbalanced regional development in China, with a large geographical span and uneven levels of development. We divide the sample into eastern, central, and western regions to analyse the heterogeneity effect of companies with different Central Environmental Protection Inspection areas referring to the study by Zhao et al. (2022). Column (1) of Table 5 shows that the relationship between the Central Environmental Protection Inspection and green transformation is insignificant in eastern firms. Column (2) of Table 5 shows that the coefficient in the sample from the central and western regions is significant. This may be due to the fact that the eastern region is more developed, the local

TABLE 5 Heterogeneous effect test regression results.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	ESG								
	CEPI area		Intensity of environmental regulation		Enterprise asset size		Enterprise degree of digital transformation		
	Eastern regions	Central and western regions	High	Low	Large	Medium and small	High	Medium	Low
CEPI	0.00844	0.02934*	0.02783*	−0.00123	0.03233**	0.00889	0.04057*	0.01207	−0.01304
	(0.56)	(1.90)	(1.83)	(-0.06)	(1.97)	(0.64)	(1.83)	(0.43)	(-0.78)
Constant	0.00017	−0.00112	0.00037	0.00283	0.00145	−0.00256	0.00255	0.00029	0.00069
	(0.05)	(-0.32)	(0.10)	(0.81)	(0.41)	(-0.72)	(0.55)	(0.05)	(0.19)
Controls	√	√	√	√	√	√	√	√	√
Firm-fixed effects	√	√	√	√	√	√	√	√	√
Year-fixed effects	√	√	√	√	√	√	√	√	√
Obs	2,274	2096	2087	2,258	2,185	2,185	1,280	916	2,174

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enterprises themselves have a stronger concept of green transformation, and the Central Environmental Protection Inspections play more of a daily supervision rather than a punitive role. However, the transformation of heavy-polluting enterprises in the central and western regions is slow, and most of them are still based on the "high-energy consumption, high-pollution" approach to profitability, so the Central Environmental Protection Inspection can play a strong deterrent role, urging them to quickly transform and realise green transformation.

5.5.2 Macro-level heterogeneity analysis: intensity of environmental regulation

When the Central Environmental Protection Inspection team is stationed in a province, it will receive calls and letters from the public, attach great importance to the investigation and handling of problems reported by the public in letters and visits, and hand over cases to the localities under inspection, requiring them to make corrections while supervising. The greater the intensity of local environmental regulation, the more efficient they are in dealing with inspection issues, and the better the subsequent improvements. We measure the intensity of local environmental regulation by "investment in industrial pollution control/industrial added value" referring to the study by Fan and Mu (2017). Column (3) of Table 5 shows that the relationship between the Central Environmental Protection Inspection and green transformation is significant in firms with a high intensity of local environmental regulation. Column (4) of Table 5 shows that the relationship between the Central Environmental Protection Inspection and green transformation is insignificant in firms with a low intensity of local environmental regulation. It shows that local environmental regulation and the Central Environmental Protection Inspection can form an effective environmental supervision synergy, which creates a complementary role in promoting the green transformation process of heavy polluters.

5.5.3 Micro-level heterogeneity analysis: enterprise asset size

Firms with larger assets have their own advantages such as high capital intensity, while smaller firms lack well-developed operational processes and management mechanisms (Zhao and Li, 2021). We divide all samples into large, medium, and small enterprises based on the three quartiles of total enterprise assets referring to the study by Zhao and Li (2021). Column (5) of Table 5 shows that the relationship between the Central Environmental Protection Inspection and green transformation is significant in firms with a large enterprise asset size. Column (6) of Table 5 shows that the relationship between the Central Environmental Protection Inspection and green transformation is insignificant in firms with a medium and small enterprise asset size. It suggests that firms with larger assets have more basis and strength to promote green transformation in the process of Central Environmental Protection Inspection.

5.5.4 Micro-level heterogeneity analysis: enterprise degree of digital transformation

Currently entering the era of digital economy, digitalisation is becoming the leading force driving the transformation of enterprises, and the full use of digital technology and platforms can promote enterprise optimisation of resource allocation and scientific decision-making. We divide all samples into high, medium, and low enterprises based on the three quartiles of the digital transformation degree. Column (7) of Table 5 shows that the relationship between the Central Environmental Protection Inspection and green transformation is significant in firms with a high digital transformation degree. Column (8) of Table 5 shows that the relationship between the Central Environmental Protection Inspection and green transformation is insignificant in firms with a medium digital transformation degree. Column (9) of Table 5 shows that the relationship between the Central Environmental Protection Inspection and green transformation is insignificant in firms with a small digital transformation degree. This is most likely because in enterprises with a higher degree of digitisation, they are able to respond more efficiently to what is required by the inspectors and can also help themselves quickly check the shortcomings and improve their own deficiencies in green transformation.

5.6 Further study: the impact of spillover effects of the green transformation

According to the previous analysis, the Central Environmental Protection Inspection will promote green transformation by prompting heavy-polluting firms to enhance their green innovation capabilities, safeguard the rights of upstream and downstream supply chain players, and enhance governance diligence, thereby assuming their environmental, social, and governance responsibilities. However, due to the strong competitive interactions in the Chinese market, the business decisions of other enterprises will also affect their own business decisions. Thus, we further explore the impact of the Central Environmental Protection Inspection on the green transformation of heavy polluters within and across industries from the perspective of industry spillovers. Since firms that are the first to embark on green transformation have certain technological advantages, this may widen the gap between their green transformation and that of lagging firms. We calculated the green transition degree indicators within (ESG_in) and between (ESG_ex) industries based on the regions and industries in which the firms are located. Then, we run conventional multiple linear regressions after controlling for individual firm-fixed effects and year-fixed effects.

ESG_in is measured by the average value of the degree of green transformation in the same region, industry, and year, except for this enterprise. ESG_ex is measured using the mean value of the degree of green transformation in the same region, year, and other industries, except for this industry. In order to examine the impact of green transition spillovers, we introduce the cross terms of CEPI, ESG_in, and ESG_ex, and the corresponding estimation results are shown in columns (1) and (2) of Table 6. The results show that the coefficient of CEPI × ESG_in is significantly positive, while the coefficient of CEPI × ESG_ex is insignificant. This indicates that there is a spillover effect of green transformation of other enterprises within the industry, which will further strengthen the impact of the Central Environmental Protection Inspection on the green transformation of enterprises, but the spillover effect of green transformation between industries is not significant.

TABLE 6 Green transition spillover test results.

Variable	(1)	(2)	(3)	(4)
	ESG			
	Spillover within industries	Spillover between industries	Adjusted by operating revenues	Adjusted by total assets
CEPI	−0.42813**	0.24996	0.00174	0.00387
	(−2.22)	(0.71)	(0.13)	(0.31)
CEPI*ESG_in	0.12709**			
	(2.23)			
ESG_in	−0.03539			
	(−0.87)			
CEPI*ESG_ex		−0.07093	0.85002	0.96762
		(−0.68)	(0.73)	(0.58)
ESG_ex		0.07931	−2.59514	−4.28824*
		(1.07)	(-1.47)	(-1.68)
LNSIZE	−0.00765	0.01259	0.00902	0.00779
	(−0.45)	(0.87)	(0.62)	(0.53)
LEV	−0.05020	−0.07918*	−0.08851**	−0.08887**
	(-0.93)	(-1.77)	(-1.98)	(-1.98)
ROA	−0.08066	−0.07106	−0.06563	−0.05906
	(−0.76)	(−0.79)	(−0.74)	(−0.66)
JIANREN	0.01664	0.00560	0.00628	0.00632
	(1.17)	(0.45)	(0.51)	(0.51)
GROWTH	−0.00606	−0.01368	−0.01108	−0.01091
	(-0.41)	(-1.09)	(-0.86)	(-0.85)
TOP	−0.00551	−0.02811	−0.03389	−0.03448
	(−0.06)	(−0.38)	(−0.46)	(−0.47)
PAY	0.03782***	0.04652***	0.04451***	0.04422***
	(3.32)	(4.72)	(4.50)	(4.47)
EPS	0.01454	0.01259	0.01138	0.01123
	(1.43)	(1.58)	(1.43)	(1.41)
MB	0.00373	−0.02661	−0.02407	−0.02427
	(0.11)	(-0.93)	(-0.85)	(-0.85)
BOARD	−0.00295	0.00030	−0.00173	−0.00151
	(-0.18)	(0.02)	(-0.11)	(-0.10)
TBQ	−0.00072	0.00153	0.00190	0.00179
	(−0.15)	(0.37)	(0.46)	(0.43)
CWYS	−0.03190	−0.12422	−0.15189	−0.15477
	(−0.14)	(−0.60)	(−0.75)	(−0.76)
TAT	0.05335	0.03546	0.04859	0.04869
	(1.42)	(0.84)	(1.12)	(1.13)

(Continued on following page)

TABLE 6 (*Continued*) Green transition spillover test results.

Variable	(1)	(2)	(3)	(4)
	ESG			
	Spillover within industries	Spillover between industries	Adjusted by operating revenues	Adjusted by total assets
IND	0.09405*	0.10236**	0.10152**	0.09990**
	(1.86)	(2.06)	(2.05)	(2.02)
SA	0.43141***	0.36316***	0.37472***	0.38004***
	(4.65)	(3.99)	(4.12)	(4.20)
EPU	0.00147***	0.00131***	0.00137***	0.00137***
	(14.22)	(11.84)	(16.45)	(16.12)
Constant	4.07323***	2.96839***	3.38014***	3.43759***
	(7.17)	(5.45)	(6.50)	(6.66)
Firm-fixed effects	√	√	√	√
Year-fixed effects	√	√	√	√
Obs	2,845	4,356	4,370	4,370
R^2 within	0.782	0.782	0.782	0.783

In order to avoid the inter-industry green transition spillovers calculated by the industry aggregation approach leading to the mutual cancellation of spillovers in different directions, we further constructed ESG_ex by referring to the study by Javorcik (2004), that is, adjusting ESG_ex using the operating revenues and total assets of the industry as the weights. The calculation involves the 2017 version of the input–output matrix, and the corresponding regression estimates are shown in columns (3) and (4) of Table 6, respectively. The results show that after considering the input–output relationship between industries, there is still no obvious spillover effect of green transformation between industries.

6 Discussion

In order to clarify whether and how environmental regulations can promote corporate green transformation, we take central environmental supervision as the starting point and conduct research from the perspective of ESG. The study found that the Central Environmental Protection Inspection can indeed improve corporate ESG performance and promote corporate green transformation. Despite obtaining the expected conclusion, there are still some issues that need to be discussed in conjunction with existing theories and conclusions.

(1) This study found that the Central Environmental Protection Inspection can help companies improve their ESG performance and promote their green transformation. This is similar to the research findings that show that environmental regulations can effectively promote corporate environmental performance (Martínez-Zarzoso et al., 2019; Yu et al., 2019). Second, most existing research identifies the Central Environmental Protection Inspection as campaign-style environmental governance (Ma and Zhao, 2023). However, we start with the theoretical analysis of the characteristics of both campaign-style and conventional governance of the Central Environmental Protection Inspection and comprehensively analyse the characteristics of the Central Environmental Protection Inspection. This study recognises the environmental governance role of the Central Environmental Protection Inspection, which is also an extension and expansion of existing research. In addition, according to the theory of resource dependence, enterprises and the surrounding environment are interdependent. Although the Central Environmental Protection Inspection encourages enterprises to take environmental responsibility, it will also affect stakeholders inside and outside the enterprise. Huang (2021) also pointed out that the environmental responsibility, social responsibility, and governance responsibility of enterprises are interrelated. This study found that the Central Environmental Protection Inspection can promote the overall ESG level of enterprises, fully proving the correctness of the above theories and judgements. The fact shows that in order to better assume the environmental responsibility and cope with the gradually normalised supervision mechanism, enterprises have the motivation to improve their performance in social responsibility and governance responsibility.

(2) The Central Environmental Inspection encourages enterprises to take on environmental, social, and

governance responsibilities, thereby improving their ESG performance and achieving green transformation. The specific paths are to enhance green innovation capabilities, safeguard the rights and interests of upstream and downstream entities in the supply chain, and strengthen governance diligence. From the perspective of environmental responsibility, Porter's hypothesis suggests that reasonable environmental regulations can help companies improve their competitiveness (Porter and Linde, 1995). Our research found that companies respond to inspections by strengthening their green innovation capabilities, thereby achieving green transformation and supporting the applicability of Porter's hypothesis in the Chinese context. From the perspective of social responsibility, stakeholder theory holds that companies care about the interests of stakeholders, and ultimately, all stakeholders will provide feedback to the company, ultimately achieving sustainable development (Freeman, 1984). This study found that enterprises have improved the performance stability and resource allocation efficiency by maintaining the rights and interests of upstream and downstream entities in the supply chain, providing a material guarantee basis and public trust for responding to central environmental inspections, and adding new evidence to the stakeholder theory. From the perspective of governance responsibility, corporate executives have strengthened their diligence in internal governance in response to inspections, promoting internal innovation within the company. This indicates that to this day, the agency theory can still effectively explain corporate behaviour.

(3) With the relocation of inspection areas to the west, strengthening of local environmental regulations, and increasing asset size and digitalization of enterprises, the impact of the Central Environmental Protection Inspection on the green transformation of heavy-polluting enterprises becomes greater. Zhao and Li (2021) found that the impact of this system on the transformation and upgrading of manufacturing enterprises is more significant in eastern provinces and enterprises with larger asset scales. Similar to the above conclusion, the grouping study on asset size in this study proves that in the process of Central Environmental Protection Inspection, enterprises with larger asset sizes have more foundation and strength to promote green transformation. However, in terms of the study of inspection areas, the findings of this study are contrary to the conclusions obtained by Zhao et al. This may be because their research period was from 2012 to 2018 and based on a multi-period DID model for testing. They failed to comprehensively examine the role of the Central Environmental Protection Inspection over a longer period of time or effectively eliminate model bias. The research on the strength of environmental regulation in this study is similar to previous studies, both of which prove that the greater the strength of environmental regulation, the more beneficial it is for the sustainable development of enterprises (Yu et al., 2019; Martínez-Zarzoso et al., 2019). Regarding digital transformation, the existing literature suggests that it can not only enable enterprises to acquire and allocate resources more efficiently and reasonably but also provide strong impetus for the healthy development of the environment (He and Su, 2022; Cao et al., 2023). The conclusion of this article is similar to that of existing research, which found that the higher the degree of digital transformation in enterprises, the stronger the effect of the Central Environmental Protection Inspection on green transformation.

(4) Compared with other industries, the spillover effect of green transformation within the industry has enhanced the positive impact of the Central Environmental Protection Inspection on the green transformation of enterprises. This conclusion is similar to that obtained by Zhu et al. (2023), who found that the spillover effect within industries is more significant, while it is not significant between industries. This is because companies that take the lead in green transformation can provide transformation models and references for other companies in the industry, which is beneficial for peer companies to better respond to the Central Environmental Protection Inspection. However, there are differences in technical barriers, industry standards, and other factors among enterprises in different industries, and the focus of the Central Environmental Protection Inspection may also vary due to industry differences. Therefore, the impact of inter-industry green transformation on the relationship between the Central Environmental Protection Inspection and corporate green transformation is relatively weak.

7 Conclusion and future research directions

7.1 Conclusion and recommendation

In order to clarify how the command-based environmental policy can promote the green transformation of heavy polluters in China, we use a dual machine learning approach to test the impact of the first round of the Central Environmental Protection Inspection on the green transformation of heavy polluters listed in Shanghai and Shenzhen A-shares from 2011 to 2022 based on the ESG perspective. The following conclusions were obtained: (1) the Central Environmental Protection Inspection can promote the green transformation of heavy-polluting firms, and the conclusions still hold after the robustness test of removing other policy impacts, resetting the dual machine model, applying the instrumental variable method, and controlling for province–time-fixed effects, which shows that the Central Environmental Protection Inspection, an innovation in environmental governance, can create a favourable space for the green transformation of firms; (2) the mechanism test shows that the Central Environmental Protection Inspection can prompt enterprises to undertake environmental responsibility, social responsibility, and governance responsibility through enhancing green innovation ability, safeguarding the rights and interests of upstream and downstream subjects of suppliers, and enhancing the diligence of governance and then promote the green transformation of enterprises; (3) the heterogeneity test found that with the westward migration of the Central Environmental Protection Inspection region and the increase in local

environmental regulation intensity at the macro-level policy, as well as the increase in digitisation and asset size at the micro-level enterprise, the Central Environmental Protection Inspection plays a more significant role in promoting the green transformation of heavy-polluting enterprises; and (4) further research finds that there is a spillover effect of green transformation of other enterprises in the industry, which further strengthens the impact of the Central Environmental Protection Inspection on the green transformation of enterprises, but the spillover effect of green transformation between industries is not significant.

The findings of this study help environmental governance actors, such as enterprises, the Central Environmental Protection Inspection, and local environmental protection agencies, to understand how the Central Environmental Protection Inspection can promote the green transformation of enterprises based on taking ESG responsibilities. The article also provides the following insights for enterprises and Central Environmental Protection Inspection to facilitate green transformation.

In terms of the construction of the Central Environmental Protection Inspection system, it is necessary to continuously promote the normalisation of the Central Environmental Protection Inspection and deepen and improve the Central Environmental Inspection system. First, the Central Environmental Protection department should promote the transformation of the functions of local inspection bureaus, improve the environmental supervision network, and prepare for the normalisation of Central Environmental Protection Inspection, laying a foundation for the implementation of the Central Environmental Protection Inspection in local areas. Second, it is recommended that the Central Environmental Protection Inspection pay attention to ESG-related issues of enterprises. In addition to considering the environmental responsibility of enterprises, it should also refine social responsibilities such as community service, charity, and supply chain relationships, as well as governance responsibilities such as internal system construction and compensation incentives, to further urge enterprises to participate in ESG. Third, the Central Environmental Protection Inspection needs to fully consider the region and industry in which the enterprise is located. On one hand, for heavy-polluting enterprises in the central and western regions with weak environmental regulations, the Central Environmental Protection Inspection should increase its supervision efforts to help extensive development enterprises deeply understand their own environmental behaviour blind spots and deepen their green transformation. On the other hand, when facing enterprises with lower levels of digital transformation and smaller asset scales, the Central Environmental Protection Inspection team needs to invest more time and energy to make up for the lack of resources caused by these inherent deficiencies and help enterprises find broader channels for green transformation. In addition, the Central Environmental Protection Inspection should also pay attention to identifying the differences in green transformation among enterprises in different industries, clarifying the commonalities of green transformation among enterprises in the same industry, and improving the pertinence of inspections. Finally, the Central Environmental Protection Inspection should strengthen the cooperation with local governments, optimise inspection processes, and improve the inspection efficiency and quality.

From the perspective of local governments, they should strengthen their response to higher-level environmental protection departments, such as the Central Environmental Protection Inspection, and improve the efficiency of cooperation between central and local environmental protection departments. First, local governments should improve the communication process with the Central Environmental Protection Inspection working group, provide necessary information and personnel to the inspection group in a timely manner, and provide corresponding supporting support. Second, local governments should urge enterprises to promptly identify and rectify deficiencies based on the inspection and rectification opinions and submit and publicly disclose the rectification results as soon as possible. Third, local governments should strengthen environmental regulation efforts and form a good complementarity with the Central Environmental Protection Inspection. Local governments in central and western provinces should follow the example of eastern provinces and eliminate the differences in the effectiveness of the Central Environmental Protection Inspection in different provinces. At the same time, special attention should be paid to enterprises with smaller asset scales and weaker digital transformation, providing operational convenience for such enterprises and helping them achieve green transformation through the Central Environmental Protection Inspection. Fourth, a stricter regional environmental leadership performance-assessment mechanism and accountability mechanism should be established to enhance the environmental awareness of officials and strengthen accountability for ineffective environmental protection work in order to ensure the effective implementation of policies.

From the perspective of enterprises, they can use the Central Environmental Protection Inspection to conduct self-examination and self-correction; comprehensively examine the current status of responsibility fulfilment in environmental, social, and governance aspects; and achieve green transformation. First, enterprises should vigorously promote green innovation, gain core competitiveness in the fierce market, and obtain the driving force for sustainable development from a technological perspective. Second, enterprises should proactively maintain relationships with suppliers and customers, enhance the supply chain value, improve performance stability, gain social trust, and lay an economic foundation for green transformation. Third, enterprises should establish a sound corporate governance system, construct development plans from the perspective of green transformation, select executives with strong or experienced green transformation concepts, and add green transformation assessment mechanisms.

7.2 Limitations and further research

This study has the following limitations.

First, limited by the fact that the Central Environmental Protection Inspection can only obtain data at the provincial level, it is impossible to determine whether the inspected enterprises during the Central Environmental Protection Inspection process are listed enterprises, as well as the intensity and breadth of the inspection. Therefore, this article can only choose to use the DID model to conduct policy effect testing from the provincial level. If the

Environmental Protection Bureau can publicly disclose enterprise-level data in the future, subsequent research can use such data to deepen the depth of environmental inspection-related research.

Second, the combined policy effects of the Central Environmental Protection Inspection and other types of environmental regulations can also be studied, and the effectiveness of public participation in environmental governance during the Central Environmental Protection Inspection process can be explored in depth.

Data availability statement

The datasets presented in this article are not readily available because the research data will also be used for subsequent research, and it is currently inconvenient to share the data with other researchers. Requests to access the datasets should be directed to Wanting Wang, wwtsxzy@foxmail.com.

Author contributions

WW: data curation, software, writing–original draft, and writing–review and editing. CM: supervision, validation, and writing–review and editing. SL: visualisation, and writing–review and editing.

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Conflict of interest

Author CM was employed by China Development Bank Shanxi Branch.

Author SL was employed by State Grid Shanxi Electric Power Company Yangquan Power Supply Company.

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