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The full title:
Can environmental information disclosure spur corporate green innovation?

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Can environmental information disclosure spur corporate green innovation?

Abstract: How can the disclosure of environmental information (EID) stimulate corporate green innovation (CGI)? This research challenges the prevailing assumption that environmental regulations impact CGI by influencing corporate compliance costs. Instead, it offers a fresh theoretical framework to explain how EID affects CGI. This study combines signal theory and resource dependence theory to develop a moderated mediation model, illustrating how EID reduces information asymmetry and alleviates corporate financial constraints (CFC). To test these hypotheses, this study utilized data from A-share listed companies spanning the period 2004 to 2017. This study considered the year 2009 as a crucial point of analysis, marking the period before and after the implementation of China's first EID policy in 2008. This study employed a Difference-in-Differences (DID) model. The results reveal that EID has a positive impact on CGI by mitigating CFC, with non-state-owned enterprises (non-SOEs) exhibiting a more pronounced mediating effect. These findings remain robust even when the parallel trend assumption was tested to eliminate interference from other factors. This study unveils the mechanism through which voluntary environmental regulation, represented by EID, influences CGI by mitigating information asymmetry and alleviating CFC. These results deviate from the predictions of compliance cost theory and Porter's hypothesis regarding the impact of traditional environmental regulations on CGI, providing a fresh perspective on the role of voluntary environmental regulation in driving CGI.

Keywords: environmental information disclosure; corporate green innovation; information asymmetry; corporate financial constraint; signal theory; resource dependence theory.

1. Introduction

Green innovation bridges ecological construction and economic growth (Sun et al., 2022) and leads to growth prospects and a competitive edge (Przychodzen et al., 2020). Some scholars believe that corporate green innovation (CGI) is the foundation and key to realizing a carbon neutrality target (Muhammad et al., 2022). However, CGI has significant externalities and high costs (Zhang et al., 2023); thus, companies lack the motivation to initiate CGI spontaneously (Li et al., 2022a). Environmental policy instruments can be classified into traditional environmental regulations and voluntary environmental regulations, whereas traditional environmental regulations include market-oriented and command-and-control. There is a temporary improvement in pollution quality with traditional environmental regulations (Lu et al., 2020). Environmental information disclosure (EID) represents a voluntary environmental policy that encourages firms to take steps to preserve the environment (Zhou et al., 2022).

Studies conducted in the past have primarily examined the effects of command-and-control and

market-oriented policies on CGI (Li et al., 2023a). Some scholars have proposed the compliance cost theory, arguing that environmental regulation inhibits CGI by adding additional burdens (Gollop & Robert, 1983). Many studies have provided evidence to support the compliance cost theory (Stucki et al., 2018; Jiang et al., 2021; Stucki et al., 2021). Nevertheless, in terms of the "Porter Hypothesis" (Porter & Linde, 1995), other scholars contend that flexible and reasonable environmental regulations can offset all or part of the compliance costs and thus effectively stimulate corporate willingness toward green innovation. As proposed by Porter and Linde (1995), the Porter hypothesis holds that suitable environmental regulation will stimulate firms to innovate and compensate for increased costs, which has been in-depth studied in research (Wang et al., 2022). Compared with command-and-control environmental regulations, market-based and voluntary environmental regulations have greater incentives for corporate innovation (Cai et al., 2020; Su et al., 2020). Furthermore, environmental regulation and green innovation have a U-shaped relationship according to some researchers (Ouyang et al., 2020), while others have found an inverted U-shaped relationship (Shang et al., 2021). Hence, there is no consensus in the current studies on the influence of environmental regulations on CGI (Shao et al., 2020).

The role of EID as a voluntary environmental regulation instrument has attracted growing attention over the past few years (Li et al., 2022b). Previous studies have focused on evaluating and analyzing its effectiveness, such as its contribution to reducing emissions (Tian et al., 2016; Liu et al., 2020), decreasing urban air pollution (Yang et al., 2018; Feng et al., 2021), and bettering government environmental governance (Li et al., 2018a). Li et al. (2022a) found that EID can spur green innovation through a local environment. However, under the same local environment, the CGIs of different corporations may still differ significantly. What is the impact of EID on intrinsic corporate motivation to engage in CGI? Corporate internal mechanisms between EID and CGI are still unexplored.

This study offers a new theoretical perspective on the relevance of EID to CGI by considering the mediating effect of corporate financial constraint (CFC), which is distinct from the external and regional perspectives of previous studies and from compliance cost theory and the Porter hypothesis. This study challenges the dominant assumption that environmental regulations affect CGI by influencing corporate compliance costs. By emphasizing the influence of EID on decreasing information asymmetry and weakening the CFC, this study reveals the hidden mechanisms of the power of voluntary environmental regulation represented by EID on CGI. Previous studies have largely focused on how voluntary environmental regulations (e.g., EID) affect regional environmental pollution, and few studies have analyzed the implementation effects of voluntary environmental regulations (e.g., EID) from the perspective of corporate internal factors. This study examines the internal impact mechanism between EID and CGI by combining signaling and resource dependence theories and proposing CFC as a possible mediating channel.

2. Research background

2.1. Institutional background

China's Ministry of Environmental Protection issued the "*Measures for the Disclosure of Environmental Information (Trial)*" in 2008, governing how environmental protection administrative departments will disclose government environmental information and how enterprises will disclose corporate sustainability governance information. To determine objectively how laws and regulations are implemented on EID by the government and enterprises, the Institute of Public and Environmental Affairs (IPE) and the Natural Resources Defense Council (NRDC) collaborated to create the Pollution Information Transparency Index (PITI) to assess the degree of EID systematically. Since 2008, the PITI has released assessment results for 113 Chinese cities. In 2013, the Ministry of Environmental Protection of the People's Republic of China implemented "*Measures for the Self-Monitoring Information Disclosure by State Monitored Enterprises (Trial)*", and in 2016, established environmental information disclosure and public participation in an unprecedented chapter of the new Environmental Protection Law. In 2022, the Ministry of Ecology and Environment (formerly Ministry of Environmental Protection) issued "*The Measures for the Administration of Legal Disclosure of Corporate Environmental Information and the Format Guidelines for Legal Disclosure of Corporate Environmental Information*", which set up a solid and vital legal basis for information disclosure, and marked the beginning of a new era of corporate EID in China. After decades of exploration, EID systems have gradually improved.

On the basis of previous analyses (e.g., Ren et al., 2020; Chen et al., 2021; Hu et al., 2021; Li et al., 2023b), this study tested the influence of EID programs on CGI in China. By staggered introducing policy measures, the PITI formulated a credible natural experiment and natural control group to measure the CGI in cities and published. By treating the staggered introduction of the SO2 emissions trading pilot policy as an insightful natural experiment, Ren et al. (2020) found that the policies led to a significant increase in firms' patenting of environmental innovations. Chen et al. (2021) argued that the relevance of low-carbon city policies on corporate carbon emissions performance is effectively validated given the excellent nature of the natural experiment of Low-carbon city construction. The Green Credit Guidelines promulgated by China were used as the basis for Hu et al.'s quasi-natural experiment study (2021). They found that these policies had a significant impact on the CGI. All the above-mentioned studies exploited a policy or regulatory change that generated an external change in firms' green behavior. Despite economics' success in identifying and analyzing existing policies, treatment selection is still a distinct aspect of natural experiments, and such experiments are still rare. A quantitative analysis of how EID programmes impact CGI is presented in this study. The staggered release of the PITI in different Chinese cities provides a series of credible natural experiments as the basis for this investigation. This study used the unique setting of the PITI in China as a quasi-natural experiment and explored how EID affects CGI. It provides a reference for further EID effectiveness and for perfecting and developing an EID system in the context of China.

2.2. Theoretical background

The Signaling Theory (ST) can be traced back to Spence's (1973) contribution to labor economics, where he studied the implications of asymmetric information within economic behavior models. In his formulation of ST, Spence's (1973) seminal research argues that educational signals in labor markets reduce information

asymmetries between potential employers and job candidates (Bergh et al., 2019). ST was applied to settings in which there is (indirect) interdependence (Scitovsky, 1954) between the receiver and sender of a signal and information is shared asymmetrically among the two parties (Healy & Palepu, 2001). Consequently, ST has been studied widely in several organizational areas, including financial management (Francis et al., 2010), business strategy (Basdeo et al., 2005), entrepreneurship management (Vanacker & Forbes, 2020), and human resource management (Leahey, 2007). ST implies that information disclosure can decrease the information asymmetry between market actors (Spence, 2002) and mitigate market failures (Zerbini, 2017). Specifically, the ST argument posits that information disclosure is efficient to the extent that it can shift market preferences and avoid adverse selection (Rao & Monroe, 1989). Based on the ST, concern has been raised about the potential impact of information disclosure on strategic decisions (Wang, 2017; Xie et al., 2019). Information disclosure embodies the quality of a corporation and has an essential impact on the market and performance, thus affecting strategic corporate decisions (Feng et al., 2021). Researchers argue that a corporation changes its strategic decisions if its level of information disclosure changes (Connelly et al., 2011). Information disclosure makes companies more susceptible to external scrutiny, causing them to adjust their strategic decisions to meet resource providers' quality requirements (Dawkins & Fraas, 2011). Furthermore, companies have an incentive to improve their performance to enhance disclosure, creating an attractive image for consumers and investors (Wang et al., 2020), thereby gaining a competitive advantage. Thus, EID exerts an impact on corporate environmental behavior, and it is believed that EID influences CGI to some extent.

Resource dependence refers to a corporation critically dependent on stakeholders outside of the corporation to supply essential resources (Pfeffer & Salancik, 1978). According to resource dependence theory (RDT), firms reduce uncertainty owing to the unpredictability of external stakeholders by managing or adapting to external constraints such as joint ventures/alliances (e.g., Pfeffer and Salancik, 1978; Sutton et al., 2021; Hillman et al., 2009). Many companies depend on stakeholders such as business partners, investors, regulators, and customers (Drees & Heugens, 2013). However, a lack of time and cognitive resources prevents companies from managing all stakeholders (Sutton et al., 2021). Companies pay closer attention to individual stakeholders who have the most significant impact on their performance to simplify their tasks (Schwenk, 1984). While the importance of different stakeholders varies across companies, the relationships between companies, governments, and customers are crucial (Hillman et al., 2009). Given firms' dependence on the government in setting and enforcing the rules (Pfeffer & Salancik, 1978) and acquiring funds for production operations from investors, a wealth of research focuses on how firms obtain funds from the government and investors. This study demonstrates that through information disclosure, companies can meet the expectations and requirements of the government and investors (Zerbini, 2017). Information disclosure can help firms successfully manage the sources of their dependencies and influence their perceptions and, in turn, their related performance (Sutton et al., 2021).

RDT posits that firms' survival and growth hinge on their ability to secure vital resources from external sources. EID plays a pivotal role in helping firms access critical resources from governments and financial

institutions (Feng et al., 2021). Furthermore, voluntary environmental regulations, exemplified by EID, serve as a conduit through which firms can communicate corporate information to the capital market and consumers, ultimately diminishing the information asymmetry that often exists between firms and specific external stakeholders. Firms are incentivized to realign their internal resource allocation and embark on green innovation to convey positive signals that meet the sustainability expectations of these external stakeholders (Dyer & Singh, 1998).

However, the existing body of research has primarily centered on the influence of disclosure on firms' ability to secure essential resources from government and financial institutions, as viewed from the perspective of RDT. This focus has, in many cases, disregarded the potential impact of disclosure on internal resource allocation and behavior, such as green innovation, as envisioned by Stakeholder Theory (ST). As a result, this study, as outlined in the following section, integrates insights from both ST and RDT to advance the following theoretical propositions: (1) Information disclosure assists firms in procuring resources from government and financial institutions but may also curtail their autonomy, consequently influencing their behavior; and (2) In scenarios where firms are increasingly reliant on individual stakeholders, resource configurations are tailored to meet the demands of these stakeholders, driving firms to transmit positive information through disclosure, thereby incorporating EID, CFC and CGI into a unified theoretical framework.

3. Hypothesis development

Through integrating ST and EDT, this study constructed a moderated mediation framework (Figure 1) that describes why and when EID relates to CGI. This study hypothesizes that CFC works as a central mediator in the relation between EID and CGI (why), with Corporate Ownership Type (COT) acting as a boundary condition (how).

Insert Figure 1 about here

3.1. EID and CFC

According to ST, stakeholders can only passively obtain limited corporate environmental information (Lyon & Maxwell, 2011). Companies can establish communication with stakeholders through EID to decrease information asymmetry and attract stakeholder attention (Feng et al., 2021). Most existing studies argue that companies with higher stakeholder attention are susceptible to external scrutiny, which motivates them to disclose environmental information (Abeysekera & Dawson, 2015). However, reverse causation exists from stakeholders' attention to EID (Wang et al., 2020), which enhances investors' concerns about the company. EID reflects a company's achievements in environmental protection and its potential to enhance future corporate value (Martinez-Ferrero et al., 2017). Companies attract investors' attention by disclosing environmental information, thus winning their favor (Schreck & Raithel, 2018). Investors' attention is a double-edged sword because it may increase external pressure on companies, which strictly scrutinize EID content and standards

and encourage them to implement them more actively to meet stakeholders' expectations (Ahern & Sosyura, 2015). Hence, EID attracts investor attention and authentically raises firms' environmental awareness, facilitating relationships with multiple regulatory investors (Zhao, 2012). Therefore, a company's financial constraint can be improved.

EID attract more attention from investors and increase their financing. When individual investors have insufficient information about investments, they may suffer losses and become hesitant to continue investment activities (Wang et al., 2020). Normally, individual investors may have extensive information compared with experienced or institutional investors, whose sources of information are more extensive (Chung & Wang, 2016). Therefore, they may not effectively identify the actual environmental performance of listed companies and may be attracted to companies with high EID as having growth potential and increasing their investment (Liu et al., 2022a). EID helps companies establish legitimacy and a high level of citizenship (Li et al., 2019) and gives firms low legitimacy risk or high transparency, and investors prefer to invest in companies with high EID levels (Correa et al., 2016). Firms with better environmental performance are distinguished from those with poorer environmental performance through EID to enhance their reputation and sustain their corporate image (Lemma et al., 2019). Attracted by the positive signal of EID, inventors who value the importance of corporate sustainability tend to fund companies that provide environmental disclosures (Cheng et al., 2017). Consequently, EID increases direct finance and decreases CFC.

EID enables firms to obtain government financial subsidies, bank loans, and preferential interest rates for green credit, reducing firms' indirect financing costs. First, corporate environmental behavior has significant environmental benefits and positive externalities (Zhang et al., 2023), and the government has strongly supported corporate environmental behavior to improve environmental pollution through financial subsidies and other means (Wu et al., 2022). Government financial subsidies are targeted at companies with high levels of social responsibility and environmental behavior (Cohen et al., 2016). The government will screen the targets of financial subsidies through EID to provide financial subsidies to enterprises with high levels of EID. Therefore, EID reduces information asymmetry among firms and the government, and can help firms gain government subsidies and government-related preferential policies to alleviate CFC further. Second, when companies obtain loans from banks, they often need to provide relevant information to conduct loan reviews before issuing loans. EID is one way to understand the environmental performance, operating conditions, and business risks of listed companies (Xu & Li, 2020). Therefore, companies decrease the cost of indirect bank financing through EID to further alleviate CFC. Third, because the Chinese stock market has an unbalanced financing structure (Wu et al., 2022)., direct financing channels are not developed in China and green credit is essential for firms to obtain financing (Liu et al., 2022a). Green credit policies subsidize the difference between the market interest rate and the actual interest rates for green projects (preferential rates), encouraging banks to lend to green industries and spreading some lending risk from banks to the government (Yang et al., 2019). By disclosing positive environmental information and using positive disclosure words (Cho & Patten, 2007), companies release information about their green projects, which helps them obtain preferential rates for

green credit. Consequently, EID facilitates firms' access to more financial and political resources, thus further alleviating CFC. Hence, the following hypothesis was established:

H1: EID can alleviate corporate financing constraints.

3.2. CFC and CGI

CFC arises from financial frictions due to the inevitable information asymmetries in capital markets and agency costs (Rashid & Jabeen, 2018). Financial frictions make a firm's internal funds unsubstitutable for external funds, resulting in a higher cost of external funds (either unsecured debt or equity) than the opportunity cost of internally generated funds produced by cash flows and retained earnings (Myers & Mailuf, 1984). CFC can lead to underinvestment in companies. CFC hinder information processing, centralized control, and resource conservation (Hovakimian, 2011), leading them to be more conservative than innovative, and improving efficiency rather than pursuing innovation (Zhang et al., 2021). Additionally, CFC forces companies to invest prudently in limited funds (Naeem et al., 2019). Limited resources are prioritized for investment in low-risk innovation projects, thereby reducing business risks and improving innovation efficiency (Rashid et al., 2018). As a result, CFC has become one of the irremovable obstacles that companies face when making investments (Huang et al., 2022; Zahler et al., 2022).

CGI is a crucial part of a company's strategic decisions and is associated with enhanced performance and competitiveness (Przychodzen et al., 2020). CGIs are distinguished from other types of innovations based on their unique characteristics. First, the main trait is uncertainty (Shi et al.,2019), involving technologies that are still in the beginning stages of development and the outcomes are unknown and uncertain for potential investors (and sometimes for innovators) (Mina et al., 2013). Second, due to double externalities, CGI benefits are often not monetized or fully captured (Cecere et al., 2020). The advantages they provide to economic actors are greater than those provided by those who invest. Therefore, companies have little incentive to develop green innovations (Cecere et al., 2014). Third, the long profitability period of CGI investments is contrary to the short-term profitability of financial capital markets, which makes it difficult to effectively integrate CGI with traditional finance (Muhammad et al., 2022). Therefore, a long profit cycle hinders large-scale investments in CGI in the financial markets. Fourth. CGI is riskier than other innovations because its costs tend to be higher and irreversible (Su, 2020). The evolution of environmental regulations makes CGI profitability uncertain (Cecere & Mazzanti, 2017). CGI investment has multiple characteristics including high risk, lengthy cycle time, unrecoverable costs, and highly uncertain returns (Yu et al., 2021). These characteristics make it difficult for companies to obtain external financial support for CGI investments, subject to more external financial constraints (Hu et al., 2021). In addition, companies invest in innovative projects financed by sufficient free cash flows (Hall et al., 2016). Companies decide to invest in research when they have an internal cash surplus (Cecere & Mazzanti, 2017). However, internal funds are limited, particularly for companies that require significant green innovation funding. Consequently, CGI requires adequate internal and external funding and is exposed to more serious financial constraints (Yu et al., 2021). Therefore, the following hypothesis was established:

H2: Higher CFC can induce lower corporate green innovation.

3.3. The mediating role of CFC

Increasingly, governments may adopt information disclosure as the demand for environmental requirements increases, because of sustained economic growth and rising living standards. EID increases the transparency of corporate pollution behavior and improves the ability of the government and the public to monitor and control the environment (Li et al., 2022a). The key implementers in the decision-making and implementation of EID include the government as an institutional provider, the enterprise as the participant, and the public as the consumer. EID can alleviate information asymmetry, change the equilibrium between supply and demand in the environmental protection market, and weaken the negative externalities of environmental pollution. As participants, companies actively pursue green innovation for future benefits in their interactions with other participants (Ben Arfi et al., 2018). EID improves the government's ability to monitor environmental pollution. Green innovation encourages the efficient use of materials and advocates increased resource productivity (Ho et al., 2023), which not only reduces the net cost required for a company to obtain legitimacy and policy support but also transforms products or related processes to create competitive advantages (Chang, 2011). EID raises public consciousness about the importance of environmental protection. Green innovation benefits a company by helping it build a positive image and satisfy its customers' sustainable requirements, which in turn increases its market advantage and cash flow (Dangelico & Pujari, 2010). EID puts double the pressure on the corporation to have an anti-driving effect on the management model, whereas green innovation technology aligns with the same aim of sustainable development. Through the development of green innovation technologies, companies can develop a sense of responsibility, build a positive image, gain social and cultural benefits, and contribute to the sustainability of their innovation and development (Khan, 2011). According to these, the following hypothesis was developed.

H3: EID is positively related to CGI.

The ST asserts that information disclosure is a central means of weakening financial frictions arising from information asymmetry in capital markets (e.g., Francis et al., 2010; Lemma et al., 2019; Liu et al., 2022a). Green innovation is embedded in a company's human resources (e.g., researchers and technicians) and is often an intangible asset and capital (Cecere & Mazzanti, 2017). To avoid losing part of the green knowledge base due to employee turnover, companies increase their Research and Development (R&D) cycles for green innovation (Hall & Lerner, 2010). The R&D cycle for green innovations exacerbates information asymmetry among investors and companies that develop green technologies, raising opportunistic behavior, adverse selection, and moral hazards that exacerbate financial friction (Mina et al., 2013; Hall et al., 2016). This study builds on H1, H2, and H3 to suggest that the information transmission function of EID can alleviate CFC and enhance CGI. EID strengthens coordination and cooperation between stakeholders and enterprises, and strengthens information sharing (Hall et al., 2021). First, EID transmits environmental information to investors and customers. High-level EID can lead to fewer penalties and litigation risks owing to environmental pollution (Lemma et al., 2019). EID can serve as a signal conveying the sound operating conditions of

enterprises, and private investors may invest in companies (Liu et al., 2022a). In addition, consumers voluntarily choose to buy environmentally friendly products and pay a premium, thus alleviating CFC and promoting CGI (Albuquerque et al., 2019). Second, CGI is highly dependent on social trust, and an excellent social image helps improve their financial capacity (Li et al., 2020). Considering the legitimacy theory, the legitimacy theory, companies release positive signals of green development to the outside environment by disclosing environmental information to gain cognitive legitimacy and match societal expectations for environmental protection (Li et al., 2019). Cognitive legitimacy lowers the difficulty of obtaining green innovation resources from financial institutions and the government (Ji et al., 2020), further strengthens the easing effect of EID on CFC, and promotes CGI. Therefore, the following hypothesis was adopted in this study.

H4: CFC plays a mediating role in the relationship between EID and CGI.

3.4. The moderating role of corporate ownership type

The impact of EID on CGI is often determined by institutional and environmental factors (Carpenter et al., 2004; Xiang et al., 2020). In particular, in emerging economies, institutional factors affect CGI by influencing strategy direction (Jiang et al., 2013), R&D resources, and business management systems (Borisova et al., 2012). Furthermore, from an institutional perspective, ownership structure must be taken into account in studies on the role of institutional factors in organizational governance (Peng et al., 2008), which is a significant determinant of resource allocation and strategic choices (Cheng et al., 2017). However, there is limited study on the effects of EID on CGI from the perspective of ultimate ownership in China, which consists of two ownership types: state-owned enterprises (SOEs) and non-SOEs (Wang et al., 2016).

Building on the above, this study proposes that corporate ownership type, which indicates that the shareholder has determined voting rights and cannot be controlled by anyone else (Wang et al., 2017), is a critical boundary condition for the CFC mediation effect. Specifically, this study predicts both stages of CFC mediation to be amplified in non-SOEs: a) from EID to CFC and b) from CFC to CGI.

First, CFC is often affected by the ownership structure of the company (Hu et al., 2021). The "revolving door channels" for leaders of SOEs to enter government agencies give them not only a natural "blood relationship" but also informal links with the government (Chen et al., 2021). Unlike non-SOEs, which have limited financing, SOEs usually have easier access to loans from banks (Cui et al., 2022). However, EID creates a fair institutional environment for SOEs and non-SOEs, and the allocation of economic resources is effectively supervised and restricted (Wei & He, 2022). Resource dependency theory suggests that SOEs are more dependent on the government than non-SOEs, and a fair institutional environment is not conducive to SOEs' access to relevant resources (Wang et al., 2019a, 2019b). When it comes to the institutional context of EID, non-SOEs can rely on good environmental performance to meet the green credit requirements of banks and governments (Xu & Li, 2020). Moreover, non-SOEs have more resource allocation flexibility than SOEs do (Schreck & Raithel, 2018), allocate more resources to EID to shape a green image, and obtain more resources from the market (Li et al., 2020). In summary, company ownership affects the relationship between

EID and CFC. EID by non-SOEs has a more significant mitigating effect on CFC than that by SOEs.

Second, this study argues that ownership can also affect R&D resource allocation in pursuit of CGI, which affects the impact of CFC on CGI (Borisova et al., 2012). Under the dual pressure of government policies and market competition, CGI by non-SOEs, which pursue profit maximization in the face of CFC, is more adventurous (Wei & He, 2022). They seek to obtain a competitive advantage by allocating resources to CGI. Consequently, non-SOEs have greater incentives and advantages for CGI. However, SOEs with a business philosophy of increasing GDP and fiscal revenues and helping the government to achieve its broader political and economic goals (Xie et al., 2015) are more strategically focused on stability and efficiency. Additionally, SOEs receive stable subsidies from the government, which weakens the effect of CFC on CGI. Therefore, CFC has a more pronounced effect on CFC in non-SOEs. Thus, the following hypothesis was formulated:

H5: The strength of the mediated effect of CFC on the relationship of EID and CGI will be stronger for non-SOEs.

4 Research design

4.1. Data and sample

In this study, the hypotheses were tested based on a dataset of China's A-share listed companies from 2004 to 2017. A variety of economic databases ranging from corporate, industry, and city levels were used to extract, compile, and construct comprehensive research datasets. For instance, to examine CGI, green patent data was obtained through the China National Intellectual Property Administration website with prior practice (Huang, 2017; Hu et al., 2021) using the International Patent Classification (IPC) classification number listed in the IPC Green Inventory (IPC-GI) and the enterprise name (including any former name) as keywords to extract data. The IPC-GI was obtained from the World Intellectual Property Organization (WIPO, https://www.wipo.int), which comprises seven data fields: alternative energy production, agriculture or forestry, energy conservation, waste management, nuclear power generation, transportation, and administrative, regulatory, and design aspects. This study focuses on the patent application year as the patent production year. Other corporate data were obtained from the China Stock Market and Accounting Research (CSMAR) database, which contains all public information disclosed by Chinese listed companies.

Since 2008, when the first EID policy was implemented, the Institute of Public and Environmental Affairs (IPE) and the Natural Resources Defense Council (NRDC) started collaborating to create the Pollution Information Transparency Index (PITI), and for a decade, they have released an annual assessment of 113 cities in China for the years 2008-2017 (Li et al., 2022a). Hence, this study used data of 2004-2017 for hypothesis testing and treated the year 2009 as the demarcation line for examining the before and after effects of the introduction of the EID policy.

Regarding the characteristics of green technological innovation and the reliability of the sample, the following criteria were selected for data filtering: (1) companies in the financial, real estate, and other service

industries were not considered; (2) Excluded were companies with more debt than assets; and (3) companies with missing data were not used. Consequently, 15,246 firm-year observations (i.e., samples) were obtained for use in study.

4.2. Variable construction

4.2.1. Dependent variable

Corporate Green Innovation (CGI) is the dependent variable. An innovation involves investments in R&D, inventions, and patents over various stages. Compared with R&D investment, patents reflect corporate innovation more directly (Cai et al., 2021). Therefore, a green patent application was applied to measure the dependent variable CGI. This is measured by the number of green patents a company generates in a given period, indicating the green innovation level. Considering that the patent application process takes a long time, patent application data rather than patent authorization data were used in this study due to the consideration of timeliness (Du et al., 2019).

4.2.2. Independent variable

Environmental Information Disclosure (EID) is the independent variable. In this study, a quasi-natural experiment was conducted. This study follows Jia et al. (2016) and first constructed an explanatory variable for the quasi-natural experiment as a post×policy. The 113 cities in the 2013 PITI report were selected as PITI cities based on data consistency. This study regarded a firm in the treatment group as being located among the 113 cities, whereas those located in other cities were in the control group. In the next section, this study discusses a more detailed discussion of the setup of the treatment and control samples. If a firm is in the treatment group, the variable indicator Post is defined as 1 for the observation years after 2008 when the policy was implemented, and 0 otherwise.

Company Financial Constraint (CFC). Many studies have used the financing constraint index to measure the outside financial friction encountered by firms seeking external financing support. Kaplan and Zingales (1997) first proposed a financial constraint index by qualitatively classifying financial constraints among a limited number of firms and characterizing the association between the degree of financial constraints and the set of variables representing the firm's characteristics. The existing representative indices of financial constraints are the Kaplan-Zingales (KZ) index (Lamont et al., 2001), Whited-Wu (WW) Index (Whited & Wu, 2006), and Size-Age (SA) index (Hadlock & Pierce, 2010). In line with Hadlock and Pierce's approach (2010), this study employs the natural logarithm of the absolute value of the SA index to gauge CFC, thereby addressing potential endogeneity concerns (Whited & Wu, 2006):

$$SAindex = -0.737SIZE + 0.043SIZE^2 - 0.04AGE$$
$$CFC = \ln(|SAindex|) \quad (1)$$

Where *SIZE* is the firm's size and *AGE* is the age of being listed. According to Zhai et al. (2022), the higher the CFC, the more severe the firm's financing constraints.

Corporate ownership type (COT): Ownership is used as a dummy variable to measure whether the ultimate owner is state related. If the owner is the Chinese government, it is 1, otherwise 0 (Wang & Qian, 2011).

4.2.3. Control variables

Taking into account prior research (Hu et al., 2021; Shao et al., 2020; Ma et al., 2021), a number of variables were used as the control variables: firm size (logarithm of total assets), age of listing (logarithm of listed years plus 1), Tobin's Q (TobinQ), asset-liability ratio (Levrg), return on capital (ROA), and capital intensity (CAP). Other important characteristics of boards are also controlled for by the following variables: independent director, which indicates the ratio of independent directors on the board, and largest shareholder, which indicates the proportion of largest shareholders on the board. All variables are defined in Table 1.

Insert Table 1 about here

4.3. Model specification

The model specification consists of two main components. The first part involves the construction of a quasi-natural experiment, employing a Difference-in-Differences (DID) model, to assess the impact of EID on CGI. The second part of the study delves into the mechanisms through which EID influences CGI, with a particular focus on CFC. It involves a comprehensive empirical analysis of how EID contributes to the advancement of CGI and identifies the moderating effects of COT within these channels.

4.3.1 DID model

This study tested the hypotheses using a DID model procedure (Singh & Agrawal, 2011; Jia et al., 2019). It treats public policy as a quasi-natural experiment and mitigates endogeneity problems by comparing differences in sample groups before and after the experiment (Liu et al., 2022b). The model is expressed as follows:

$$CGI_{it} = \alpha_0 + \alpha_1 DID_{it} + \alpha_2 X_{it} + u_i + \lambda_t + \theta_{it} + \varepsilon_{it} \quad (2)$$

where i denotes a firm, and t represents a year. The dependent variable CGI_{it} refers to dependent variable. DID is a dummy variable and $DID_{it} = Pilot_{it} \times Post_{it}$, Pilot = 1 if firm *i* belongs to the set of PITI report and Post = 1 if the city is belongs to PITI after 2008. This paper considers firms belong to 113 cities in the PITI report as the treatment group and other firms as the control group, where X_{it} denotes the control variables, and u_i, λ_t and θ_{it} represent the fixed effects of individual, year and industry, respectively, ε_{it} is the error term.

4.3.2 Moderated-mediation model

Next, this paper investigates the mechanism of EID on CGI, and further explores the mediating effect of CFC. The specific setting has certain similarity with the work of Baron and Kenny (1986), which can be

defined as:

$$CFC_{it} = \gamma_0 + \gamma_1 DID_{it} + \gamma_2 X_{it} + u_i + \lambda_t + \theta_{it} + \varepsilon_{it} \quad (3)$$

$$CGI_{it} = \mu_0 + \mu_1 CFC_{it} + \mu_2 X_{it} + u_i + \lambda_t + \theta_{it} + \varepsilon_{it} \quad (4)$$

$$CGI_{it} = \eta_0 + \eta_1 DID_{it} + \mu_3 CFC_{it} + \eta_4 X_{it} + u_i + \lambda_t + \theta_{it} + \varepsilon_{it} \quad (5)$$

where CFC_{it} represents CFC. The remaining variables are the same as those in equation (2). Technically, the α_1, γ_1, μ_1 and η_1 significantly verified the existence of the mechanism, and CFC plays a mediating effect for EID on CGI.

Finally, to find out how EID affects CFC and CGI, this paper further explores the moderating role of COT. This study added the moderating interaction variable in the benchmark regression of Eq. (2)-(4), which can be expressed as:

$$CFC_{it} = \gamma_0 + \gamma_1 DID_{it} + \gamma_2 COT_{it} + \gamma_3 DID \times COT_{it} + \gamma_4 X_{it} + u_i + \lambda_t + \theta_{it} + \varepsilon_{it} \quad (6)$$

$$CGI_{it} = \mu_0 + \mu_1 CFC_{it} + \mu_2 COT_{it} + \mu_3 CFC_{it} \times COT_{it} + \mu_4 X_{it} + u_i + \lambda_t + \theta_{it} + \varepsilon_{it} \quad (7)$$

$$CGI_{it} = \alpha_0 + \alpha_1 DID_{it} + \alpha_2 COT_{it} + \alpha_3 DID_{it} \times COT_{it} + \alpha_4 X_{it} + u_i + \lambda_t + \theta_{it} + \varepsilon_{it} \quad (8)$$

where COT_{it} denotes corporate ownership type, and γ_3, μ_3 and α_3 are the moderating effect coefficients to be estimated. The remaining variables are the same as above.

5. Empirical results

5.1. Descriptive statistics and correlation analysis

The descriptive statistics and correlations between the variables are presented in Table 2. Among the 15,246 samples collected between 2004 and 2017, the mean value of green patent applications (CGI) was 4.043 and the standard deviation was 32.81. This indicates excellent variation in green innovation levels among the sample enterprises, most of which do not engage in green innovation. The mean values for Pilot and Post sessions were 0.799 and 0.714, respectively. After the promulgation of 2008, EID accounted for 71.4% of the total sample, and the experimental group accounted for 79.9% of the total sample. Other variables showed a reasonable range of values. Before investigating the impact of EID on CGI, this study must assess the degree of relationship between various variables to prevent multicollinearity in parameter estimation. According to Table 2, there was a correlation of less than 0.8 between the variables in the model. Therefore, ordinary least squares regression is performed directly.

Insert Table 2 about here

5.2. Regression results

5.2.1. Main effects

Hypothesis 1 states that EID alleviates CFC. Model 1 in Table 3 shows a statistically significant

negatively correlation between EID (B= -0.003, p<0.05) and CFC. After removing possible confounding factors, implementing EID alleviates CFC by approximately 0.3%. As expected, the control variables were significantly related to CFC. Firm size, Tobin's Q, return on capital, and largest shareholder are positively related to financial constraint mitigation. Firm age, asset-liability ratio, capital intensity, and independent directors are negatively related to financial constraint mitigation. Overall, the Hypothesis 1 is confirmed by the evidence. Hypothesis 2 states that a lower CFC level would increase the likelihood of CGI. Model 3 in Table 3 shows a statistically significant negative correlation between CFC (B=-36.251, p<0.001) and CGI. Hypothesis 3 stated that EID is positively related to CGI. Model 2 in Table 3 shows statistically significant positive correlation between EID (B=3.264, p<0.001) and CGI. In addition, The enterprise's size (Size) coefficients are significantly positive, indicating that green innovation will increase with enterprise size. The coefficients of the independent directors (FIR) are significantly negative, indicating that an independent directors is the main obstacle to innovation. The coefficients of gearing (Levrg) and capital intensity (CAP) are significantly negative and the coefficient of Tobin's Q is significantly positive, indicating that a decrease in resources is not conducive to green innovation and vice versa. This is consistent with the theoretical expectations. The coefficients of the other control variables are not significant, which indicates that they are not key factors driving CGI. Thus, this study succeeded in finding statistical support for hypotheses 2 and 3.

Insert Table 3 about here

5.2.2. Mediation effect of CFC.

Hypothesis 4 posits that CFC, serving as an underlying mechanism, mediates the influence of EID on CGI. To examine these mediating effects, this study employed Pardo and Marta's causal steps approach (2013), as summarized in Table 3.

First, the study estimated the impact of EID on CFC in Model 2. The results revealed a positive relationship between EID and CFC (B=3.264, p<0.01).

Second, the existing mediator, CFC, was regressed. As demonstrated in Model 1, EID exhibited a statistically significant and negative effect on CFC (B=-0.003, p<0.05).

Third, the study incorporated the mediator as an additional variable into the main model and observed that CFC had a significant and positive effect on CGI (as evident in Model 4: B=-35.761, p<0.001). Notably, when CFC was introduced into the model, the magnitude of the effect of EID on CGI (B=3.245, p<0.01) diminished.

Insert Table 4 about here

To rigorously examine the mediation hypothesis (H4), this study employed a bias-corrected bootstrap approach (Hayes & Preacher, 2010) with 10,000 bootstrap samples, and 95% Confidence Intervals (CIs) were

estimated using the statistical software package Stata. Zero was excluded from the bootstrap CI to verify the mediation effects (Tang et al., 2021).

The bootstrapping analyses in Table 4 revealed a significant positive indirect effect of EID on CGI through CFC. The indirect effect was calculated as 0.17 (SE=0.07, CI=[0.0594386, 0.3266394]), providing support for H4. Moreover, the results indicated that the direct effect of EID on CFC, after accounting for partial mediation, was not statistically significant (B=1.0873394, SE=0.92391564, CI=[-0.7163097, 2.924585]).

When considering the combined direct and indirect effects, EID exhibited a significant overall impact on CFC (B=1.2600866, SE=0.9665141, CI=[0.6225784, 3.222222]). In summary, these findings suggest that EID does not directly influence CGI but does so through the mediating mechanism of CFC. The bootstrap tests provide empirical support for the CFC mechanism proposed in H4.

5.2.3. Moderated Mediation Effects of Corporate Ownership Type

Hypothesis 5 states that COT plays a moderating role in both the first, second and total stages (Hayes, 2015), with an indirect effect in the first (EID→CFC), second (CFC→CGI) and total stages (EID→CGI) . This study began by examining the first-, second- and total-stage moderated mediation models by analyzing the index of moderated mediation derived through bootstrapping (Hayes, 2015), traditional interaction effects, and interaction effect plots (Aiken et al., 1991). According to Haves (2015), bootstrapping can be used for generating statistical inferences. The statistical inference that this index differs from zero serves as "*a formal test of moderated mediation*", indicating that "*any two conditional indirect effects estimated at different values of the moderator are significantly different from each other*" (Hayes, 2015).

First, the first-stage moderated mediation model was explored using the Sem command in Stata (Hayes, 2013). Table 5 summarizes the conditional indirect effect of EID on CGI through CFC. The findings showed the indirect impact is significant and positive if the type of corporate ownership is non-SOEs (B=2.349016, SE=0.3118058, CI=[1.737888, 2.960144]) and becomes less positive when the type of corporate ownership is SOEs (B=1.086372, SE=0.1986579, CI=[0.6970101, 1.475735]). This study relied on traditional interaction effects to test the moderation hypotheses. Table 6 (Model 1) shows that the interaction term between EID and COT had a significantly positive impact on CFC (B=0.004, SE=-2.06, $p<.05$), indicating that COT weakens the negative effect of EID on CFC. The following slope plot (Figure 2a) depicts that the impact of EID on CFC is stronger if the type of corporate ownership is non-SOEs but weaker if the type of corporate ownership is SOEs.

Second, the second-stage moderated mediation model was explored by utilizing the Sem command in Stata (Hayes, 2013). As shown in Table 5, the indirect effects of EID on CGI via CFC varied significantly among two types of corporate ownership. There was a significant indirect effect when corporate ownership was SOEs (B=1.977544, SE=0.3225365, CI=[1.345384, 2.609704]), but weaker when corporate ownership was SOEs (B=1.27913, SE=0.1541897, CI=[0.9769237, 1.581336]). In Table 6 (Model 2), the interaction

between CFC and COT affects CGI positively and significantly (B=19.084, SE=2.80, p<.01), indicating that COT weakens the negative effect of CFC on CGI. It is shown in Figure 2b that the negative effect of CFC on CGI is greater when the corporate ownership type is non-SOEs than when the type of corporate ownership was SOEs.

In a comprehensive approach, the model was examined using the Sem command in Stata (Hayes, 2013) to simultaneously assess all stages of moderation. The results of this study indicate that the indirect effect of EID on CGI, mediated by CFC, is significantly positive when corporate ownership is non-SOEs (B=1.890018, SE=0.241908, CI=[1.415887, 2.364149]). However, when corporate ownership is SOEs, the effect is comparatively weaker (B=1.289561, SE=0.2687725, CI=[0.7627769, 1.816346]).

As shown in Table 6 (Model 3), the interaction between EID and COT exerts a positive and significant impact on CGI (B=-2.584, SE=-1.70, p<0.1), signifying that COT attenuates the positive influence of EID on CGI. As depicted in Figure 2c, the positive effect of EID on CGI is more pronounced when corporate ownership is non-SOEs compared to cases where the corporate ownership type is SOEs.

In summary, these findings lend support to H5, indicating that COT moderates the indirect effect of EID on CGI through CFC. This moderated effect is more favorable when corporate ownership is non-SOEs as opposed to when corporate ownership is SOEs.

Insert Table 5 about here

Insert Table 6 about here

Insert Figure 2a about here

Insert Figure 2b about here

Insert Figure 2c about here

5.3. Parallel trend test

The principle of the difference-in-difference method is that groups with experimental and control

conditions are comparable. A significant difference in CGI was not observed between the treatment and control groups in the absence of EID. In particular, the parallel trend assumption was tested. Figure 3 shows a parallel trend chart of difference-in-differences. Figure 3 shows the average CGI of the city-level enterprises over time for municipalities. CGI was higher in the treatment group before EID in 2008 than in the control group, showing a parallel trend. Moreover, during the EID period (2009-2017), the CGI of the treatment group increased rapidly, significantly exceeding that of the control group. Furthermore, the interaction items of the time dummy variables for the years before the event and pilot were constructed and added to Eq. (1). Pilot×Year2004, Pilot×Year2005, Pilot×Year2006, and Pilot×Year2007. For 2011, the observed value equals 1 for Year2007, and 0 otherwise. Year2004, Year2005, and Year2006 take the same settings. There were no significant differences between treatment and control groups before the 2008 EID was promulgated, suggesting that the treatment and control groups followed parallel trends. As shown in Table 7, the coefficients remain positive and significant for Treat×Post but are insignificant for Pilot×Year2004, Pilot×Year2005, Pilot×Year2006, and Pilot×Year2007; the parallel trend assumption is fulfilled.

Insert Figure 3 about here

Insert Table 7 about here

5.4. Robustness tests

5.4.1. Concurrent exclusion policy

Other parallel environmental policies also influenced EID implementation. We excluded significant environmental policies after 2008, including Sulfur Dioxide Emission Trading Policies in 2007, Carbon Emission Trading Policies in 2011, Chinese Ambient Air Quality Standards 2012, and Air Pollution Control in Key Areas during the Twelfth Five-Year Plan 2013 (Chen et al., 2021). Specifically, relevant policy dummy variables and the cross-term of the time trend were added to the basic model to control for the impact of other relevant environmental policies on the CGI. Models (2)–(5) in Table 7 show the regression results. Compared with the baseline results, the Period×Treated EID dummy variables and time trend are still significantly positive. However, the other environmental policy dummy variables and time trends were insignificant. This result indicates that other policies did not interfere with the main conclusions.

5.4.2. Placebo test

To address the possibility that the significant positive effects of EID on CGI in the baseline regression could be influenced by unobserved random factors, a placebo test was conducted following the methodology outlined by Zhou et al. (2022). In this test, a placebo treatment group was generated by randomly selecting a set of cities, while the remaining cities served as control groups. A false dummy variable, denoted as post-f,

was created, and the false cross-product treat-f was computed based on the model presented in Table 3 (Model 2).

To validate the baseline results, this procedure was repeated 1000 times to obtain the estimated coefficient and t-value distribution of the false interaction term. Figure 4 illustrates the kernel density diagram of the estimated coefficient and t-value resulting from the 1000 repetitions, with the red line representing the true value. As depicted in the figure, both the coefficient estimates and t-values exhibit a distribution approximating a normal curve with a mean close to 0. Importantly, no regression t-value exceeds the true regression t-value, indicating that the observed positive effect of EID on CGI is relatively robust and not likely due to random factors.

Insert Figure 4 about here

5.4.3. Add the city fixed effects

While this paper incorporates controls for time fixed effects, individual fixed effects, and industry fixed effects in the baseline regressions, it is important to acknowledge that there may still be unobservable factors at the city level that evolve over time, such as variations in the innovation environment across different cities. To mitigate the influence of these unobservable factors, we introduce city fixed effects (City FE) into the model.

The outcomes are presented in model 1 of Table 8, and the introduction of city fixed effects demonstrates that, even after accounting for city-specific time trends, the coefficients pertaining to the independent variables remain significantly positive at the 5% level. This additional analysis further strengthens the robustness of the regression findings in this paper.

5.4.4. Alternative proxies for CGI

There are fake and unqualified patents in Chinese enterprises' patent application activities, forming an "innovation illusion" (Zhang et al., 2015). However, patent acquisition can truly reflect an enterprise's innovation ability. Therefore, this study took the total of corporate green patents obtained (CGI_O) as a proxy for CGI. A robustness test was conducted using CGI_O as an alternative variable and the results are presented in Table 8. As shown in Table 8, Models (2), Pilot×Post coefficients are both significant and positive with a 1% level of significance. Thus, EID is conducive to CGI, and the conclusion is reliable and robust.

5.4.5. Different time points of policy shock.

China formally implemented Measures for Environmental Information Disclosure (Trial) in May 2008. However, this study uses 2008 as a practical time point for external policy shocks. In addition, companies usually need an R&D cycle, and 1–2 years are usually needed for a patent from application to authorization. Hence, this study moved the time point back by one year, that is, 2009, as the reference point, and every year after 2009 was considered the post-pilot period. This study finds that the re-regression results are in agreement with baseline results, as reported in Models (3) in Table 8, although the absolute value of the estimated

coefficient changes. These results indicate that findings are both reliable and robust.

Insert Table 8 about here

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6. Conclusions and Discussion

The results yield insights into why and when EID drives CGI. First, EID promotes CGI by easing the CFC. Second, the benefit of EID is reinforced when the corporations are non-SOEs. This study offers a novel perspective by integrating ST and RDT to study the impact of EID on CGI by unearthing the mechanisms of mitigating information asymmetry and alleviating CFC. By considering EID as a unique signal transmission mode, this work highlights the unique resource acquisition benefit of EID, which is different from the compliance cost and Porter Hypothesis explanation prevalent in prior literature, shedding light on future research.

6.1. Contributions to the literature

First, it enriches the research framework of the influence of environmental regulation, especially voluntary environmental regulations, on CGI. Although environmental regulations are likely to have an impact on CGI has received consideration from previous studies, different types of environmental regulations differ in terms of flexibility, stability, rigorousness, and the probability of triggering CGI (Marzucchi & Montresor, 2017). Most scholars test the effects of command-and-control and market-oriented environmental regulations on CGI. Concerning the impact of voluntary environmental regulations on CGIs, little investigation has been conducted. Concerning the impact of voluntary environmental regulations, most of the existing studies have been represented by low-carbon pilot cities (LCPC) programs but have paid less attention to EID (Zhou et al., 2022; Zhang et al., 2023). Li et al. (2022a) investigated the influence of EID on green innovation mechanism tests conducted at the city level, ignoring the micro-firm-level influence. Although cities are the main actors in EID, companies are the main contributors to green innovation (Zhou et al., 2022). Neglecting firm-level research leads to an insufficient comprehension of how EID affects CGI mechanisms. This study fills the gap of the prior research by analyzing the resource base of CGI. This study also responds to the call for an analysis of each type of environmental regulation as a distinct theoretical construct (Walker et al., 2004).

Second, this study provides new insights into how the implementation of EID policies affects CGI by integrating ST with RDT by studying EID associated with firms' external dependence, which is a significant gap underexplored in the literature (Khan et al., 2021). Research on RDT focuses on how firms actively adapt to external government policy requirements and achieve government resources and help. However, EID is distinct from other environmental regulations and goes beyond RDT's view that firms cannot manage numerous stakeholders simultaneously due to limited time and cognition. The enhanced reputation generated by high-quality EID can constitute a resource that satisfies government requirements and maintains relationships with other stakeholders such as consumers, investors, and financial institutions. If EID policies

are properly implemented, firms can reduce information asymmetry with stakeholders by responding to EID policies that convey information to other stakeholders, as described by ST. This study presents a new perspective on the influence of EID policies on CGI by arguing that firms can simultaneously obtain resources from multiple stakeholders through EID. This study integrates resource dependence theory and signaling theory, two streams that had previously been unconnected.

Third, this study contributes to the literature on state capitalism by exploring why the effectiveness of the same mechanisms of EID varies across institutional settings (Aguilera et al., 2015). Government policies impact corporate environmental behavior less in SOEs than in non-SOEs. This result is somewhat surprising, because institutional theory generally assumes that SOEs have a natural "blood relationship" with the government, and the effect of government environment policies on corporate environmental behavior is expected to be more pronounced in SOEs (Wang et al., 2019a, 2019b). However, the findings of this study challenge this statement. This is because non-SOEs must satisfy government demands and thus cultivate and maintain political connections to receive corresponding resources from the government (Zhang et al., 2016). The institutional context in which a firm performs determines whether government policies must be implemented to obtain appropriate resources. The lack of close formal and informal links between non-SOEs and the government makes it unaffordable for non-SOEs to bear the cost of going against the government's wishes (Jia et al., 2019). Therefore, this study contributes to a deeper understanding of the functional nuances of environmental policy implementation by exploring the moderating role of different institutional conditions that influence firms to respond strategically to government demand.

6.2. Policy and managerial implications

The findings of this study bear significant implications for the implementation of EID policies, CGI, and the broader green transformation of the Chinese economy. Here are several key policy recommendations:

Enhancing Regulatory Oversight: It is imperative for the government to establish and enforce robust standards and quality requirements for corporate EID. Presently, China's regulations regarding corporate EID lack the necessary level of detail, allowing companies significant leeway in determining the specific content of their disclosures. This gap can lead to opportunistic behaviors among corporations, such as inaccurate reporting, omissions, and selective disclosure of environmental information. Such behaviors undermine the effectiveness of the EID policy in driving CGI.

Facilitating Information Access: Governments should create platforms that make corporate-disclosed environmental information readily available to consumers, investors, researchers, and other stakeholders. EID serves as a vital communication tool that reduces information asymmetry and capital costs, thereby fostering CGI (Yu et al., 2018). Establishing EID platforms can enhance the efficiency of information dissemination, reduce agency-related problems, and promote constructive interactions between corporations and stakeholders.

Promoting Intergovernmental Collaboration: There is a need for strengthened intergovernmental cooperation that transcends departmental and hierarchical boundaries. Particularly, in the context of financial subsidies and green credit screening, financial institutions should establish reasonable standards for reviewing

environmental information and verifying the actual environmental performance of companies. This approach should prioritize the substance of environmental performance over the quantity of environmental information disclosed. These measures will incentivize financial institutions to prioritize environmental performance, increase their vigilance towards environmental risks, and enhance their support for CGI through financing.

These recommendations are crucial for harnessing the full potential of EID policies and advancing the objectives of CGI and the green transformation of the Chinese economy.

This study offers valuable insights for companies.

Firstly, companies should recognize the importance of disclosing environmental information for securing the necessary resources for innovation. They should strive to enhance the quality of their environmental information disclosure, as it can significantly contribute to their pursuit of sustainable development (Wang et al., 2020). The empirical findings of this study highlight that Environmental Information Disclosure (EID) conveys positive signals, facilitating access to both internal and external resource support while mitigating financing constraints. Consequently, it is imperative for companies to establish and continuously enhance the framework for their environmental information disclosure system, ensuring the effectiveness of these disclosures. By providing stakeholders with authentic and relevant data, companies can foster green innovation and enhance their sustainable competitiveness.

Secondly, the moderating influence of EID, from a corporate perspective, warrants careful consideration. The study reveals that EID alleviates financing constraints and encourages green innovation in non-State-Owned Enterprises (non-SOEs). Therefore, non-SOEs facing financial challenges should seize the opportunity to leverage EID as a means of improving communication with banks and other financial institutions. This strategic approach can help them secure loan funds and reduce associated costs. Furthermore, non-SOEs should integrate environmental information disclosure with the development of green innovation, harnessing the positive impact of EID to drive eco-friendly transformation. This approach will enable companies to align economic, social, and environmental benefits effectively.

Lastly, capital market investors rely on corporate disclosures to evaluate a company's value, thereby reducing investment risk and achieving long-term investment objectives. Therefore, management should shift from the previous one-sided perspective that investment in environmental protection, social responsibility, and disclosure merely adds to costs. They should embrace a more comprehensive view that recognizes the potential for environmental protection and social responsibility to enhance corporate governance and non-financial performance. Such an approach will attract long-term value-based investments from investors, ultimately contributing to the overall sustainable development of society.

6.3. Limitations and opportunities for future research

The limitations of this study provide opportunities for future research. First, the channels through which EID affects CGI may vary, and this study considers the mediating role of CFC only from the resource allocation perspective. Exploring whether more variables mediate the relationship between EID and CGI might be a valuable topic for future research. For example, prior research finds that EID stimulates the green

innovation of listed companies by promoting product sales and increasing media attention (Xiang et al., 2020). Second, this study emphasizes the Chinese context, which may have practical implications for developing countries, whereas they may not apply to other developed countries. Examining whether the relationship between EID and CGI differs in countries with different cultural backgrounds and economic conditions could be a valuable direction for future research. Third, the boundary condition of this study is the corporate ownership type. In the future, studies could explore how other aspects such as industry moderate the mediating effect of CFC. Fourth, the findings may not apply to small and medium-sized firms because they were based on the experiences of large listed companies. Future studies may provide new insights using samples of small- and medium-sized firms.

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Figures

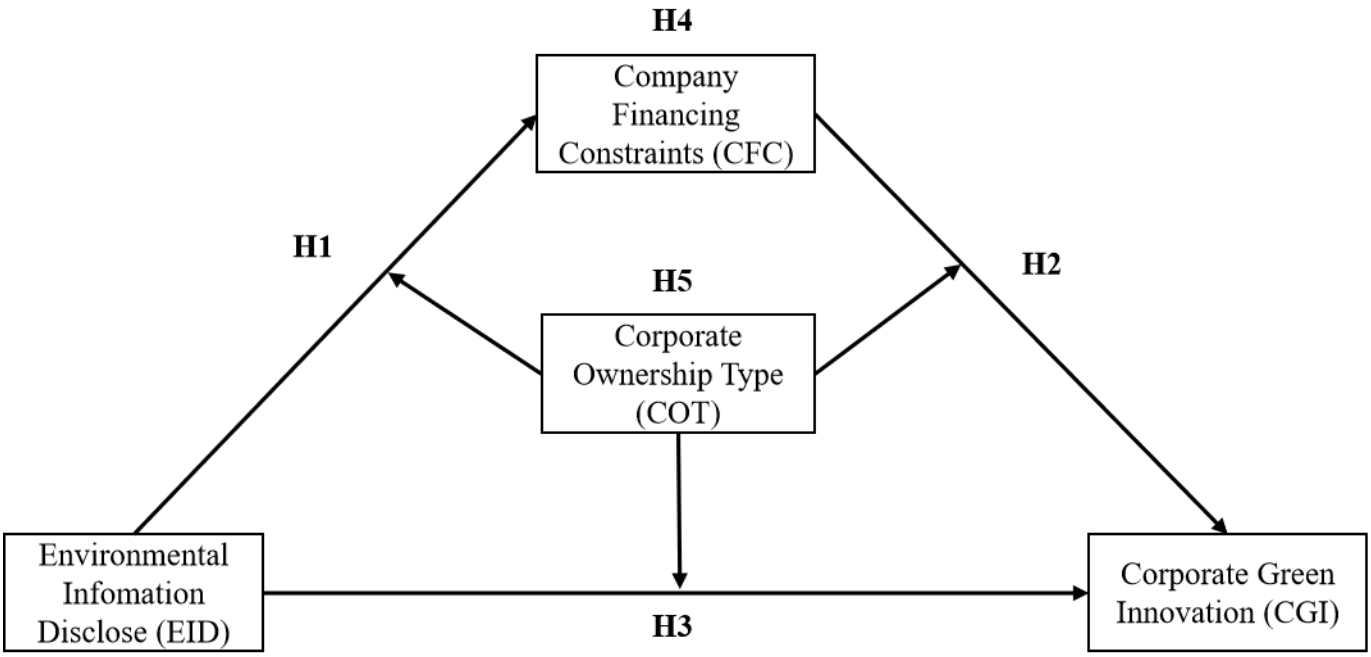

Figure 1. The framework of theoretical research in the paper.

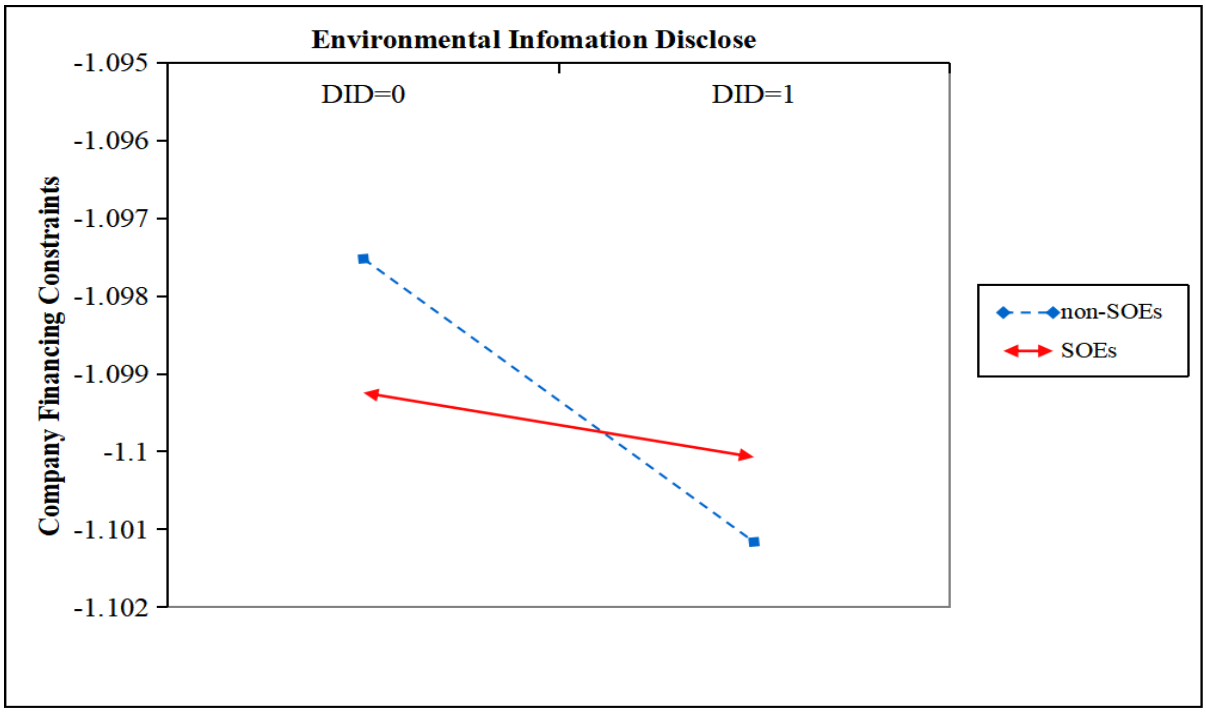

Figure 2a. The moderation effects of corporate ownership type on the relationship between environmental information disclosure(EID) and company financing constraints(CFC)

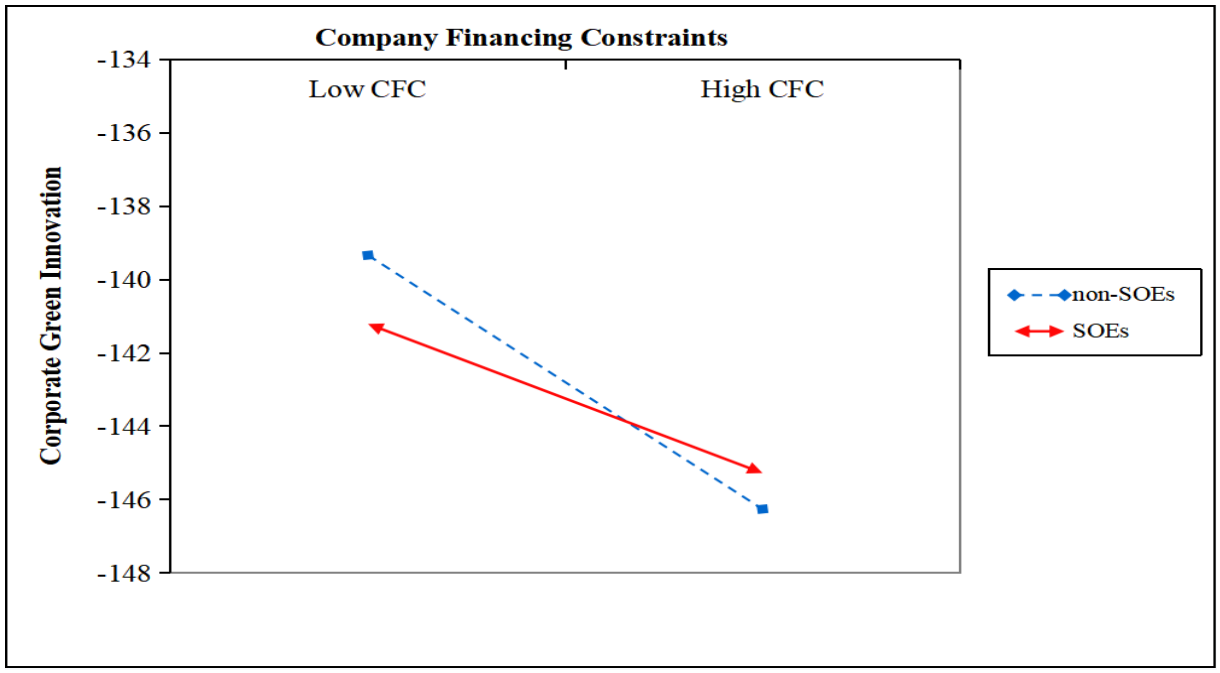

Figure 2b. The moderation effects of corporate ownership type on the relationship between company financing constraints(CFC) and corporate green innovation(CGI)

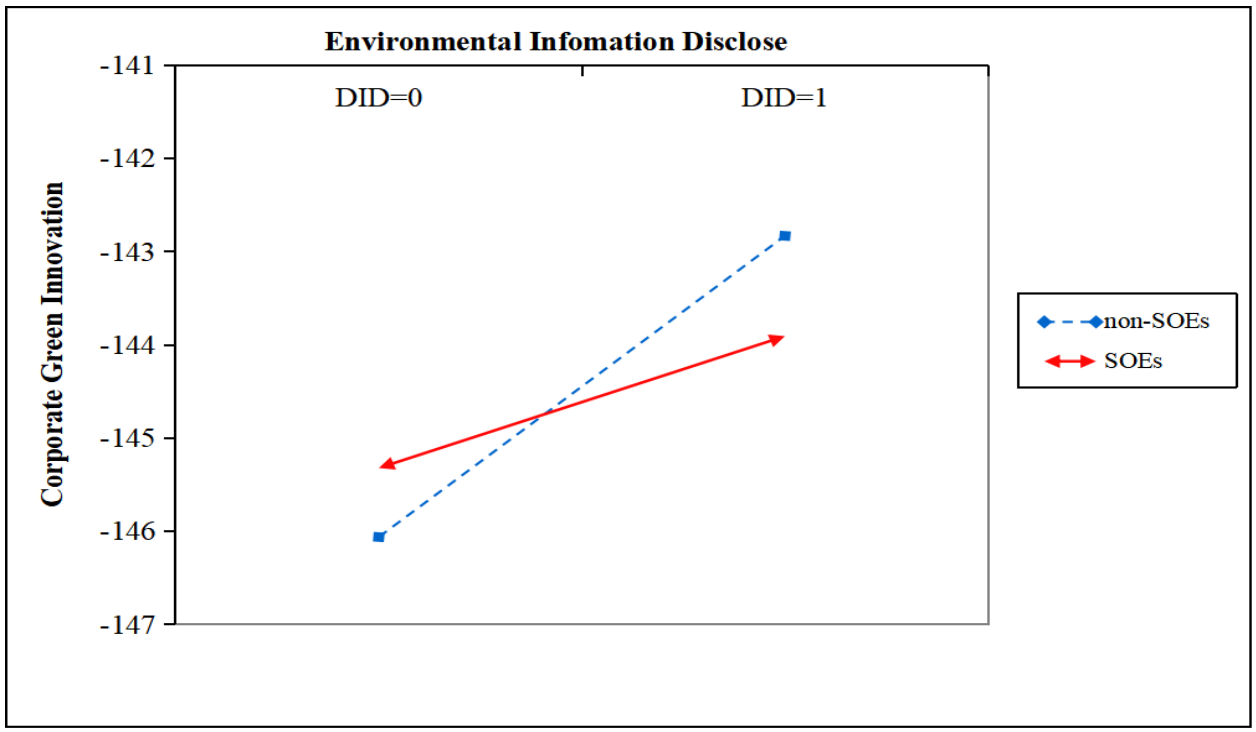

Figure 2c. The moderation effects of corporate ownership type on the relationship between environmental information disclosure(EID) and corporate green innovation(CGI)

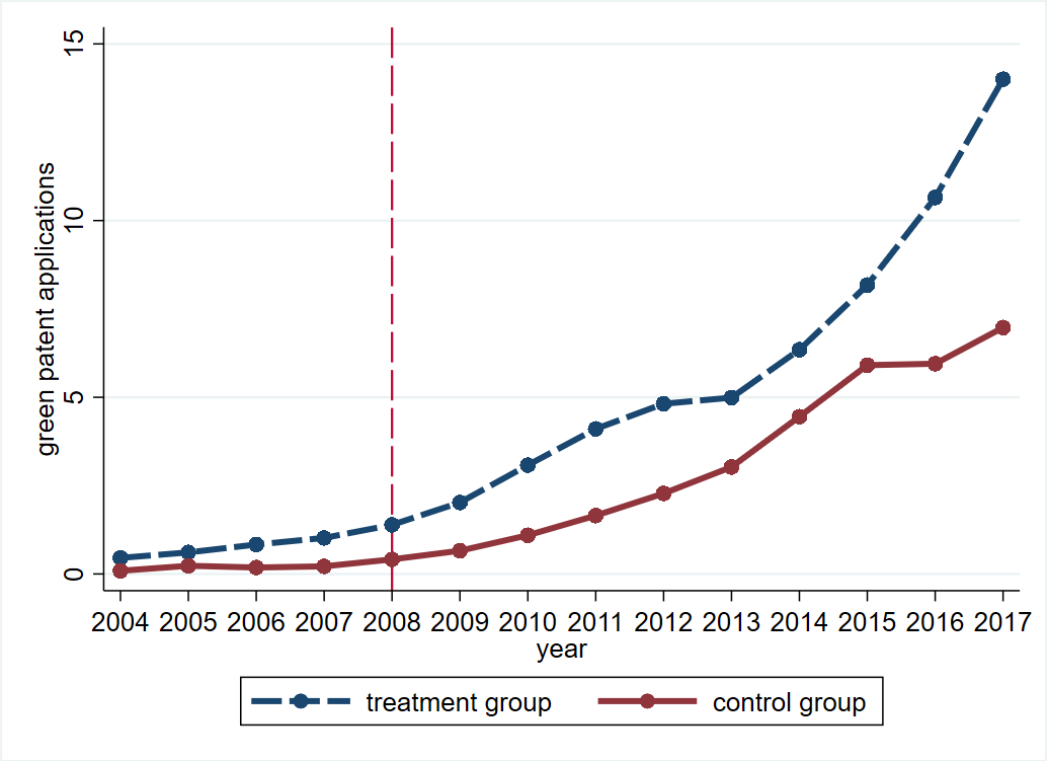

Figure 3. The average number of green patent applications by city-level enterprises before and after the implementation of environmental information disclosure.

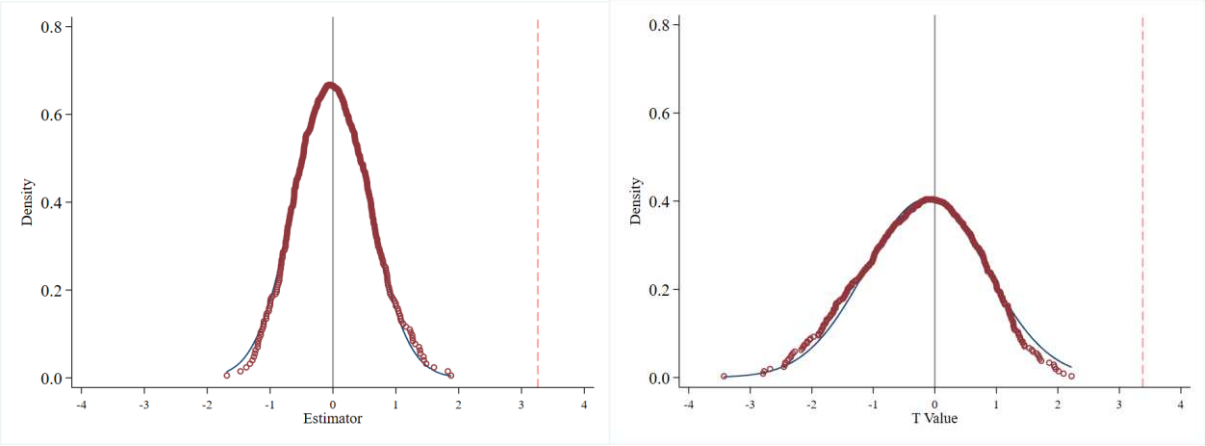

Figure 4. The coefficient of treat_f (left) and the distribution of its t-value.

Tables

Table 1 Variable definitions

Variable	Definitions
CGI	The number of green patents applications of an enterprise in a year
Pilot	A dummy variable equal to 1 if a firm is located in the the experimental group city and 0 for the control group city
Post	A dummy variable equal to 1 for 2008–2017, and 0 for 2004–2007
SIZE	The logarithm of total assets
AGE	The logarithm of listed years plus 1
TobinQ	market value of equity divided by replacement cost of capital
LEV	Total liabilities divided by total assets
ROA	Net income divided by total assets
CAP	The logarithm of the ratio of total assets to operating revenue
FIR	The proportion of shares held by the largest shareholder
IND	The proportion of shares held by the independent directors
CFC	The logarithm of the absolute value of the SA index
COT	A dummy variable equal to 1 if the ultimate owner of a firm was the Chinese government and its agencies and 0 otherwise

Table 2 Descriptive statistics and correlations among study variables

variable	Mean	Standard Deviation	1	4	5	6	7	8	9	10	11	12
1CGI	4.043	32.81										
2PILOT	0.799	0.4										
3POST	0.714	0.452										
4SIZE	22.05	1.342	0.2242*									
5AGE	12.4	5.313	0.0577*	0.2968*								
6TobinQ	1.921	1.665	-0.0262*	-0.3110*	0.1627*							
7LEV	0.145	0.133	-0.0465*	-0.1378*	-0.1443*	-0.0398*						
8ROA	0.031	0.149	0.008	0.0433*	-0.0083	0.0403*	-0.3825*					
9CAP	0.647	0.829	-0.0540*	0.0034	0.1084*	0.0450*	-0.1214*	-0.0681*				
10FIR	36.73	15.7	0.0391*	0.2069*	-0.1349*	-0.1538*	-0.0353*	0.0374*	-0.0748*			
11IND	0.363	0.052	0.0111	0.0927*	0.1375*	0.0654*	-0.0541*	0.0049	0.0464*	-0.0254*		
12CFC	-0.008	0.079	0.1569*	0.8512*	0.1874*	-0.2706*	-0.1874*	0.1257*	-0.1098*	0.2158*	0.0547*	
13COT	0.334	0.472	-0.0187*	-0.0149*	-0.2354*	-0.1463*	0.0245*	-0.009	-0.0619*	0.2050*	-0.0818*	-0.00950

Notes: the standard errors are in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3 Regression results for mediation effect of company financing constraint

	CFC				CGI			
	Model1		Model2		Model3		Model4	
Variables	B	SE	B	SE			B	SE
SIZE	0.051***	(141.97)	4.937***	(18.54)	6.819***	(15.36)	6.808***	(15.34)
AGE	-0.012***	(-10.63)	0.199	(0.25)	0.183	(0.21)	0.229	(0.26)
TobinQ	0.001***	(2.93)	0.730***	(3.30)	0.716***	(3.15)	0.741***	(3.26)
LEV	-0.025***	(-8.55)	-4.257**	(-1.98)	-4.078*	(-1.84)	-4.607**	(-2.08)
ROA	0.061***	(18.99)	-3.422	(-1.43)	-0.888	(-0.36)	-1.120	(-0.45)
CAP	-0.010***	(-19.93)	-1.766***	(-4.61)	-2.263***	(-5.56)	-2.250***	(-5.53)
FIR	0.000***	(5.19)	-0.046**	(-2.53)	-0.035*	(-1.84)	-0.036*	(-1.89)
IND	-0.028***	(-4.32)	-0.619	(-0.13)	-1.521	(-0.30)	-1.282	(-0.26)
Constant	-1.099***	(-123.44)	-103.570***	(-16.01)	-144.689***	(-14.37)	-145.125***	(-14.41)
DID	-0.003**	(-2.47)	3.264***	(3.38)			3.245***	(3.27)
CFC					-36.251***	(-5.34)	-35.761***	(-5.27)
R-squared	0.790		0.396		0.398		0.398	
Sobel Z								3.445***
Observations	15246							
Individual FE	YES							
Year FE	YES							
Industry FE	YES							

Notes: the standard errors are in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. B, SE and FE stands for Beta, Standard Error and Fixed Effect respectively.

Table 4 The results of mediation effect of bootstrapping methods

Effects	B	SE	95% CI
Indirect effect	0.17274714	0.07168039	[0.0594386, 0.3266394]
Direct effect	1.0873394	0.92391564	[-0.7163097, 2.924585]
Total effect	1.2600866	0.9665141	[0.6225784, 3.222222]

Notes: B, SE and 95% CI stands for Beta, Standard Error and 95% Confidence Intervals respectively.

Table 5 Conditional indirect effect of CFC on CGI at different Types of COT

Stage	Condition of COT	Conditional indirect effect through CFC		
		B	SE	95% CI
First	non-SOEs	2.349016***	0.3118058	[1.737888, 2.960144]
	SOEs	1.086372***	0.1986579	[0.6970101, 1.475735]
Second	non-SOEs	1.977544***	0.3225365	[1.345384, 2.609704]
	SOEs	1.27913***	0.1541897	[0.9769237, 1.581336]
Total	non-SOEs	1.890018***	0.241908	[1.415887, 2.364149]
	SOEs	1.289561***	0.2687725	[0.7627769, 1.816346]

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. B, SE and 95% CI stands for Beta, Standard Error and 95% Confidence Intervals respectively.

Table 6 Regression results for moderation effect of corporate ownership type

	CFC		CGI			
	Model1		Model2		Model3	
Variables	B	SE	B	SE	B	SE
SIZE	0.051***	(141.79)	6.827***	(15.37)	6.827***	(15.37)
AGE	-0.012***	(-10.70)	0.184	(0.21)	0.184	(0.22)
TobinQ	0.001***	(2.97)	0.746***	(3.28)	0.791***	(3.47)
LEV	-0.025***	(-8.50)	-4.578**	(-2.06)	-4.494**	(-2.02)
ROA	0.061***	(18.98)	-1.123	(-0.45)	-1.148	(-0.46)
CAP	-0.010***	(-19.72)	-2.205***	(-5.41)	-2.199***	(-5.40)
FIR	0.000***	(5.06)	-0.037*	(-1.93)	-0.036*	(-1.91)
IND	-0.028***	(-4.29)	-1.180	(-0.24)	-0.996	(-0.20)
Constant	-1.099***	(-123.37)	-145.049***	(-14.40)	-143.302***	(-14.28)
DID	-0.003***	(-2.61)	3.119***	(3.14)	3.249***	(3.28)
COT	-0.001	(-0.85)	0.252	(0.41)	-0.316	(-0.52)
CFC			-35.991***	(-5.31)	-34.647***	(-5.10)
DID×COT	0.004**	(2.06)	-2.584*	(-1.70)		
CFC×COT					19.084***	(2.80)
R-squared	0.790		0.398		0.399	
Observations			15246			
Individual FE			YES			
Year FE			YES			
Industry FE			YES			

Notes: the standard errors are in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. B, SE and FE stands for Beta, Standard Error and Fixed Effect respectively.

Table 7 Parallel trend test and concurrent environmental policy results.

	Parallel trend test		Concurrent environmental policy							
	Model1		Model2		Model3		Model4		Model5	
Variables	B	SE	B	SE	B	SE	B	SE	B	SE
Pilot×Post(DID)	3.015***	(3.06)	3.188***	(3.30)	3.194***	(3.30)	3.199***	(3.31)	3.174***	(3.28)
Pilot×Year2004	-1.524	(-0.67)								
Pilot×Year2005	-1.229	(-0.54)								
Pilot×Year2006	-1.054	(-0.46)								
Pilot×Year2007	-0.817	(-0.36)								
Air Pollution Control in Key Areas during Twelfth Five Year Plan			0.168	(0.17)						
Sulfur dioxide Emission Trading Policies					-1.338	(-1.19)				
Carbon Emission Trading Policies							0.351	(0.34)		
Chinese Ambient Air Quality Standards 2012									-2.187**	(-2.16)
Constant	-104.269***	(-16.03)	-104.604**	(-16.10)	-104.383***	(-16.07)	-104.698***	(-16.10)	-103.896***	(-15.99)
Controls	YES		YES		YES		YES		YES	
Observations	15246		15246		15246		15246		15246	
R-squared	0.396		0.396		0.396		0.396		0.396	
Individual FE	YES		YES		YES		YES		YES	
Year FE	YES		YES		YES		YES		YES	
Industry FE	YES		YES		YES		YES		YES	

Notes: the standard errors are in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. B, SE and FE stands for Beta, Standard Error and Fixed Effect respectively.

Table 8 The results of other robustness tests.

Variables	Add city fixed effect Model 1		Replace dependent variable Model 2		Change policy shock time Model 3	
	B	SE	B	SE	B	SE
DID	1.965**	(2.10)	2.205***	(3.88)		
DID_{T-1}					2.328*	(1.92)
SIZE	2.822***	(5.89)	2.418***	(15.43)	4.915***	(18.46)
AGE	2.298*	(1.71)	0.041	(0.09)	0.201	(0.26)
TobinQ	-0.383*	(-1.75)	0.321**	(2.47)	0.714***	(3.23)
LEV	4.157*	(1.82)	-2.278*	(-1.80)	-3.597*	(-1.67)
ROA	-0.192	(-0.09)	-2.095	(-1.48)	-3.199	(-1.33)
CAP	-0.084	(-0.17)	-0.912***	(-4.05)	-1.798***	(-4.69)
FIR	-0.033	(-1.15)	-0.016	(-1.50)	-0.044**	(-2.45)
IND	6.266	(1.20)	2.881	(1.01)	-0.925	(-0.19)
Constant	-65.093***	(-6.03)	-51.735***	(-13.59)	-103.728***	(-15.98)
Observations	15246		15246		15246	
R-squared	0.620		0.401		0.395	
City FE	YES		NO		NO	
Individual FE	YES		YES		YES	
Year YES	YES		YES		YES	
Industry FE	YES		YES		YES	

Notes: the standard errors are in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. B, SE and FE stands for Beta, Standard Error and Fixed Effect respectively.