**RESEARCH ARTICLE**

# Central environmental inspection and corporate environmental investment: evidence from Chinese listed companies

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## Abstract

As a new type of environmental policy, the central environmental inspection (CEI) policy is an important innovative strategy in economic transition. Using the panel data of Chinese listed companies from 2011 to 2018, we apply the extended STIRPAT model to examine the direct impact of CEI policy on corporate environmental investment and its heterogeneity effects. The main findings are as follows: (1) The CEI policy has a positive influence on the environmental investment of all listed companies. (2) The promotion effect of CEI policy is quite different among five-round campaigns; while companies in later rounds fails to learn some experiences and lessons from the earlier rounds. (3) Due to the differences in property rights, industries, and environmental situations, the positive effect of CEI policy will be more significant in non-SOEs, companies in non-heavy-pollution industries, and companies in provinces with poor environment performance. This study supplements the research of environmental regulations, potentially contributing to the next stage of green and sustainable development in China.

**Keywords** Central environmental inspection · Environmental investment · Environmental policies · Sustainable development · Responsible editor: Eyup Dogan

## Introduction

Since economic globalization in the twentieth century, the world economy has maintained a prosperous development for several decades (Lucas 2009). However, the climate change and environmental pollution problems induced by rapid economic development has caused a great threat to our human lives (Watts et al. 2018). In order to reduce the negative externality of economic activities, countries around the world have reached number of agreements such as the Paris Agreement,[1] and also made up their own environmental policies. After several years of practices, environmental policies have been proved to be effective in addressing global climate changes and environmental pollutions (Ju and Fujikawa 2019). According to different purposes, the designs and effects of environmental policies can be varied in countries (Elmore 1979; Naughton 2017; Xi et al. 2018; Xie et al. 2017).

The Ministry of Ecology and Environment of China (MEE) has issued the central environmental inspection (CEI) policy in 2016,[2] which is regarded as a particularly important innovative strategy in the transition process of environmental governance (Li et al. 2020; Zhang et al. 2018). Unlike previous regulations, this is the first time that the environmental policy is carried out with detailed descriptions of institutional framework, procedural norms,

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[1] Retrieved from the United Nations Framework Convention on Climate Change. http://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement. Last accessed 28 January 2022.

[2] Some researches also use the name of central environmental protection inspection (CEPI) policy; we will use CEI policy as its abbreviation in this study.

and legal responsibility. According to MEE, there are five rounds of CEI policy, among which the pilot round campaign in Hebei province has received more than 135,000 complaints from the public, imposed penalties on 29,000 firms, and held 18,199 officials accountable.[3] In sum, this is a novel and high-profile environmental policy with Chinese unique characteristics and practical experiences.

Although the importance and effectiveness of CEI policy have been widely proved in practices, there are relatively little research on it, let alone from the micro-firm level. On the one hand, most of the studies about CEI policy has paid attention to its effect on environmental performance, e.g., air pollution (Jia and Chen 2019; Kou et al. 2021; Lu 2022; Wang et al. 2021a, b, c; Zheng and Na 2020; to name but a few). Needless to say, the main function of CEI policy is to protect the environment. Based on different scales of data, all these researches have found that CEI policy can effectively improve air quality by reducing the pollution such as $PM_{2.5}$ and $PM_{10}$. On the other hand, some studies have focused on the topic of environmental governance (Li et al. 2020; Zhang and Li 2020). As a supplement to other types of environmental regulations, CEI policy can enhance the government's ability to protect the environment.

However, what reactions will companies make when faced with CEI policy? As one of the main culprits of environmental pollution, it will be necessary to explore and analyze how a company responds to CEI policy. Currently, the researches about company reactions are relatively limited, and only a few studies have discussed corporate economic performances. As for the stock price, Tian et al. (2019) and Zeng et al. (2021) pointed out that the CEI policy could send some negative signals to the capital market, which would cause negative abnormal returns to companies. In terms of other indirect influences, Wang et al. (2021a, b, c) and Yu et al. (2021) paid attention to corporate total factor productivity and tax avoidance activities, respectively. The conclusions also showed that the CEI policy has led to the closure of a large number of high-pollution companies.

Compared with previous research, this study explores the direct impacts of CEI policy on corporate environmental investment by extended STIRPAT model. Firstly, in order to deal with the strict environmental requirements of CEI policy, the companies have to reduce or eliminate their influences on the environment, which indicates that they have to put great efforts into making sure that their business projects will meet the minimum requirement of CEI policy. On that basis, environmental investment will be regarded as the active behavior of companies under the pressure of environmental regulations. Secondly, as for the economic

performances such as the stock price, the environmental investment could serve as a positive signal to society, which will attract investors and increase companies' social reputations. Based on these two reasons, it will be important and necessary to study how corporate environmental investment changes under the CEI policy.

This study may supplement the research of environmental regulations by exploring the direct impact of CEI policy on corporate environmental investment and its heterogeneity effects. It is found that the CEI policy has a positive influence on the environmental investment of all listed companies, while the effect may be different due to property rights, industries, and so on. As a result of that, it is necessary and important to build a normalized and legalized environmental protection system in the future.

The rest of this study proceeds as follows: "Theoretical analysis" provides a theoretical analysis aiming to build up the foundation of this research. "Research design" introduces the research design, including evaluation method and sample data, and our empirical results are presented in "Empirical results," followed by discussion and concluding remarks in "Conclusion."

## Theoretical analysis

As the largest developing country worldwide, China has attracted substantial attention with its rapid economic growth (Allen et al. 2005; Liang and Teng 2006; Riedel et al. 2020; Yao 2006; Yu 1998; to name but a few). Meanwhile, the environmental problems that arise during economic development are also thought-provoking (Ahmed et al. 2020; Chai et al. 2021; Wang et al. 2021a, b, c; to name but a few). Since the "reform and opening up," China's rapid economic growth has been accompanied by severe problems such as resource wastage, low efficiency, and environmental pollution. The Chinese government has placed the ecological environment, especially air pollution, on the agenda to achieve sustainable development and high-quality growth. Since 2013, the Chinese government has successively promulgated lots of laws to improve environmental quality.

In China, most laws and regulations are based on its unique top-down political system, which is quite useful and effective in practices (Dou and Qi 2019; Jia et al. 2021). In other words, the central government usually dominates the top-level framework designs of policies, while the local governments will assume the specific responsibility for their implementations (Tian et al. 2019). However, there will be some agent problems when economic development goals conflict with environment protection targets (Yu 2016). Generally speaking, local officials can be promoted more quickly if they achieved greateconomic development (Jia et al. 2021; Kong et al. 2018; Meng et al. 2019). As a result, local governments tend to enforce environmental policies

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[3] Retrieved from the Ministry of Ecology and Environment of China (MEE). https://www.mee.gov.cn/ywgz/zysthjbhdc/. Last accessed 28 January 2022.

less strictly as long as they will cause some losses to the local economy, especially for those companies who have contributed to local economic development (Li et al. 2020). As the primary source of local fiscal revenue, companies with high pollution may be less likely to be punished by the government, which will reduce the positive effects of environmental policies. Therefore, it will become extremely necessary to change this phenomenon.

Although there are lots of environmental regulations, the agent problem still cannot be solved fundamentally until the implementation of the CEI policy. Under the framework that "the Party committee and government department share common responsibility",[4] the main purpose of CEI policy is to make all local officials pay attention to the ecological environment in essence (Jia and Chen 2019; Pan and Yao 2021; Wang et al. 2021a, b, c). As a new type of environmental policy, the CEI policy has shifted and enhanced the environmental responsibility from "government departments" to "local companies"," and then to "the Party committe". As an essential participant in economic activities, companies will receive more business pressures under the environmental requirements of CEI policy.

One the one hand, corporate environmental investment might be increased involuntarily. The CEI policy uses the power and rights authorized by the central government to punish high-pollution companies, that is to say, these companies can no longer be protected by the local government (Tian et al. 2020; Wang and Shen 2016). After all, the local government itself could also be accountable if there are some ultra vires behaviors (Chen et al. 2021; Wang et al. 2021a, b, c). Moreover, although it is newly campaign-style enforcement, the CEI policy also has the characteristics of other normal environmental regulations (Kostka and Mol 2013; Kostka and Zhang 2018). Specifically, compared with other regulations, the CEI policy have more environmental requirements to the companies. Furthermore, the pollution shelter hypothesis tells us that environmental regulations will increase the additional production costs of companies (Farrell 1987; Schwartz 2020). Therefore, companies will tend to carry out their business activities in regions with less strict regulations (Li et al. 2021). Nevertheless, this behavior of evading regulations is no longer practical due to the campaign-style enforcement of CEI policy. The random but comprehensive selection of provincial regions for environmental inspection makes it impossible for enterprises to

evade regulations in the short term. In this sense, companies have to increase their environmental investment to improve environmental performance and avoid penalities.

On the other hand, companies tend to increase their investment in enviornmental protection voluntarily. Porter (1991b) proposed that environmental regulations can strengthen companies' innovation output during the production process, and the profits from innovation can eventually offset the costs and losses due to the compliance with environmental regulations (Deephouse and Suchman 2008; Suchman 1995). Traditional economic theory holds the view that environmental policies may hurt economic growth. In other words, implementing environmental regulations may improve environmental quality; it will also increase companies' production costs, which could affect other business activities and reduce their competitiveness. However, the Porter hypothesis argues from an innovation perspective that well-designed environmental policies may induce innovation, which may partially offset the costs of compliance with environmental regulations (Porter 1991a). This indicates that environmental regulations could also promote innovative activities, which motivates companies to enhance environmental investment in polllution mitigation and green innovation. In sum, we may simply propose the assumption that under the pressure of CEI policy, companies would increase their environmental investment to improve the ability to alleviate adverse environmental impacts.

# Research design

## Sample data

All data in this study are collected from Chinese A-share listed companies. First, as for the dependent variable, we manually collect the firm-level environmental investment ($EI_{i,t}$) from annual financial reports. The investment information is disclosed under the item of "construction in progress", and those projects related to desulfurization, denitrification, waste gas treatment, and energy-saving will be regarded as the environmental investment (Johnston 2005; Zhang et al. 2019).

Second, we choose the following control variables from China Stock Market and Accounting Research Database (CSMAR)[5] based on relevant research. (1) Firm size ($Size_{i,t}$): According to the marginal cost theory, large companies can reduce production cost by scale effect, which may have more investment activities than others. We use the total asset to measure the firm size (Dong et al. 2022; Zhang et al. 2019). (2) Financial leverage ($Lev_{i,t}$): The financial risk will have a

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[4] In China, there are two important persons in all level's government; one is the head of the government departments; the other is the secretary of the Party committee. In the past, it is the head of government departments that takes responsibility for environmental governance. However, the CEI policy requires the secretary of the Party committee to undertake the work for environmental protection. As a result of that, the Party committee and government department will share the common responsibility for local environment.

[5] China Stock Market and Accounting Research database (CSMAR) is one of the largest and most accurate financial and economic databases in China. Retrieved from CSMAR Database. https://www.gtarsc.com/. Last accessed 25 January 2022.

**Table 1** Descriptive statistics and sources of variables

| Variable | Definition | Obs | Mean | SD | Min | Max | Source |
|---|---|---|---|---|---|---|---|
| Policy | Central environmental inspection | 2092 | 0.59 | 0.07 | 0.00 | 1.00 | MEE |
| EI | Environmental investment | 2092 | 4.56 | 0.04 | 0.00 | 10.13 | Author |
| Size | Company size | 2092 | 22.43 | 0.02 | 19.94 | 26.27 | CSMAR |
| Lev | Financial leverage | 2092 | 0.46 | 0.00 | 0.05 | 0.91 | CSMAR |
| Agen | Agency cost | 2092 | 0.14 | 0.00 | 0.01 | 0.80 | CSMAR |
| Mang | The proportion of senior managers | 2092 | 0.05 | 0.00 | 0.00 | 0.68 | CSMAR |
| Earn | Stock returns | 2092 | 0.36 | 0.01 | -1.40 | 8.91 | CSMAR |
| Ten | The proportion of the top ten shareholders | 2092 | 0.57 | 0.00 | 0.22 | 0.92 | CSMAR |
| SOE | State-owned enterprises | 2092 | 0.50 | 0.01 | 0.00 | 1.00 | CSMAR |

This table reports the descriptive statistics and sources of each variable. The dataset contains annual data for Chinese A-share listed companies from 2011 to 2018.

certain influence on investment activities, and we use debt to asset ratio to measure financial leverage level (Wen et al. 2018). (3) Agency cost ($Agen_{i,t}$): Calculated by administrative expenses, the agency costs measure the expenditure between shareholders and managers (Luo et al. 2018). (4) The proportion of senior managers ($Mang_{i,t}$): The companies with more senior managers in an appropriate range may have a better ability to deal with environmental issues (Dezsö and Ross 2012). (5) Stock returns ($Earn_{i,t}$): It measures the basic business performance of a company (Howell 2016). (6) Ownership ($Ten_{i,t}$): This variable measures the proportion of the top ten shareholders. (7) State-owned enterprises ($SOE_{i,t}$): The value of this variable will be 1 if it is an SOEs. Coase (1981) illustrated that some externality problems such as environmental pollutions could be alleviated if there is a clear definition of property rights.

Moreover, we clean the data as follows: (1) Due to the reason that the environmental investment information is not mandatorily required to be disclosed in annual financial reports, some listed companies choose not to disclose it, so we delete these companies from our sample. (2) When the net profit of is negative for two consecutive years, the China Securities Regulatory Commission will add "ST" to its stock name. If the financial performance does not improve in the third year, the "*ST" will then be added.[6] Since these two types of companies have a relatively high business risk, we delete them from our sample. (3) As for the missing values for some variables, we will use the linear interpolation method to replace the null values (Chen 2014). If the missing values cannot be replaced and fixed by this method, we delete them from our sample. (4) We minorize (winsorize) the extreme values to a 1% tailing. (5) Due to the financial crisis in 2008 and data availability for environmental

investment, we choose the data from 2011–2018. Frankly speaking, before 2011, there were few companies that chose to disclose the environmental investment information. We have manually collected all the firm-level environmental investment data to our best. (6) To reduce the heteroscedasticity problems, all variables are in natural logarithm form if applicable. The descriptive statistical results of all variables are shown in Table 1.

## Empirical model

Due to the complex relationship in the environmental and economic system, it will become challenging to assess the effect of environmental policies by the structural econometric model (Low and Meghir 2017). Therefore, the reduced form of the econometric model has been widely used to estimate the average treatment effect (ATE) in practices (Athey and Imbens 2017; Feng et al. 2017), such as ordinary least squares (OLS) analysis, instrumental variable (IV) estimation, natural experiment, and randomized controlled trials (RCTs). Proposed by Ehrlich and Holdren (1971) and Dietz and Rosa (1994; 1997), the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model is regarded as an effective method to estimate the relationship between economic activities and environmental behaviors (Acheampong et al. 2019; Solarin 2020). Based on previous research, our study construct the following extended STIRPAT model in Eq. (1), which is also an OLS model in essence.

Proposed in 2016, the CEI policy chooses Hebei province as the pilot round campaign without any advance announcement, and then it covers the other 30 provinces within a very short time. As for companies, the CEI policy could be regarded as an unexpected external shock that the companies have to adjust their business patterns although they may not be willing to accept this environmental regulation. Those high-pollution companies will be punished with a large amount of money if they cannot reduce the negative

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**Table 2** Basic information of each round campaign of CEI policy

| Round | Time | Covered provinces |
|---|---|---|
| 0 (Pilot) | 2016 Jan 04–2016 Feb 05 | Hebei |
| 1 | 2016 Jul 12–2016 Aug 19 | Inner Mongolia, Heilongjiang, Jiangsu, Jiangxi, Henan, Guangxi, Yunnan, Ningxia |
| 2 | 2016 Nov 24–2016 Dec 30 | Beijing, Shanghai, Hubei, Guangdong, Chongqing, Shaanxi, Gansu |
| 3 | 2017 Apr24–2017 May 28 | Shanxi, Anhui, Tianjin, Hunan, Fujian, Liaoning, Guizhou |
| 4 | 2017 Aug 07–2017 Sept 15 | Jilin, Zhejiang, Shandong, Hainan, Sichuan, Tibet, Qinghai, Xinjiang |

**Table 3** Effect of CEI on environmental investment and baseline estimations

|  | (1) EI | (2) EI | (3) EI | (4) EI | (5) EI | (6) EI |
|---|---|---|---|---|---|---|
| Policy | 0.143* (0.077) | −0.247 (0.314) | 0.562* (0.294) | 0.387* (0.159) | 0.070 (0.136) | 0.325* (0.189) |
| Size | −0.958*** (0.045) | −1.181*** (0.180) | −1.046*** (0.071) | −1.011*** (0.053) | −0.839 (0.106) | −0.736*** (0.070) |
| Lev | −0.135 (0.228) | 0.228 (0.573) | 0.397 (0.436) | 0.307 (0.264) | −1.045 (0.564) | −0.740** (0.331) |
| Agen | 2.580*** (0.479) | 2.149 (1.374) | 1.624*** (0.968) | 3.521*** (0.539) | 1.791 (0.837) | 4.254*** (0.691) |
| Mang | −0.573 (0.341) | −1.665 (1.558) | −0.431 (1.003) | −0.328 (0.454) | −0.319 (1.173) | −0.902* (0.524) |
| Earn | −0.157*** (0.052) | 0.088 (0.147) | −0.274 (0.051) | −0.144 (0.115) | −0.288 (0.047) | −0.065 (0.084) |
| Ten | −0.278 (0.229) | 0.644 (0.991) | −0.733 (0.419) | 0.137 (0.403) | −1.008 (0.653) | 0.230 (0.377) |
| SOE | 0.029 (0.068) | 0.049 (0.438) | 0.022 (0.108) | −0.040 (0.151) | 0.241 (0.164) | −0.072 (0.113) |
| Frim_FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Year_FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Cluster | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 2092 | 79 | 564 | 600 | 354 | 495 |
| Adjusted R2 | 0.545 | 0.794 | 0.582 | 0.581 | 0.613 | 0.458 |

This table reports *baseline* estimations of *CEI* on *environmental investment*. All the regressions are clustered at target firm level. All the regressions include firm fixed effect and year fixed effect. Standard error statistics are presented in parentheses.

*Significance levels of 10%; **significance levels of 5%; ***significance levels of 1%

environmental externality. Actually, the pilot round environmental campaign has imposed penalties on 29,000 companies with 1.43 billion RMB in less than a month, which also support our external opinion about CEI policy:

$$EI_{i,t} = \alpha + \beta Policy_{i,t} + \theta X_{i,t} + u_i + \sigma_t + \varepsilon_{i,t} \qquad (1)$$

As can be seen in Eq. (1), $i$ denotes company and $t$ represents time. (1) $Policy_{i,t}$ is a dummy variable which represents the implementation of CEI policy. With the help of difference-differences method, we adjust the setting of the independent variable in STIRPAT model. If company $i$ is located in the policy campaign area in year $t$, the value of $Policy_{i,t}$ will be set to 1. Specifically, we use the real business operation location of companies to identify which provinces they belong to. The basic information of each round campaign of CEI policy is shown in Table 2.[7] $\beta$ is the coefficient representing the average effect of CEI policy. (2) $EI_{i,t}$ is the dependent variable which represents the environmental investment of company $i$ in year $t$. (3) $X_{i,t}$ is a set of all control variables, and $\theta$s are their coefficients. (4) $\alpha$ is the constant term, and $\varepsilon_{i,t}$ is the error term (residual term). $u_i$ and $\sigma_t$ may indicate firm fixed effect and year fixed effect, respectively.

## Empirical results

### Benchmark analysis

The benchmark results are shown in Table 3. Column (1) represents the overall effect of CEI policy ($Policy_{i,t}$) on environmental investment ($EI_{i,t}$). It can be found that the coefficient of our independent variable ($Policy_{i,t}$) is significantly positive, indicating that CEI policy has improved corporate environmental investment by 14.3%. On the one hand, real-time monitoring and frequent re-inspections under the pressure of CEI policy increase the pollution costs of companies (Tian et al. 2019). When companies are

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[7] Retrieved from the Ministry of Ecology and Environment of China (MEE). https://www.mee.gov.cn/ywgz/zysthjbhdc/. Last accessed on 25 January 2022.

**Table 4** Effect of CEI on environmental investment, heterogeneity estimations

|  | (1) *SOEs* | (2) *Non-SOEs* | (3) *High-pollution* | (4) *Low-pollution* |
|---|---|---|---|---|
| *Policy* | 0.123 (0.112) | 0.274*** (0.079) | 0.126 (0.132) | 0.163* (0.085) |
| *N* | 1054 | 1038 | 888 | 1204 |
| Adjusted $R^2$ | 0.583 | 0.455 | 0.569 | 0.534 |

This table reports *heterogeneity* estimations of *CEI* on *environmental investment*. To conserve space, this table only shows the results of independent variable and other necessary statistics; others are consistent with Table 3.

proven to be responsible for local pollutions, they need to pay a large number of penalties, which may require higher costs to business operations. Therefore, companies would choose to eliminate the potential pollution by increasing their investment in environmental protection. On the other hand, the environmental investment helps companies build a good reputation among the public. Socially responsible investment (SRI) theory holds the view that environmental investment may serve as a credible signal that companies are committed to protecting the environment (Oehmke and Opp 2020). Under the CEI policy, companies would obtain a good social reputation if they choose to conduct climate- and environment-friendly activities.

There are five round campaigns of CEI policy, and the results are shown in columns (2)–(6). Generally speaking, although companies in later round campaigns may learn some experiences and lessons from the earlier rounds, there is no obvious evidence supporting the "learning effect" in CEI policy. Column (2) represents the result of pilot round campaign in Hebei province; it can be found that the coefficient of CEI policy cannot meet the minimum significant requirement. Due to lack of experience, companies in Hebei province do not pay enough attention to this new environmental regulation. In practice, 29,000 companies were punished in just 1 month, possbily due to the challenges for Hebei province to adjust their production structures of high-polluted companies during a short time. The results in columns (3), (4), and (6) show that the later round campaigns have a significantly positive effect on environmental investment ($EI_{i,t}$), suggesting that companies in these provinces have learned some lessons from the earlier campaigns. Although they cannot get the information about the starting time of CEI policy, they can conduct a series of environmentally-friendly business activities to prepare for it.

However, the coefficient of CEI policy in column (5) is not significantly positive, indicating that the "learning effect" is not robust and the CEI policy still has a strong external characteristic. Despite the fact that companies can hedge some environmental pressures from the experiences they have learned, the CEI policy still has a punishment effect that the companies in later round campaigns have to put more efforts to protect the environment.

## Heterogeneity analysis

### SOEs and industries

Due to the differences of property rights and industrial structure, the overall effect of CEI policy ($Policy_{i,t}$) on environmental investment ($EI_{i,t}$) is significantly different. We use sub-sample estimations to explore these two heterogeneity effects; the results are shown in columns (1)–(4) of Table 4.

First, compared with non-SOEs, SOEs have a relatively closer political relationship to the government, which may lead to the effectiveness reduction of environmental regulations. The results of SOEs and non-SOEs are represented in columns (1) and (2), respectively. It can be found that the CEI policy does not significantly increase the environmental investment ($EI_{i,t}$) of SOEs. On the one hand, although the CEI policy is designed under the framework of "the Party committee and government department share common responsibility," it cannot change the original social and political status of SOEs, which suggests a better business position of SOEs. Besides, profit maximization should not be the business priority for SOEs; they are expected to undertake some social responsibilities. Therefore, SOEs have less motivation to increase additional environmental investment.

Generally speaking, the sector with severe-overcapacity, high-pollution, or high-consumption characteristics will be regarded as "two high and one surplus" industry. According to the Industrial Classification for National Economic Activities,[8] we get the classification code for two high and one surplus industry, and then divide the whole sample into high-pollution and low-pollution industries (Costantini et al. 2013; Gutiérrez and Teshima 2018; Tian et al. 2019). The results are represented in columns (3) and (4), respectively. It can be found that the coefficient of CEI policy in column (3) cannot reach the significant requirement. This rather contradictory result may be due to the efficient campaigns in the short time of CEI policy. Although these companies want to adjust their production structure and reduce the

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**Table 5** Effect of CEI on environmental investment and heterogeneity estimations

|  | (1) Low-$PM_{2.5}$ | (2) High-$PM_{2.5}$ | (3) Low-$CO_2$ | (4) High-$CO_2$ |
|---|---|---|---|---|
| *Policy* | 0.177 (0.146) | 0.159* (0.080) | 0.112 (0.110) | 0.197* (0.101) |
| *N* | 891 | 1189 | 1146 | 925 |
| Adjusted R2 | 0.529 | 0.562 | 0.596 | 0.490 |

This table reports *heterogeneity* estimations of *CEI* on *environmental investment*. To conserve space, this table only shows the results of independent variable and other necessary statistics; others are consistent with Table 3

environmental pollution, they cannot finish all the transformations in a short time. The CEI policy may still punish them. The first goal of these companies is to stop some high-pollution productions, and then put the efforts into environmental investment and protection.

## PM$_{2.5}$ and CO$_2$

Furthermore, the environmental performance such as air quality and carbon emissions in each province may also influence corporate resonses to CEI policy. The province with more companies, especially the high-pollution companies, may have a worse environmental situation than other areas. We also use sub-sample estimations to explore these two heterogeneity effects; the results are shown in columns (1)–(4) of Table 5.

Columns (1) – (2) show the sub-sample estimation results of PM$_{2.5}$ level and columns (3)–(4) show that of CO$_2$ emissions. By comparison, we can find that the coefficient of CEI policy is more significant among the provinces with higher PM$_{2.5}$ CO$_2$ emissions. On the one hand, as the most direct evidence, the environmental pollution can be observed by the public. The PM$_{2.5}$ level or CO$_2$ emissions will increase to a high value if there are heavy pollutions in a short time. Therefore, the central government will also pay attention to these areas even if there is no CEI policy. Companies in these provinces may have a stronger internal incentive to reduce the negative externality influence on the environment, which may lead to a more significant result of CEI policy. On the other hand, there are indeed more companies in industrial regions like Tianjin province, which could also enhance the average effect of CEI policy. As can be seen in column (1) of the table, the benchmark result of CEI policy on environmental investment is 14.3%, which is relatively lower than that of columns (2) column (4) in Table 5.

## Instrumental variable estimation

This study finds that the CEI policy could help listed companies increase their investment in environmental protection projects. However, companies who pay attention to environmental protection may also be active in implementing national-level policies. There may be a two-way causal relationship between the CEI policy and environmental investment. We attempt to address the issue by finding instrumental variables. The CEI policy aims to promote the transformation of economic development, so that adequate preparations can be made for the next stage of high-quality and sustainable economic development. Based on Acemoglu et al. (2001) who used historical data as instrumental variables, we use the investment environment index (*INV*) as an instrumental variable. This data is calculated by Ant Technology Group Co., Ltd.

On the one hand, as institutional evaluation data, the regional investment environment cannot directly affect the environmental investment of listed companies. On the other hand, the frequent or severe changes of the regional investment environment will attract the central government's attention because it may represent local economic performance. Although the CEI policy can be regarded as an external shock for companies, the exact rounds and time for each province might be influenced by the local economic environment. That is to say, if there is a relatively better regional investment environment for a province, it may have a good economic resilience when faced with national policies; the central government would be more likely to implement environmental policies such as the CEI policy. Based on the above two points, the investment environment index satisfies the requirements of exogeneity and relevance of instrumental variables.

**Table 6** Instrumental variable estimations

|  | (1) First stage | (2) Second stage |
|---|---|---|
| *INV/Policy* | 0.023*** (15.14) | 0.247*** (6.35) |
| *N* | 2092 | 2092 |
| Anderson Canon. Corr. LM statistic | 146.281*** | – |
| Cragg-Donald Wald F statistic | 151.68 > 16.38 | – |
| Hansen J statistic | 0.000*** | – |

This table reports *instrumental variable* estimations of *CEI* on *environmental investment*. To conserve space, this table only shows the results of independent variable and other necessary statistics; others are consistent with Table 3.

**Table 7** Effect of CEI on environmental investment and alternative estimations

|  | (1) *EI* | (2) *EI* | (3) *EI* |
|---|---|---|---|
| *Policy* | 0.143 (0.097) | 0.145* (0.077) | 0.146* (0.079) |
| *N* | 2092 | 2055 | 2051 |
| Adjusted $R^2$ | 0.545 | 0.545 | 0.543 |

This table reports *alternative* estimations of *CEI* on *environmental investment*. To conserve space, this table only shows the results of independent variable and other necessary statistics; others are consistent with Table 3

The estimation results of two-stage least squares (2SLS) are shown in Table 6. It can be found that after using the instrumental variables, the coefficient of the independent variable ($Policy_{i,t}$) maintains significantly positive and changes slightly due to local average treatment effects. The three tests of instrumental variables show that there are no obvious problems such as over-identification, under-identification, and weak instrumental variables (Larcker and Rusticus 2010). In sum, this result may eliminate the concern of two-way causal relationship to some extent.

### Alternative estimations

In order to increase the robustness of our conclusions, we have carried out other estimations. First of all, we conduct a falsification estimation. Specifically, we advance the time of CEI policy by 2 years; the results are presented in column (1) of Table 7. It shows that there is no noticeable effect of CEI policy on environmental investment before CEI implementation, which may prove the external characteristics of this policy on the one hand and also illustrate the reliability of our baseline results on the other.

Secondly, considering the possible influence of some province-level municipality areas (Beijing, Shanghai, Tianjin, and Chongqing), we delete them from our sample for robustness estimation in column (2). Besides, the benchmark results have shown that companies in later round campaigns may learn some experiences and lessons from the earlier rounds; we also delete the pilot round campaign in Hebei province in column (3). The results show that the independent variable ($Policy_{i,t}$) maintains significantly positive without obvious changes, which supports the robustness of our benchmark analysis.

### Conclusion

Since the twentieth century, climate change and environmental pollution problems have caused great harm to human beings. With the outbreak of the COVID-19 pandemic at the

end of 2019, the whole society has paid attention to environmental protection and sustainable development. As an important participant in social activities, companies' development is not only associated with economic advancement, but also with climate and environment. Using the panel data of Chinese listed companies from 2011 to 2018, we apply the extended STIRPAT model to examine the direct impact of central environmental inspection (CEI) policy on corporate environmental investment and its heterogeneity effects.

The main findings are as follows: (1) The CEI policy has a positive influence on environmental investment of all listed companies with an average treatment effect of 14.3%. (2) The promotion effect of CEI policy is quite different among five round campaigns, while there is no obvious "learning effect" in CEI policy because of its external characteristic. (3) Due to the differences inproperty rights, industries, and environmental situations, the positive effect of CEI policy is more significant in non-SOEs, non-heavy-pollution industries, and provinces with poor environmental performance. (4) The result of companies in heavy-pollution industries may be confusing, but it still makes sense considering the external and high-efficiency characteristics of CEI policy. Although these companies want to adjust their production structure and reduce the environmental pollution, they cannot finish all the transformations in a short time. Therefore, the positive effect of CEI policy on environmental investment is insignificant.

The policy implications of the above conclusions are obvious: (1) It is necessary to strengthen and promote the CEI policy. Currently, although the five-round campaigns have covered all provinces in China, there are several ways to enhance its effect. The central government can assign a higher level official to be the head of this policy, increasing the politic power to governance environment. (2) It is important to build a nationally normalized environmental protection system. As a supplement to other types of environmental regulations, CEI policy can play the role tighter with other policies. The central government can build a multi-level and normalized environmental protection system by combining all these environmental regulations. (3) As for different provinces and cities, it would be helpful to implement the CEI policy with various degrees of strictness.

Needless to say, this study has some limitations. First, there may be a bias in the sample selection. Since data on environmental investment are only available from the annual financial reports, we have manually collected all the firm-level environmental investment data to our best. More importantly, before 2011, few companieschose to disclose their environmental investment information. Secondly, due to data limitation, it is impossible to distinguish between regulatory and voluntary environmental investment. As for future research, we will try our best to get relatively

comprehensive sample data. Currently, the data used in this study is the best we can get right now.

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