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**Article**

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# How does smog affect firms' investment behavior? A natural experiment based on a sudden surge in the PM2.5 index



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## ABSTRACT

This study examines the effect of environmental regulations on the investment behavior of high-polluting enterprises. Our data are from A-share listed firms in China from 2006 to 2014. We use a sudden surge in the PM2.5 index as an exogenous event to conduct a natural experiment. We find that after the event with a series of regulatory policies introduced, investment expenditure declines significantly in local state-owned enterprises (SOEs) and non-state-owned enterprises (non-SOEs), whereas investment opportunity declines significantly in non-SOEs compared with SOEs. However, there are no significant changes in central SOEs' investment expenditure and investment opportunity. Further analysis shows that investment expenditure and investment opportunity decline for high-polluting enterprises located in East China but increase for those located in West China. Our study is the first to investigate the effect of smog on enterprises' investment behavior. Our findings reveal that environmental regulation has influence on the investment behavior of enterprises with different property rights and regional differences.

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## 1. Introduction

The relationship between economic growth and environmental quality has been a major discussion topic for both scholars and the public. China's rapid economic growth has given rise to many environmental pollution problems, and the resulting environmental degradation has become a threat to the Chinese economy. Recent increases in smog and PM2.5 concentrations have also drawn the attention of the Chinese scholars on

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environment and corporate behaviors. As the sudden surge in the PM<sub>2.5</sub> index at the end of 2011 is of particular importance, we hereafter use the term “2011 event” to refer to it.

Ecological environment and environmental pollution are the most important factors that influence China’s sustainable economic development and living environment (Tian and Cheng, 2014). China’s Ministry of Environmental Protection and provinces with severe smog problems adopted strict environmental regulations after the 2011 event. The new National Ambient Air Quality Standard and the relevant governance regulations put the operational and investment behavior of high-polluting enterprises under close monitoring. The State Council of China released the “Action plan on air pollution control on 12 September 2013” with the implication that air pollution governance has ushered in new demand and a source of external pressure on the transformation of economic development pattern. The plan sets out the specific responsibilities of the government, enterprises and society and has caused the approval of key projects in underdeveloped regions to be suspended. However, there is no evidence that the strengthening of environmental regulations after the 2011 event has had any effect on enterprises’ financial behavior.

China is the world’s largest developing country. In the course of its modernization and industrialization, it has inevitably faced tension between economic growth and environmental quality. Pollution abatement may impose additional pollution treatment costs, thus reducing the productivity and market competitiveness of enterprises (Jorgenson and Wilcoxon, 1990). Gray (1987) finds that U.S. Occupational Safety and Health Administration and Environmental Protection Agency regulations reduced productivity growth in the manufacturing industry by an average of 0.44 percentage point per year, accounting for over 30 percent of the slowdown in the 1970s. Consistent with Gray (1987), other studies draw similar conclusions based on sub-manufacturing industries such as paper-making, mining, oil and steel (Gollop and Roberts, 1983; Barbera and McConnell, 1990; Gray and Shadbegian, 1995). Grimaud and Rouge (2008) argue that environmental regulation is similar to an environmental tax on non-renewable resources. Although it can slow the emission of pollutants and improve resource allocation, it has no effect on R&D or innovations in abatement technology. In contrast, Porter and Van Der Linde (1995) find that properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them and that strict environmental regulations can actually enhance competitiveness. Palmer et al. (1995), however, hold an opposing view that strict environmental regulations can bring much more cost less than the benefit. Berman and Bui (2011) examine the effect of air quality regulations on productivity in some of the most heavily regulated manufacturing plants in the United States. They study the oil refineries of the Los Angeles (South Coast) Air Basin and find that despite the high costs associated with the local regulations, productivity rose sharply between 1987 and 1992. As the years between 1987 and 1992 were a period of decreased refinery productivity in other regions, the authors conclude that abatement cost measures may grossly overstate the economic cost of environmental regulations because such measures can increase productivity. This paper uses different data, such as Mexican offshore oil and gas industry, Japanese manufacturing, Quebec (Canada) manufacturing and Taiwan industry data, and draws similar conclusions. Obviously, the literature has not yet reached a consensus about the effects of environmental regulations on enterprises, and neither does it provide evidence of or an explanation for the micro mechanism of air pollution and enterprises’ investment behavior.

With improving living standards and increasing environmental awareness, protection of the environment is now widely considered a stable and influential social norm (Green, 2006). The 3rd plenary session of the 18th Communist Party of China Central Committee proposed the establishment of a comprehensive ecological civilization system to protect the ecological environment. This provides us with an opportunity to analyze the effect of strict environmental regulations on enterprises’ investment behavior and the underlying mechanism that brings about this effect; thus, this study has strong theoretical value and policy implications.

We use the difference-in-differences method to investigate the effect of government environmental regulations on high-polluting enterprises’ investment behavior (investment expenditure and investment opportunity sensitivity) based on Chinese A-share listed firms from 2006 to 2014 and examine whether the effect varies across property rights, enterprise locations and high-polluting enterprises. We find that after the 2011 event, investment expenditure declined significantly in both local SOEs and non-SOEs, whereas investment opportunity sensitivity declined more significantly in non-SOEs than in SOEs. There are no significant changes in central SOEs in terms of investment expenditure and investment opportunity sensitivity. Further analysis shows that investment expenditure and investment opportunity sensitivity decline for high-polluting

enterprises located in East China but increase for those located in West China. Findings reveal that there exist SOE/non-SOE discrimination and regional differences in the implementation of environmental regulations. The findings also demonstrate that environmental supervision in China has caused polluting enterprises to move to “lower pressure” areas.

This study contributes to the literature in the following ways. First, we take the 2011 event as a natural experiment and use the difference-in-differences method to investigate the effect of government environment regulations on high-polluting enterprises’ investment behavior. This effectively reduces the interference of endogenous problems. Second, it analyzes the effect of environmental regulations on specific firms from the perspective of the institutional environment and reveals that heavy polluting corporations located in areas with strict supervision have moved to areas with looser supervision. Third, unlike the previous studies, this study reveals the dynamic effects of environmental regulation on the investment behavior of enterprises with different property rights. The findings can be used to design future regulations on high-polluting enterprises to reduce the chance of another surge in the PM2.5 index. Finally, this study complements the literature on the effects of government environmental regulations on micro-enterprises’ financial decisions.

The remainder of this paper is organized as follows. In the next section, we provide an overview of the related literature and propose the hypotheses. Section 3 describes the research design, and Section 4 presents the analysis of the empirical results. Sections 5 and 6 provide further analyses and robustness tests, and Section 7 concludes the paper.

## 2. Literature review and hypothesis development

### 2.1. Surge in the PM2.5 index and enterprises’ investment expenditure

After inspecting Beijing’s air pollution governance performance in February 2014, the President of the People’s Republic of China, Xi Jinping, proposed that controlling PM2.5 was the primary task for dealing with smog and improving air quality. Severe smog had appeared around Beijing and North China in autumn 2011. The resulting air pollution and low visibility had caused the closures of many highways and the cancellations of many flights. This caused a great deal of public concern and many complaints. As the air pollution became more severe, attention turned to PM2.5, the key index of smog severity. When PM2.5 suddenly exceeded the threshold of the detecting instrument,  $500 \mu\text{g}/\text{m}^3$ , the public panicked. China’s environmental pollution problem, especially the severe pollution in Beijing–Tianjin–Hebei, then attracted worldwide attention. PM2.5 includes all particulate matter in the air with an aerodynamic diameter of  $2.5 \mu\text{m}$  or smaller, including toxic heavy metals and hazardous organic pollutants that are not present in normal air. This particulate matter can be inhaled directly into the lungs, causing severe harm to human health. The main sources of PM2.5 include fuel combustion from automobiles, power plants, wood burning, industrial processes and diesel-powered vehicles. To reduce social panic, the government introduced a series of regulatory policies. For example, the State Council issued a new “National Ambient Air Quality Standard” in 2012, in which PM2.5 was officially added to the general evaluation items, and issued an “Action Plan on Prevention and Control of Air Pollution” that introduced 10 measures to improve air quality in September 2013. The plan required the establishment of a regional coordination mechanism and arrangements for regional environmental treatment. Beijing–Tianjin–Hebei and the Yangtze River Delta established a regional coordination mechanism for air pollution control. The State Council signed target responsibility letters with all the provincial governments, conducted annual examinations and strictly enforced the accountability system. On 25 April 2015, the Chinese Communist Party (CCP) Central Committee and the State Council formally announced the publication of “Opinions on Accelerating Ecological Civil Construction,” which set out clear requirements and guidance to accelerate ecological civil construction and divided the relevant provinces into nine areas to synergize efforts toward healthy economic growth and sustainable environmental protection. This elevated governance strategies for pollution such as smog to the national level.

We believe that understanding how to guide the operational and investment behavior of high-polluting enterprises is key to the successful implementation of pollution regulations. Allen et al. (2005) show that the completeness of China’s shareholder protection law falls between that of the English-origin countries and that of the French-origin countries. The former have the highest protection measures, whereas the latter

have the poorest. However, China's enforcement of the law is nearly as weak as in the world's poorest countries. Engau and Hoffmann (2011) show that in response to post-Kyoto regulatory uncertainty, firms have predominantly pursued reduction, and to a lesser extent adaptation, regardless of their investment strategies. While Xiong and Xu (2007) find that the relaxed environmental regulation has a positive effect on attracting foreign direct investment, the lack of regulation is likely to attract high-polluting industries. Heavy pollution has a significant crowding-out effect on foreign direct investment, but the effect is not significant in low-pollution areas. The recurrent protests against PX projects are related to the p-xylene chemical, a petroleum chemical. It is a colorless transparent liquid, the smell of which is similar to that of toluene. If heavy pollution projects cannot be effectively controlled, strong dissatisfaction with the government's environmental regulations will result. Strengthening environmental regulations may either have an inhibiting effect on the investment expenditure of high-polluting enterprises or increase these enterprises' uncertainty about their future, leading them to postpone their investments (Viscusi, 1983).

Heavy pollution also has significant implications for the capital market. Excessive emissions from high-polluting enterprises lead to PM<sub>2.5</sub> surges and violate basic social norms and requirements. These enterprises are then at the center of public attention. Following the 2011 event, high-polluting enterprises have had to take action in response to queries from the media and the public. Hong and Kacperczyk (2009) provide evidence of the significant effects of social norms on markets by studying the investing environment of “sin” stocks—publicly traded companies involved in the production of alcohol, tobacco and gambling. They find that sin stocks are less likely to be held by norm-constrained institutions such as pension plans than by mutual or hedge funds that are natural arbitrageurs, and they receive less coverage from analysts than do other stocks with comparable characteristics. If high-polluting enterprises have low levels of compliance to social norms, institutional investors will withdraw their investments (Li and Yifeng, 2011). At the same time, institutional investors in high-polluting enterprises “vote with their feet” by reducing their investments in polluting projects to impose pressure on managers. Chava (2014) finds that investors demand significantly higher expected returns on stocks excluded by environmental pollution (such as hazardous chemicals, substantial emissions and climate change concern) than firms without such environmental concerns. Lenders also charge significantly higher interest rates on bank loans issued to firms with such environmental concerns. Meanwhile, firms' environmental risk exposure is associated with lower accuracy and higher dispersion in analysts' earnings forecasts, and analysts are more likely to revise their stock recommendations downward if firms experience an increase in their environmental risk exposure, and the inverse is also true (De Franco et al., 2013). These firms are charged higher audit fees (Simunic et al., 2014). Furthermore, firms that violate environmental protection regulations or have environmental accidents have lower market value (Lundgren and Olsson, 2010; Dasgupta et al., 2006). Darnall et al. (2007) find that strict environmental regulation is negatively correlated with firm performance. Firms that face strict regulation pay more when environmental accidents occur, and their operational costs increase, thus lowering investment incentives. With so many obstacles for high-polluting enterprises at the refinancing step and the strengthening of regulations following the 2011 event, high-polluting enterprises have to reduce their investment expenditure. We thus propose the following hypothesis:

**H1a.** *Ceteris paribus*, government environmental regulations have effectively restrained the investment expenditure of high-polluting enterprises following the 2011 event.

Although high-polluting enterprises have been influenced by the 2011 event, such influences vary across types of property rights. The operating environments and operating goals are quite different in SOEs and non-SOEs. In 2007, the China Banking Regulatory Commission issued a notification (No. 161) requiring financial institutions to supervise loan origination for high-polluting industries. This requirement seems to have had little effect on SOEs with bank loan advantages and loose budget constraints. Some SOEs may take a flexible or passive approach to environmental regulations by claiming that their products support the national security strategy. Despite resistance from institutional investors and medium and small investors, it is extremely difficult to prevent SOE managers from investing in projects that cause heavy pollution under the strong incentive of promotion championship. To maintain a competitive advantage, local governments typically lower environmental standards to attract foreign direct investment (Ljungwall and Linde-Rahr, 2005). Thus, as long as governments at all levels continue to prioritize GDP and given that environmental pollution is not a one-ballot veto, environmental protection cannot entirely reorganize the pollution industry.



In contrast, high-polluting non-SOEs will reduce their investments in projects that cause heavy pollution because these firms are under the implicit control of institutional investors who can “vote with their feet.” This may help protect the environment and increase public satisfaction, and it may offset the temporary decline in economic performance. During the process of implementation, local governments might provide certain protection for SOEs out of vested interests because SOEs are important in achieving local GDP goals. For example, the Central Environmental Protection Inspectorate openly affirmed the supervision opinions of Hebei province on 3 May 2016: Tangshan Iron Company, a branch of the largest SOE in Hebei province (Hebei Steel Group), increased its steel production capacity, which violated the “Guidance on resolving contradiction severe overcapacity” issued by the State Council.<sup>1</sup> This case illustrates that continual environmental pollution is closely associated with the failure of some SOEs to meet their environmental responsibilities. The above analysis shows that the strengthening of environmental regulations as a result of the 2011 event implies that high-polluting non-SOE enterprises are the most influential. Thus, we propose the second hypothesis:

**H1b.** *Ceteris paribus*, non-SOEs’ reduction in investment expenditure is greater than that of SOEs after the 2011 event.

## 2.2. The surge in the PM2.5 index and enterprises’ investment opportunity sensitivity

Classic corporate governance theory assumes that agency conflict is the key factor that influences corporate investment efficiency, but the theory may not work in China during the transitional economy phase. If there is a close association between pollution governance and government officials’ promotion, officials will focus their efforts on strengthening the supervision of high-polluting enterprises and adopt the carrot and stick policy to make polluting enterprises rely on them to prevent heavy pollution.

How the PM2.5 index can be decreased and how the occurrence frequency of the PM2.5 surge can be reduced are important environmental and social problems. First, as the Chinese government has tight control over enterprises and the economy, the government may simultaneously use the grabbing hand and the helping hand to ensure effective policy implementation. Chen et al. (2010) find that the Chinese government often intervenes in enterprises’ investment decisions by way of property rights or political connections for political or social purposes, which distorts investment behavior and reduces investment opportunity sensitivity. As government intervention might distort enterprises’ investment decisions, enterprises’ high-polluting investment projects that caused the 2011 event must be strictly supervised. For instance, the government may approve fewer projects and reduce bank loan origination. This may further reduce the value of future profitable projects. However, if high-polluting enterprises make huge investments in governance to reduce PM2.5 emissions, it will reduce their profits and investment opportunities.

Xu and Xiao (2011) argue that environmental regulations enhance the environmental policy risk of high-polluting enterprises and that environmental regulations increase the information asymmetry between projects and the capital market and decrease investment efficiency. La Porta et al. (1999) find that a “game” exists between the government and enterprises—that is, a tacit exchange of interests between the government and enterprises: politicians use certain means (subsidies or bribes) to attract entrepreneurs to comply with political goals. Public subsidies are the key equilibrium between the government and enterprises when the government wants to exchange its resources with high-polluting enterprises to reduce PM2.5 emissions. The government often requires high-polluting enterprises to disclose more environmental information with the use of public subsidies (Lin et al., 2015). This increases the supervision of these specific firms’ investment projects and further reduces the value of the projects. The government’s aim is to guide high-polluting enterprises to implement industry upgrades and technology innovations and to gradually eliminate or close high PM2.5 emissions projects in the hope of significantly reducing investment in heavily polluting projects. In addition, although high-polluting enterprises play a key role in the PM2.5 index’s sudden surge, they still pursue corporate value maximization like other industries do. As long as there is demand for the products, the optimal choice is to enlarge the operational scale and increase investment in projects. Environmental regulations

<sup>1</sup> [http://finance.ifeng.com/a/20160503/14360248\\_0.shtml](http://finance.ifeng.com/a/20160503/14360248_0.shtml).

distort firms' optimal investment decisions, leading to inefficient investment, fewer future investment opportunities and a mismatch between intrinsic investment expectation and investment opportunity. Therefore, we propose the following hypothesis:

**H2a.** *Ceteris paribus*, governmental environmental regulations effectively reduced the investment opportunity sensitivity of high-polluting enterprises after the 2011 event.

To explore the underlying reasons for the sudden surge in the PM2.5 index, we should not only analyze the high-polluting enterprises but also the environmental regulation background and its effect on enterprises. The goal of emission reduction set out in the 11th Five-Year Plan period was achieved, and the central government extended the goal in the 12th Five-Year Plan, in which a strictly binding policy seems to be the key to reversing the deterioration of the ecological environment. However, these rules have had little effect on emission reduction. This shows that we need a deeper exploration of the underlying institutional factors to resolve PM2.5 pollution.

The central idea behind China's environmental governance is to control overall pollution and to allow specific entities to assume the corresponding responsibilities. In reality, administrative approval for investment in heavy-polluting industry is scarce because resource capacity is limited. This results in an interesting "game" between the government and the enterprises, where the distribution of emission-reducing tasks in a certain area is the key point. SOEs assume greater social responsibilities, and their investment behavior directly influences the performance of local officials, yet these SOEs are given fewer emission-reducing tasks and may even face competition for new investment projects. Consequently, SOEs may still have certain investment opportunities under the strict environment regulations. Using data from the Wind and CCER databases, we find that state-owned and state-holding enterprises account for 70 percent of A-share listed firms in China and that nearly half of state-owned-capital industries are high-polluting. The Ministry of Environmental Protection announced penalties for "environment-violating" enterprises on its website. The list includes some central SOEs, such as the State Electric Power Corporation, Petro China and Datang Power. This implies that SOEs' investment in heavy-polluting projects is less influenced by the government's PM2.5 environment regulations than is investment by local SOEs and non-SOEs. [Bardhan and Mookherjee \(2005, 2006\)](#) point out that local governments are more likely than the central government to be trapped by enterprises and that this exacerbates the degree of environmental pollution. Consistent with this argument, [Wang et al. \(2003\)](#) find that firms from the private sector appear to have less bargaining power than state-owned enterprises and that the greater the social impact of a firm's emissions, the less bargaining power the firm has with local environmental authorities. Under such circumstances, non-SOEs are under pressure from public opinion and credit rationing and will not spend their own money on heavy-polluting projects, leading to a lowering of investment opportunity sensitivity. [Thomas and Brown \(1995\)](#) hold the opinion that environmental regulation may prevent new entrants to the industry, and incumbents may thus become monopolists. Although social cost is increased by a monopoly, the scale of investment in high-polluting industries is decreased. The National Development and Reform Commission and the Ministry of Environmental Protection set more industry restrictions on non-SOEs (including heavy pollution industry) than on SOEs. This further reduces non-SOEs' chances of participating in heavy-polluting industry and projects. We propose the following hypothesis:

**H2b.** *Ceteris paribus*, non-SOEs' investment opportunity sensitivity reduction was greater than that of SOEs' after the 2011 event.

### 3. Research design

#### 3.1. Sample selection

We select Chinese A-share listed firms from 2006 to 2014 as our initial sample. We then refine this initial sample by removing some irrelevant data from it. The irrelevant data that we removed from our initial sample are the firms that meet the following criteria: (1) Particular Transfer and Special Treatment firms; (2) financial industry firms; (3) firms with leverage greater than 1 or less than 0; (4) B share or H share firms; (5) delisted firms; (6) firms initially listed in the current year; and (7) firms with missing data. Property rights data are

taken from the CCER database. Financial and corporate governance data are from the CSMAR database, and the classification of high-polluting industries is taken from the Wind database and compared with the CSRC (2011) industry classification.

### 3.2. Variable definitions

#### 3.2.1. Explanatory variables

*High-polluting enterprises.* Following [Li and Yifeng \(2011\)](#), we classify firms as high-polluting if they belong to one of the following 14 industries in the “Industry Classification of Environmental Protection Management in Listed Companies” published by the Ministry of Environmental Protection in 2008: thermal power, steel, cement, electrolytic aluminum, mining, metallurgy, building materials, coal, chemistry, petrochemical, pharmacy, light industry, spinning and leather. When the Ministry of Environmental Protection issued the “Emission Standard for Air Pollutants” in 2011, they considered thermal power, steel, petrochemical, nonferrous metals, chemistry industry and coal-fired boiler projects as the major monitoring areas. As the Ministry of Environmental Protection’s list is more comprehensive, we classify firms that belong to one of the 14 industries as high-polluting; high-polluting firms belonging to these 14 industries are assigned a value of 1, and all other firms are assigned 0.

*Investment opportunity.* Following [Chen et al. \(2011\)](#), we use Tobin’s Q to proxy investment opportunity, which reflects the growth and relative value-added potential. The greater the investment opportunity is, the higher the investment expenditure and investment efficiency are ([Fazzaris et al., 1988](#)). However, the use of Tobin’s Q for China is questioned, mainly because of the capital market efficiency and the reform of non-tradable shares there. After the 2005 reform, the value relevance of stock improved and capital market efficiency increased ([Liu et al., 2010](#)). We therefore use the variable measure method in this paper.

#### 3.2.2. Dependent variable

We measure investment expenditure as “cash paid to acquire fixed assets, intangible assets and other long-term assets” from firms’ cash flow statements, scaled by total assets.

#### 3.2.3. Control variables

Following [Chen et al. \(2011\)](#), [Fazzaris et al. \(1988\)](#), [Akdogu and MacKay \(2008\)](#) and [McLean et al. \(2012\)](#), we control firm age (*Age*), sales growth (*Salgrow*), fixed asset proportion (*Fixas*), proportion of shares held by the largest shareholder (*Hold1*), firm size (*Size*), leverage (*Lev*) and profitability (*Roe*).

[Table 1](#) presents the variables’ definitions.

### 3.3. Regression model

We construct Model (1) to test hypotheses 1a and 1b. Following [Mayer \(1995\)](#), [Bertrand and Mullainathan \(2004\)](#), [Liu and Liu \(2015\)](#) and [Yuan and Zuo \(2011\)](#), the basic regression model is based on the difference-in-differences method, which is used to examine the net effect of policy implementation. We compare in detail the difference between the treatment group and control group before and after policy implementation. We divide the enterprises in our refined sample into two parts: high-polluting enterprises and non-high-polluting enterprises. We also use the 2011 event as a watershed event that defines the pre-2011 event period and the post-2011 event period. The treatment group includes the high-polluting enterprises from the 14 industries that we identified in the previous section (*Dumpollute*); these industries take a value of 1, whereas all other industries take a value of 0; observations before 2011 (*Dum11*) equal 1 and 0 otherwise.

$$Invest = \alpha_0 + \alpha_1 * Dumpollute + \alpha_2 * Dum11 + \alpha_3 * Dumpollute * Dum11 + \mu_{i,t} \quad (1)$$

In the control group (*Dumpollute* = 0), the investment expenditures before (*Dum11* = 0) and after 2011 (*Dum11* = 1) are denoted by  $Invest = \alpha_0 + \mu_{i,t}$  and  $Invest = \alpha_0 + \alpha_2 + \mu_{i,t}$ , respectively, so the difference in the control group before and after 2011 is  $\alpha_2$ . In the treatment group (*Dumpollute* = 1), the investment



Table 1  
Variable definitions.

Variable	Definition
<i>Invest</i>	Investment expenditure. Measured as “cash paid to acquire fixed assets, intangible assets and other long-term assets” from firms’ cash flow statements, scaled by total assets
<i>Dumpollute</i>	Dummy variable. Firms that are listed in the “Industry classification of environmental protection management in listed companies” as thermal power, steel, cement, electrolytic aluminum, mining, metallurgy, building materials, coal, chemistry, petrochemical, pharmacy, light industry, spinning and leather industries, or whose prime business matches the listed industry, take a value of 1 and 0 otherwise
<i>Dum11</i>	Dummy variable. If the observation belongs to 2011–2014, which is after the 2011 event, it takes a value of 1 and 0 otherwise <sup>a</sup>
<i>Tobin</i>	Investment opportunity. (Market value of circulation stock + book value of non-tradable shares + book value of liability)/book value of total assets
<i>Salegrow</i>	Sales growth. Sales growth/sales at the beginning of the year
<i>Size</i>	Firm size. The logarithm value of total assets
<i>Age</i>	Firm age. Number of years since the firm was established
<i>Ebit</i>	Earnings before interest and tax. (Net profit + income tax + interest)/total assets
<i>Lev</i>	Leverage. Total liability at the end of year/total assets at the end of year
<i>Roa</i>	Return on equity. Net profit at the end of year/total assets
<i>Hold1</i>	The largest shareholders. Percentage of outstanding shares held by the largest holders
<i>Fixas</i>	The proportion of fixed assets. Net value of fixed assets/total assets
<i>S0</i>	Marketization process. Marketization process index from Fan and Wang (2011)
<i>Lloan</i>	Loan. Long-term debt/total asset
<i>Yszk</i>	Accounts receivable. Accounts receivable/total assets
<i>Yfzk</i>	Accounts payable. Accounts payable/total assets
<i>S4a</i>	Marketization process of financial industry. Marketization process index of financial industry from Fan and Wang (2011)
<i>Eqcash</i>	Cash flow from operating activities. Net cash flow from operating activities in cash flow statement
<i>S5b</i>	The proportion of enterprises with local government intervention. Local government intervention index from Fan and Wang (2011)

<sup>a</sup> The American Embassy in China initially published air quality monitoring data for Beijing at the end of October 2011, after which PM2.5 became a hot topic in the media. However, as firms disclose their financial reports on 30 April, they still had almost half a year to modify the disclosed information. We therefore classify 2011 into the post-event period (Liu and Liu, 2015). Furthermore, this paper mainly focuses on high-polluting enterprises and industries, and the Ministry of Environmental Protection published the “Industry classification of environmental protection management in listed companies” in 2008. The 2011 Event drew public attention to PM2.5, and the provisions that were issued after 2011 were intended to solve the PM2.5 problem.

expenditures before ( $Dum11 = 0$ ) and after 2011 ( $Dum11 = 1$ ) are denoted by  $Invest = \alpha_0 + \alpha_1 + \mu_{i,t}$  and  $Invest = \alpha_0 + \alpha_1 + \alpha_2 + \alpha_3 + \mu_{i,t}$ , respectively, so the difference in the treatment group before and after 2011 is  $\alpha_2 + \alpha_3$ . Thus,  $\alpha_3$  measures the difference in the effect of environment regulations on high-polluting enterprises’ investment expenditure. Then, we control for other effects that could influence the inferences in Model (1). The main regression model is as follows.

$$Invest = \alpha_0 + \alpha_1 * Dumpollute + \alpha_2 * Dum11 + \alpha_3 * Dumpollute * Dum11 + \alpha_4 * Roa + \alpha_5 * Size + \alpha_6 * Lev + \alpha_7 * S0 + \alpha_8 * Hold1 + \alpha_9 * Fixas + \alpha_{10} * Lloan + \delta_{i,t} + \varphi_{i,t} + \mu_{i,t} \quad (2)$$

We use Model (3) to test Hypothesis 2. Fazzaris et al. (1988) and Vogt (1994) find that firms that have more investment opportunities invest more and have higher investment efficiency. However, when investment opportunities are few, investment expenditure declines accordingly—that is, investment expenditure is sensitive to investment opportunity. We add the variable *Tobin* to measure investment opportunity<sup>2</sup> and add the interactions with *Dumpollute* and *Dum1*. We also control industry, year and province effects.

<sup>2</sup> Following the literature, we use the sales growth rate to substitute Tobin’s Q in the robustness test, and the results remain the same.

$$\begin{aligned}
Invest = & \beta_0 + \beta_1 * Dumpollute + \beta_2 * Dum11 + \beta_3 * Dumpollute * Dum11 + \beta_4 * Dumpollute \\
& * Dum11 * Tobin + \beta_5 * Dumpollute * Tobin + \beta_6 * Dum11 * Tobin + \beta_7 * Tobin + \beta_8 * Roa \\
& + \beta_9 * Size + \beta_{10} * Lev + \beta_{11} * S0 + \beta_{12} * Hold1 + \beta_{13} * Fixas + \beta_{14} * Lloan + \delta_{i,t} + \varphi_{i,t} + \mu_{i,t} \quad (3)
\end{aligned}$$

## 4. Empirical results

### 4.1. Descriptive statistics

Table 2 shows the descriptive statistics. The mean investment expenditure (*Invest*) is 0.059, with a minimum value of 0 and maximum of 0.5451, indicating that the distribution is reasonable, but left-skewed (median is 0.039). The mean of investment opportunity (*Tobin*) is 1.5832, with a standard deviation of 0.888, shows that the distribution is discrete. High-polluting enterprises account for 30% of the full sample (*Dumpollute*).

Table 3 reports the Pearson correlation coefficients. The correlation coefficient between *Invest* and *Dumpollute* is 0.2001 and significant at the 10% level. This means that high-polluting enterprises invest more than non-high-polluting enterprises do. The correlation coefficient between *Dum11* and *Invest* is  $-0.313$  and significant at the 1% level, showing that strengthening environmental regulation reduces firms' investment expenditure. Although the coefficient between investment opportunity (*Tobin*) and investment expenditure (*Invest*) is small (0.022), it is significant at the 1% level. Sales growth (*Salgrow*) is significantly negatively correlated with investment expenditure (*Invest*), indicating that the higher the sales growth, the more cash is occupied, leaving the firm with little cash flow to invest. The correlation coefficients of the other variables are all below 50%, showing that there is no multicollinearity.

### 4.2. Univariate statistics

Table 4 shows the univariate statistics based on property rights and periods (pre-2011 event period and post-2011 event period). We find no significant difference in the (mean or median) investment expenditure (*Invest*) of SOEs after the strengthening of environmental regulations. However, there is a significant decline in the investment expenditure (*Invest*) of non-SOEs, and the mean (median) difference is significant at the 10% (5%) level. This shows that the investment expenditure of non-SOEs was influenced more by the 2011 event than by SOEs. The investment opportunity (*Tobin*) of SOEs does not significantly change after the 2011 event but significantly decreases in non-SOEs. Table 4 shows that the values of investment expenditure and investment opportunity are lower in the post-2011 event period than in the pre-2011 event period and that SOEs' values are larger than non-SOEs' values. These results show that environmental regulations have a negative effect on investment expenditure and opportunity, but the effect is more significant for non-SOEs.

Table 2  
Descriptive statistics.

Variables	N	Mean	SD	Min	P50	Max
Invest	7308	0.0590	0.0570	0	0.0390	0.5451
Tobin	7308	1.5832	0.8880	0.7183	1.2563	5.8664
Lloan	7308	0.0760	0.0960	0	0.0290	0.7993
Dum11	7308	0.6583	0.2354	0	0	1
Fixas	7308	0.2582	0.191	0	0.2325	0.9602
Eqcash	7308	19.4126	1.5023	9.7321	19.7410	25.8725
Ebit	7308	0.0560	0.0610	0.0124	0.0500	0.6757
Dumpollute	7308	0.3032	0.4603	0	0	1
Age	7308	13.0829	3.262	1	14	30
Salgrow	7308	0.5413	0.1677	0.0070	0.5363	1.9902
Hold1	7308	36.5012	15.8903	0.8203	34.5002	100
Lev	7308	0.5407	0.1643	0.1128	0.5362	0.8547
Size	7308	22.2143	1.1876	18.1625	22.039	27.7521
Roa	7308	0.0370	0.0570	0.0023	0.0340	0.5172

Table 3  
Pearson correlation coefficients.

Variables	<i>Invest</i>	<i>Tobin</i>	<i>Lloan</i>	<i>Dum11</i>	<i>Opcash</i>	<i>Ebit</i>
<i>Invest</i>	1					
<i>Tobin</i>	0.0221**	1				
<i>Lloan</i>	−0.0923***	−0.3063***	1			
<i>Dum11</i>	−0.3137***	−0.0381***	0.1702***	1		
<i>Eqcash</i>	0.2014***	−0.2518***	0.2153***	0.1427***	1	
<i>Ebit</i>	0.0971***	0.1512***	−0.0653***	−0.0756***	0.2040***	1
<i>Dumpollut</i>	0.2001*	0.2451*	0.0031	0.1202	−0.1003	−0.0182**
<i>Age</i>	−0.3454***	0.0150	0.1297***	−0.1628***	0.0300	−0.0442***
<i>Salgrow</i>	−0.033***	−0.4065***	0.4867***	−0.1382***	0.0694***	−0.1778***
<i>Hold1</i>	−0.1102	0.1001	0.0400	0.1003	0.0900	−0.0600
<i>Lev</i>	−0.0326***	−0.4135***	0.4932***	−0.1403***	0.0735***	−0.1463***
<i>Size</i>	0.4001	−0.4712***	0.4633***	−0.0702***	0.3224***	0.1853***
<i>Roa</i>	0.0357***	0.1218***	−0.1127***	−0.1602***	0.1952***	0.3748***
	<i>Dumpollut</i>	<i>Age</i>	<i>Salgrow</i>	<i>Lev</i>	<i>Size</i>	<i>Roa</i>
<i>Dumpollut</i>	1					
<i>Age</i>	−0.1003	1				
<i>Salgrow</i>	−0.1629*	0.0153*	1			
<i>Hold1</i>	0.4003***	0.0300	0.0600			
<i>Lev</i>	−0.1775*	0.0140	0.3953***	1		
<i>Size</i>	−0.1403	0.0598***	0.4632***	0.4745***	1	
<i>Roa</i>	−0.0178*	−0.0249***	−0.2341***	−0.2013***	0.1628***	1

\* Significance at the 10% level.

\*\* Significance at the 5% level.

\*\*\* Significance at the 1% level.

Table 4  
Univariate statistics.

	After the 2011 event		Before the 2011 event		Difference test	
	Mean	Median	Mean	Median	T-test	Wilcoxon-test
<i>Invest</i> -SOEs	0.0583	0.0538	0.0598	0.0476	1.4284	1.3546
<i>Invest</i> -Non-SOEs	0.0517	0.0429	0.0530	0.0327	1.9438*	2.1429**
<i>Tobin</i> -SOEs	1.5804	1.2086	1.5968	1.3843	1.0314	1.4732
<i>Tobin</i> - Non-SOEs	1.5335	1.2328	1.5923	1.1207	3.4718***	2.3519***

\* Significance at the 10% level.

\*\* Significance at the 5% level.

\*\*\* Significance at the 1% level.

Table 5  
Investment expenditure in different industries and regions and intra-industry.

Item	<i>Invest</i> -Mean	<i>Invest</i> -Median
High-polluting enterprises	0.0595	0.0386
Non-high-polluting enterprises	0.0593	0.0391
Difference (significance)	0.0002 (T = 2.216)	0.0005 (Z = 1.8264)
High-polluting enterprises in west region	0.0661	0.0386
High-polluting enterprises in east region	0.0462	0.0113
Difference (significance)	−0.0199 (T = −18.57)	−0.0273 (Z = −26.155)
Three industries with the highest number of high-polluting enterprises	0.0579	0.0386
Three industries with the lowest number of high-polluting enterprises	0.0596	0.0425
Difference (significance)	0.0017 (T = 1.8326)	0.039 (Z = 1.926)

Table 5 shows the differences in investment expenditure by industry, region and intra-industry. We find that the investment expenditure difference between high-polluting enterprises and non-high-polluting enterprises is significant at the 5% (mean) and 10% (median) levels. The mean (median) investment expenditure of high-polluting enterprises in the western region is 0.0661 (0.0386), which is significantly higher than that in the eastern region, demonstrating that high-polluting enterprises have an incentive to move to other areas. Furthermore, the investment expenditure of the three industries with the lowest number of high-polluting enterprises is significantly higher than that of the three industries with the highest number of high-polluting enterprises, which is contrary to intuition. One possible explanation is that the industries with the lowest number of high-polluting enterprises are dispersed, the marginal supervision cost is large and there is a lack of regulation scale effect.

#### 4.3. Regression results

Table 6 shows the results of the main regression. In column 1, the coefficient on the interaction of *Dumpollute* and *Dum11* is  $-0.0159$ , which is significant at the 10% level, showing that the environmental regulations after the 2011 event decreased the investment expenditure of high-polluting enterprises. Columns 2 and 3 report the results for SOEs and non-SOEs. The coefficient on the interaction of *Dumpollute* and *Dum11* of

Table 6  
The 2011 event and investment expenditure.

Variables	(1) Full sample	(2) SOEs	(3) Non-SOEs
<i>Dumpollute</i>	0.032 <sup>*</sup> (1.83)	0.018 <sup>**</sup> (2.15)	0.0424 <sup>*</sup> (1.97)
<i>Dum11</i>	$-0.0402^{***}$ ( $-3.43$ )	$-0.0345^{***}$ ( $-4.87$ )	$-0.0168^{***}$ ( $-2.91$ )
<b><i>Dumpollute</i>*<i>Dum11</i></b>	<b><math>-0.0159^{*}</math></b> <b>(<math>-1.778</math>)</b>	<b><math>-0.0124</math></b> <b>(<math>-1.34</math>)</b>	<b><math>-0.0246^{**}</math></b> <b>(<math>-2.21</math>)</b>
<i>Lev</i>	0.0225 (0.96)	$-0.148^{**}$ ( $-1.95$ )	0.0718 (1.47)
<i>Size</i>	$0.0121^{***}$ (5.26)	$0.0178^{***}$ (2.75)	$-0.0518^{***}$ ( $-4.22$ )
<i>Hold1</i>	$-0.0014$ ( $-1.28$ )	$-0.0012$ ( $-1.04$ )	0.0305 (0.95)
<i>Roa</i>	$0.0412^{***}$ (2.48)	$0.0292^{***}$ (2.77)	$0.0728^{***}$ (3.15)
<i>S0</i>	$0.0114^{**}$ (2.16)	$-0.0943^{**}$ ( $-2.54$ )	$0.0276^{***}$ (3.09)
<i>Fixas</i>	$0.0017^{***}$ (5.27)	$0.0004^{***}$ (2.76)	$0.0026^{***}$ (2.36)
<i>Lloan</i>	$-0.0406^{***}$ ( $-2.45$ )	$-0.0374^{***}$ ( $-3.06$ )	$-0.0219^{***}$ ( $-2.87$ )
<i>Constant</i>	$-0.217^{***}$ ( $-3.75$ )	$-0.0826^{**}$ ( $-2.11$ )	$-0.107^{**}$ ( $-2.07$ )
<i>Industry</i>	Controlled	Controlled	Controlled
<i>Year</i>	Controlled	Controlled	Controlled
		$\chi(2) = 55.63$	
<i>P value</i>		0.000	
<i>Observations</i>	7308	4333	2975
<i>Adj-R2</i>	0.259	0.219	0.28
<i>F</i>	126.74	55.68	105.47

The robust t-statistics are reported in brackets.

\* Significance at the 10% level.

\*\* Significance at the 5% level.

\*\*\* Significance at the 1% level.

SOEs is  $-0.0124$  but insignificant, while the coefficient on the interaction of non-SOEs is  $-0.0246$  and significant at the 5% level. Further, the  $\chi(2)$  of the coefficients of the two sub-samples is 55.63 and significant at the 1% level. This reveals that there is a selective and discriminatory phenomenon in the implementation of environmental regulations: SOEs are less affected by the regulations, but the investment expenditure of non-SOEs is significantly decreased.

Table 7 shows the effect of the 2011 event on investment opportunity sensitivity. In column 1, the interaction of *Dumpollute*, *Dum11* and *Tobin* is  $-0.0307$ , and is significant at the 10% level. This demonstrates that the strengthening of government environmental regulation decreases investment in heavy-polluting projects and reduces investment opportunity sensitivity. Columns 2 and 3 present the results for SOEs and non-SOEs; the coefficient on the interaction of SOEs is  $-0.0275$  but insignificant, while the coefficient on the interaction of non-SOEs is  $-0.0437$  and significant at the 5% level. The above results show that the decrease in investment opportunity sensitivity caused by the strengthening of environmental regulations is asymmetric

Table 7  
The 2011 event and investment opportunity sensitivity.

Variables	(1) Full sample	(2) SOEs	(3) Non-SOEs
<i>Dumpollute</i>	0.0792* (1.79)	0.0325** (2.19)	0.0176** (2.14)
<i>Dumpollute*Dum11*Tobin</i>	<b>-0.0307*</b> <b>(-1.834)</b>	<b>-0.0275</b> <b>(-1.25)</b>	<b>-0.0437**</b> <b>(-2.25)</b>
<i>Dum11</i>	-0.0428*** (-4.46)	-0.0375*** (-2.45)	-0.0124* (-1.81)
<i>Dumpollute*Dum11</i>	-0.0711* (-1.95)	-0.0429 (-1.08)	-0.0215*** (-2.51)
<i>Dumpollute*Tobin</i>	0.0328** (2.03)	0.0415* (1.95)	0.0206** (2.37)
<i>Dum11*Tobin</i>	-0.0218* (-1.79)	-0.0207** (-2.16)	-0.0346*** (-2.539)
<i>Lev</i>	0.0572 (0.93)	-0.0933 (-1.36)	0.126 (1.57)
<i>Tobin</i>	0.0644*** (2.84)	0.0328*** (3.25)	0.0796*** (2.45)
<i>Size</i>	0.0112*** (7.21)	0.0131*** (3.07)	-0.0258* (-1.76)
<i>Hold</i>	-0.0109 (-0.55)	-0.0311 (-0.96)	0.0262 (0.41)
<i>Roa</i>	0.0315*** (2.75)	0.0292*** (3.06)	0.0703*** (4.69)
<i>S0</i>	0.0125*** (2.78)	-0.0832** (-2.06)	0.0216*** (4.05)
<i>Fixas</i>	0.0021*** (2.63)	0.0013*** (3.19)	0.0039*** (2.82)
<i>Lloan</i>	-0.0272*** (-3.63)	-0.0315*** (-4.58)	-0.0470*** (-3.22)
<i>Constant</i>	-0.346*** (-4.36)	-0.106*** (-3.15)	-0.153*** (-2.99)
<i>Industry</i>	Controlled	Controlled	Controlled
<i>Year</i>	Controlled	Controlled	Controlled
<i>Observations</i>	7308	4333	2975
<i>Adj-R2</i>	0.39	0.25	0.48
<i>F</i>	102.48	65.73	103.79

The robust t-statistics are reported in brackets.

\* Significance at the 10% level.

\*\* Significance at the 5% level.

\*\*\* Significance at the 1% level.



in SOEs and non-SOEs, further demonstrating the discrimination in the implementation of the environmental regulations.

## 5. Further analysis

### 5.1. Layers of government ownership

In general, central SOEs are large-scale enterprises in industries vital to national well-being and people's livelihoods. They are either monopolistic or oligopolistic, and hence their operational risk is low. Local SOEs are generally smaller than central SOEs and are in a disadvantaged situation in terms of the supply of capital, energy and raw materials. Thus, these local SOEs are subject to higher competitive pressure and greater

Table 8  
Different layers of government ownership.

Variables	(1) Central SOEs	(2) Local SOEs	(3) Central SOEs	(4) Local SOEs
<i>Dumpollute</i>	0.0762 <sup>*</sup> (2.14)	0.0827 <sup>***</sup> (2.58)	0.0796 <sup>*</sup> (1.77)	0.01537 <sup>*</sup> (1.86)
<i>Dumpollute*Dum11*Tobin</i>			−0.0430 (−1.36)	−0.026 <sup>**</sup> (−2.18)
<i>Dum11</i>	−0.0326 <sup>***</sup> (−2.35)	−0.0456 <sup>***</sup> (−3.72)	−0.0468 <sup>***</sup> (−3.19)	−0.0532 <sup>***</sup> (−4.251)
<i>Dumpollute*Dum11</i>	−0.0118 (−1.083)	−0.0473 <sup>*</sup> (−1.94)	−0.0215 (−0.79)	−0.04721 <sup>*</sup> (−1.69)
<i>Dumpollute*Tobin</i>			0.002 <sup>*</sup> (1.78)	0.015 <sup>**</sup> (2.13)
<i>Dum11*Tobin</i>		—	−0.031 (−1.52)	−0.042 <sup>**</sup> (−2.13)
<i>Lev</i>	0.725 <sup>***</sup> (2.38)	0.0346 (1.35)	0.824 <sup>***</sup> (2.62)	0.0582 (1.06)
<i>Tobin</i>			0.0736 <sup>***</sup> (2.88)	0.0718 <sup>***</sup> (3.72)
<i>Size</i>	0.0073 <sup>***</sup> (2.36)	0.0118 <sup>***</sup> (3.25)	0.0135 <sup>***</sup> (3.62)	0.0155 <sup>***</sup> (4.27)
<i>Hold</i>	0.0256 (1.26)	0.0517 (1.18)	0.0294 (0.63)	0.0595 (1.47)
<i>Roa</i>	0.0214 (1.32)	0.0633 <sup>***</sup> (2.45)	0.0279 <sup>*</sup> (1.77)	0.0225 (1.57)
<i>S0</i>	0.0315 (1.35)	0.0328 (1.43)	0.0361 (1.38)	0.0418 (1.12)
<i>Fixas</i>	0.0037 <sup>***</sup> (2.44)	0.0028 <sup>**</sup> (3.67)	0.0017 <sup>***</sup> (2.43)	0.003 <sup>***</sup> (2.52)
<i>Llaon</i>	−0.0291 <sup>***</sup> (−2.75)	−0.0314 <sup>***</sup> (−3.92)	−0.0374 <sup>**</sup> (−2.02)	−0.0329 <sup>***</sup> (−2.14)
<i>Constant</i>	−0.249 <sup>***</sup> (−3.13)	−0.178 <sup>***</sup> (−3.16)	−0.663 <sup>***</sup> (−2.14)	−0.195 <sup>***</sup> (−3.48)
<i>Industry</i>	Controlled	Controlled	Controlled	Controlled
<i>Year</i>	Controlled	Controlled	Controlled	Controlled
	$\chi(2) = 43.86$		$\chi(2) = 58.62$	
<i>P value</i>	0.004		0.023	
<i>Observations</i>	1531	2802	1531	2802
<i>Adj -R2</i>	0.43	0.36	0.35	0.42
<i>F</i>	26.34	48.05	55.83	62.05

The robust t-statistics are reported in parentheses.

<sup>\*</sup> Significance at the 10% level.

<sup>\*\*</sup> Significance at the 5% level.

<sup>\*\*\*</sup> Significance at the 1% level.

operational risk. The literature suggests that the layers of government ownership in SOEs lead to diverse effects. Furthermore, local government policies on industry regulation, taxation and loan support have different effects on central SOEs and local SOEs (Yuan and Zuo, 2011). The Ministry of Environmental Protection is the highest-level organization responsible for environmental regulations. Most central SOEs still have a vice-ministerial or ministerial administrative level. Managers of these SOEs are assigned by the CCP Central Committee's Organization Department, which creates certain difficulties during the supervision process and has a negative influence on the effective implementation of PM2.5 regulation. The Ministry of Environmental Protection announced the handling of penalties for enterprises with environmental violations on its website in 2013. Some central SOEs, including the State Electric Power Corporation, Petro China and Datang Power, are on the list and account for 30% of firms to be punished. Twenty-six (23.21%) central SOEs are involved in the environmental protection inspection industry. Although central SOEs and local SOEs both belong to the same system, local SOEs are more involved in local economic development services.

The theory of political asylum assumes that local government officials can benefit from the operation of local SOEs and will therefore support these firms. Ljungwall and Linde-Rahr (2005) find that local governments always opt for lower environmental standards to attract direct foreign investment and keep their competitive advantages. When the central government incorporates environmental protection performance into the evaluation system for local officials, "solicitude" becomes "intervention" and "administrative order." From the perspective of political promotion, during the distribution of pollution reduction tasks, some high-polluting provinces might promise to achieve higher reduction standards set by the central government, and the corresponding municipal and prefecture governments may also require higher reduction levels to complete the central government's pollution reduction targets (Zhou et al., 2015). Central SOEs may then use the protection of the national economy and people's livelihoods as excuses for escaping emission tasks, and non-SOEs may be affected the most. Compared with central SOEs, local SOEs undertake more responsibility for reducing investment in heavy pollution projects, thus reducing the investment opportunity sensitivity. Considering the different effects of government environmental regulations on central and local SOEs (including differences in getting key investment projects and bank loans), we believe that the investment expenditure and investment opportunity sensitivity differs between central and local SOES.

Table 8 shows the results for the layers of government ownership. In column 1, the interaction of *Dum11* and *Dumpollute* is  $-0.0118$  but insignificant. In column 2, the interaction of *Dum11* and *Dumpollute* is  $-0.0473$  and significant at the 10% level. The difference between the interaction of *Dum11* and *Dumpollute* in columns 1 and 2 is 43.86 and significant at the 1% level. This shows that the environmental regulations have an inhibiting effect on local SOEs' investment, but not on that of central SOEs'. Columns 3 and 4 examine the effect of environmental regulations on investment opportunity sensitivity in central and local SOEs. In column 3, the interaction of *Dum11*, *Dumpollute* and *Tobin* is  $-0.0430$  and insignificant, but it is significantly negative in column 4. The difference between the interactions of *Dum11*, *Dumpollute* and *Tobin* in columns 3 and 4 is 58.62 and significant at the 5% level. This shows that environmental regulations have a greater inhibiting effect on local SOEs' investment opportunity sensitivity.

## 5.2. Regional effect

Air pollution has a spillover effect and can cause transboundary pollution problems across various areas (Li et al., 2014). According to the Pollution Haven Hypothesis (Copeland and Taylor, 1994), a low environmental regulation area has an innate advantage in attracting high-polluting enterprises. The "marketization" method of resource allocation causes these areas to become popular locations for high-polluting enterprises. With recent improvements in the comprehensiveness of environmental protection requirements, the migration of polluting enterprises from their original locations to new places has become a noticeable new phenomenon. Zhou et al. (2015) find that China's pollution-intensive enterprises were mainly distributed in the Shandong peninsula, Yangtze River Delta and Pearl River Delta and in other economically developed regions before 1998 and were mostly located in the central and western regions until 2008. The eastern region has more restrictive environmental regulations and higher GDP; reducing the number of heavy polluting industries would have little effect on the economy and industrial structure. In the western region, labor costs are lower, and there are abundant low-cost energy and raw materials, which are intrinsic causes for the mushrooming of

Table 9  
Investment expenditure in different regions.

Variables	(1) West	(2) East	(3) Middle
<i>Dumpollute*Dum11</i>	0.0495** (2.112)	−0.0386* (−1.929)	0.0971 (1.161)
<i>Dumpollute</i>	−0.0101 (−0.110)	0.0156 (0.814)	−0.0816 (−1.243)
<i>Dum11</i>	−0.0741 (−0.696)	−0.0363** (−13.729)	−0.0142** (−2.109)
<i>Lloan</i>	0.0103** (2.139)	0.0014 (0.042)	0.0206** (2.511)
<i>Roa</i>	0.0990** (2.267)	0.0791*** (7.658)	0.0931*** (3.116)
<i>S0</i>	−0.0234 (−1.558)	0.0165** (31.689)	0.0740 (0.644)
<i>Hold1</i>	−0.0687 (−0.375)	−0.0429 (−1.306)	0.0144 (0.119)
<i>Lev</i>	0.0560*** (2.930)	0.0466*** (9.159)	−0.0821 (−0.539)
<i>Fixas</i>	0.001** (2.443)	0.014*** (3.087)	0.002 (0.518)
<i>Size</i>	0.0131** (2.536)	0.0269*** (3.142)	0.0108*** (3.702)
<i>Constant</i>	−0.257** (−2.341)	−0.102*** (−5.213)	−0.175*** (−2.894)
<i>Industry</i>	<i>Controlled</i>	<i>Controlled</i>	<i>Controlled</i>
<i>Year</i>	<i>Controlled</i>	<i>Controlled</i>	<i>Controlled</i>
<i>Observations</i>	515	5669	1124
<i>Adj-R2</i>	0.116	0.598	0.207
<i>F</i>	2.673	256.6	7.911

The robust t-statistics are reported in parentheses.

\* Significance at the 10% level.

\*\* Significance at the 5% level.

\*\*\* Significance at the 1% level.

high-polluting enterprises in this region. Furthermore, as economic development is relatively primitive in the middle and western regions, local officials might be willing to relax the regulatory standards on environmental pollution to attract investment and meet political performance requirements. Shen et al. (2012) find that the spatial distribution trend of pollution-intensive industries in Guangdong province is “disperse-concentrate-disperse”: they were concentrated in the Pearl River Delta from 2002 to 2005 but dispersed to other places from 2006. This provides evidence of the migration of pollution-intensive industry from Guangdong province to other places to escape the environmental regulations of the polluted area. In fact, polluting enterprises are the main source of PM2.5. We further investigate whether there are regional differences in investment behavior in high-polluting enterprises and whether these enterprises moved to other places after the 2011 event.

Many listed high-polluting enterprises invest in correlative industries by way of capital operation at the national scale. For example, Zijin Mining, whose stock code is 601899, has subsidiaries in Xinjiang, Xizang, Qinghai and Fujian provinces; Zijin Mining established the Northwest Company of Zijin Mining Group, South Investment Company of Zijin Mining Group and Zijin International Mining Corporation to take advantage of differences in environmental regulations and the policy of attracting investment to underdeveloped areas. The intention was to move the polluting industries and realize profit maximization by reducing the pollution risk and cost, thus undermining the implementation of environmental regulations.<sup>3</sup> Due to the spillover effect of air pollution, implementation of strict environmental regulations in certain areas may not be

<sup>3</sup> Bao Steel (600019) is in a similar situation: it has subsidiaries in Shanghai, Xinjiang and Shaoguan and can distribute industry on a national scale.

able to prove that the environmental regulations can decrease pollution. Hence, local government and enterprises may have strong incentives to increase the scale of their investments and gain short-term benefits. Thus, we believe that the investment projects of high-polluting enterprises probably migrated to other places where regulatory pressure is less severe after the 2011 event.

Table 9 reports the results of investment expenditure in different regions. The interactions of *Dumpollute* and *Dum11* are 0.0495, −0.0386 and 0.0971 for enterprises in the western, eastern and central regions, respectively, but are only significant for those in the western and eastern regions.

Table 10 further examines the investment opportunity sensitivity under different regions. The interaction of *Dum11*, *Dumpollute* and *Tobin* is only significantly positive (0.0825) in western region enterprises (column 1), and is insignificantly negative (−0.0296) in eastern region enterprises. Although the interaction of *Dum11*, *Dumpollute* and *Tobin* is insignificant in central region enterprises, the positive value shows that this region possibly has some pollution transfer projects. The above results demonstrate that with the strengthening of environmental regulations, investment expenditure and investment opportunity sensitivity of high-polluting enterprises were reduced in the eastern region and increased in the western region.

Table 10  
Investment opportunity sensitivity under different regions.

Variables	(1) West	(2) East	(3) Middle
<i>Dumpollute</i> * <i>Dum11</i>	0.0118** (2.342)	−0.0306* (−1.837)	0.0159 (1.325)
<i>Dumpollute</i> * <i>Dum11</i> * <i>Tobin</i>	0.0825** (2.073)	−0.0296 (−1.429)	0.0379 (0.827)
<i>Dumpollut</i> * <i>Tobin</i>	0.0133* (1.78)	0.0379** (2.15)	0.0206** (2.06)
<i>Dum11</i> * <i>Tobin</i>	−0.0135** (−2.08)	−0.0344 (−0.792)	−0.0196* (−1.86)
<i>Dumpollute</i>	0.0108 (0.267)	0.0153* (1.842)	0.0759 (1.026)
<i>Dum11</i>	−0.0124 (−0.882)	−0.0275*** (−5.178)	−0.0149** (−2.126)
<i>Tobin</i>	0.018 (0.183)	0.0436*** (2.345)	0.0787 (0.503)
<i>Lloan</i>	0.0012** (2.092)	−0.011 (−0.781)	0.0201** (2.178)
<i>Roa</i>	0.0834** (2.136)	0.0724*** (5.029)	0.0909** (3.116)
<i>S0</i>	−0.0104 (−1.256)	0.0125*** (3.716)	0.0573 (0.782)
<i>Hold1</i>	−0.0517 (−0.346)	−0.0427 (−1.581)	0.0506 (0.049)
<i>Lev</i>	0.0493*** (2.725)	0.0502*** (4.406)	−0.0792 (−0.773)
<i>Fixas</i>	0.0285** (2.328)	0.003*** (3.354)	0.0316 (0.758)
<i>Size</i>	0.0133*** (2.460)	0.0482*** (3.182)	0.0116*** (3.296)
<i>Constant</i>	−0.286** (−2.12)	−0.162*** (−3.039)	−0.165*** (−2.667)
<i>Industry</i>	<i>Controlled</i>	<i>Controlled</i>	<i>Controlled</i>
<i>Year</i>	<i>Controlled</i>	<i>Controlled</i>	<i>Controlled</i>
<i>Observations</i>	515	5669	1124
<i>Adj-R2</i>	0.235	0.307	0.196
<i>F</i>	52.07	33.89	78.52

The robust t-statistics are reported in parentheses.

\* Significance at the 10% level.

\*\* Significance at the 5% level.

\*\*\* Significance at the 1% level.

One possible explanation is that the “performance championships” of officials, the demands of polluting enterprises and environmental regulation cause high-polluting enterprises to transfer their investments.

## 6. Robustness tests

As there may be a missing value and external disturbance from macro policy to the micro mechanism, we further retest the investment opportunity sensitivity model using a “change model.” According to Li (2010), change models have three advantages: (1) testing the effect of the incremental explanatory variable on the explained variable can mitigate the effects of informal institutions that do not change over time, such as the corporate culture and managers’ preferences, on the explained variable; (2) the incremental part brings

Table 11  
Robustness test.

Variables	Full sample	Non-SOEs	SOEs
$\Delta Lev$	0.5560 <sup>***</sup> (5.772)	0.0915 (0.874)	0.6324 <sup>*</sup> (1.693)
$\Delta Size$	0.0650 <sup>***</sup> (14.940)	0.0828 (1.642)	0.0265 <sup>***</sup> (3.579)
$\Delta Roa$	0.0516 <sup>***</sup> (8.482)	0.0459 (0.226)	0.679 <sup>*</sup> (1.735)
$\Delta SO$	−0.3117 <sup>***</sup> (−3.461)	0.1314 (1.353)	−0.4796 (−1.437)
$\Delta Age$	−0.0319 <sup>***</sup> (−7.326)	−0.0282 (−0.554)	−0.0406 <sup>***</sup> (−5.987)
$\Delta Tobin$	0.1476 <sup>***</sup> (2.485)	0.0304 (0.231)	0.2379 (1.046)
$Dumpollute$	−0.0128 <sup>**</sup> (−2.028)	−0.0121 <sup>*</sup> (−1.669)	−0.0858 (−1.173)
$Dum11$	−0.0263 <sup>**</sup> (−2.374)	−0.0318 <sup>***</sup> (−3.061)	−0.0217 <sup>*</sup> (−1.793)
$Dum11 * Dumpollute$	−0.1275 <sup>*</sup> (−1.777)	−0.0206 <sup>**</sup> (−2.124)	−0.1136 (−1.286)
$\Delta Tobin1 * Dumpollute * Dum11$	−0.0762 <sup>**</sup> (−2.265)	−0.0623 <sup>*</sup> (−1.879)	−0.0260 (−0.753)
$Dumpollute * \Delta Tobin$	0.0341 <sup>*</sup> (1.675)	0.0276 <sup>*</sup> (1.974)	0.0484 (1.528)
$Dum11 * \Delta Tobin$	−0.2016 <sup>**</sup> (−2.013)	−0.1803 <sup>**</sup> (−2.355)	−0.1795 (−1.036)
$\Delta Fixas$	0.0372 <sup>*</sup> (1.695)	0.0255 <sup>**</sup> (2.124)	0.0464 <sup>**</sup> (2.017)
$\Delta Hold1$	0.553 (0.885)	0.175 (0.243)	0.710 (0.590)
$\Delta Lloan$	−0.0429 <sup>***</sup> (−2.962)	−0.0516 <sup>***</sup> (−3.814)	−0.0471 <sup>***</sup> (−2.963)
$Constant$	−0.1738 <sup>***</sup> (−3.902)	−0.1447 <sup>*</sup> (−1.983)	−0.6518 <sup>***</sup> (−3.257)
$Industry$	<i>Controlled</i>	<i>Controlled</i>	<i>Controlled</i>
$Year$	<i>Controlled</i>	<i>Controlled</i>	<i>Controlled</i>
$Province$	<i>Controlled</i>	<i>Controlled</i>	<i>Controlled</i>
$Observations$	7215	4751	2464
$Adj-R^2$	0.49	0.35	0.83
$F$	54.41	21.34	99.05

The robust t-statistics are reported in parenthesis.

\* Significance at the 10% level.

\*\* Significance at the 5% level.

\*\*\* Significance at the 1% level.



new information and can eliminate the influence of old information; and (3) the mitigation of endogenous problems. We generate the first-order difference for all continuous variables and re-regress model (3). Table 11 shows the results, which remain the same.

## 7. Conclusion

The third plenary session of the 18th session of the CCP proposed the establishment of a complete ecological civilization system to protect the ecological environment and to realize the grand blueprint of “beautiful China.” Polluting enterprises are the main source of air pollution. This study examines the effects of government environmental regulations on high-polluting enterprises’ investment behavior based on Chinese A-share listed firms from 2006 to 2014. The sudden surge in the PM2.5 index is used as a natural experimental exogenous event. We analyze the differences in investment expenditure and investment opportunity sensitivity between SOEs and non-SOEs, central SOEs and local SOEs and different regions.

We find that after the 2011 event, investment expenditure declines significantly in local SOEs and non-SOEs, whereas investment opportunity sensitivity declines significantly in non-SOEs compared with SOEs. However, there are no significant changes in central SOEs’ investment expenditure and investment opportunity sensitivity. Further analysis shows that investment expenditure and investment opportunity sensitivity decline for high-polluting enterprises located in East China but increase for those located in West China.

This paper has some policy implications. Although the Ministry of Pollution Protection and governments at all levels introduced the strictest regulations after the 2011 event, the goal of realizing a “Wild China” is still some way off under the current regulations. Effective implementation of smog governance and environmental regulations is the key to reducing PM2.5 pollution. The Ministry of Pollution Protection should collaborate with the China Securities Regulatory Commission, China Banking Regulatory Commission and commercial banks to enforce the environmental governance of high-polluting enterprises. Such enforcement of environmental governance is achieved not only by reducing investment in polluting projects but also by cutting off their financial support. Local government should fully understand the connotation of “investment opportunity” and reduce excessive interventions for companies and commercial bank credit. Local officials should adopt correct attitudes toward political performance and lessen the excessive dependence on high-polluting enterprises to support local GDP. The governments and environmental management departments should propose appropriate solutions to resolve the lack of supervision and the pollution transfer phenomenon in China as soon as possible.

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