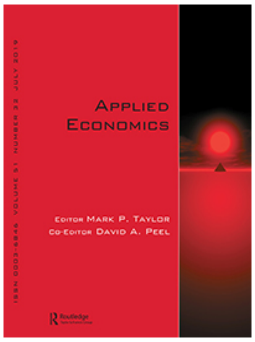

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Pollution and corporate valuation: evidence from China

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ABSTRACT
Environmental pollution brings severe challenges in the context of a high growing economy of China. Pollution events bring serious ecological cost to the environment, direct costs from sanction, and reputational damage to the listed firms. We study the market reaction to 145 pollution events in China during Jan 2008 and Feb 2015. We find that the 2-day cumulative abnormal returns (CARs) of pollution events are significantly negative, which shows the disciplining effect of the stock market on the listed firms. In addition, pollution events with sanctions have lower CARs than otherwise, which are heterogeneous among different sanction types such as shutting down, fines and rectification. Finally, water pollution has lower CARs than other pollution types. We find that direct economic loss is an important reason for the negative market reactions to pollution events.

KEYWORDS
Pollution; event study; market reaction; sanction

JEL CLASSIFICATION
G14; G21; K32

I. Introduction

Environmental problems have become increasingly serious in the context of a high growing economy in China. A report from the Asian Development Bank in 2012 shows that no more than 1% out of 500 cities in China have reached the air quality standards of the World Health Organization, and 7 of the World top 10 most polluted cities are in China (Zhang and Crooks 2012). In Jan 2013, a grey haze that far exceeded the air quality standards affected the entire North China, and the poor air quality resulted in large crowds in the respiratory departments of several hospitals (Wong 2013). And a few chemical firms were reported to have raw sewage discharge problems in 2014, which end up in severe pollution of the Tengger Desert.[1]

With increasing concerns about the pollution problems, the market reaction to pollution events of listed firms has attracted substantial attention in China. The results may cast light on the environmental pollution risk for the investors, which may affect the environmental investment of listed firms. It may also help the regulators design rules on environmental information disclosure.

When a pollution event of listed firms is exposed to the general public, it provides new information to the investors. On the one hand, there is a disclosure effect (Shane and Spicer 1983; Hamilton 1995). On the other hand, pollution events can affect the cash flow of listed firms due to direct economic losses from sanctions (Karpoff, Lott, and Wehrly 2005), and bring reputation losses due to a poor corporate social responsibility in environmental performance (Flammer 2013).

While the market reaction to pollution events have been widely studied in the literature, there are limited studies focusing on the mechanism through which pollution events affect the stock price. Also, most of the studies on the stock market reaction to pollution events are from industrial countries, while a study in an emerging economy like China is of high importance both from the academic and practical perspectives. The threat of a severe penalty by the investors can provide incentives for pollution control by listed firms, which can complement a weak law enforcement in developing countries.

The disclosure of pollution events offers investors some information about firms' environmental performance. In addition, the disclosure of

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[1]Source: Industrial pollution in Tengger Desert, sina.com, 2014.09.11.

pollution events contains information such as sanction and pollution type, which may have heterogeneous effect on the market reactions. As China has not adopted an effective system for the environmental information disclosure, it is difficult to access pollution information in general. We collect pollution events disclosed by the media and provide a new research data. Firms in developing countries do not have sufficient incentives to curtail pollution due to a weak regulatory environment, e.g. the benefit of pollution is higher than the potential cost of complying with the regulations.

We identify 145 pollution events of A-share listed firms reported by eight major newspaper from Jan 2008 to Feb 2015 and hand-collected information such as sanction and pollution types. We examine the stock market reaction to the pollution events of listed firms in China. Furthermore, we link the CARs with the firm characteristics, pollution type, sanction information, especially penalties from the central and local government to reveal the underlying mechanism.

Our results cast light on the supervision of the environmental performance of listed firms in China, which can incentivize these firms to promote environmental investment and information disclosure, and remind investors of the environmental risks in listed firms.

This paper proceeds as follows: Section II is literature review. Section III introduces the data and methodology of this paper. Section IV is the empirical results and analysis. Section V concludes the paper.

II. Literature review

The optimal penalty theory suggests that total punishment for a misconduct behaviour is equal to its total social cost (Becker 1968). The total punishment for the misconduct includes the cost of external civil, criminal and administrative penalties, as well as reputation damage. If the reputation damage is severe, the legal punishment will be small, and vice versa.

As a violation of the laws and regulations, pollution events may also bring punishment for the firm. On the one hand, pollution events may lead to direct fines, compensation and disposal costs. On the other hand, they may also bring damages to the firm's reputation. For example, consumers may thereby resist the production from environment-pollution firms. Karpoff, Lott, and Wehrly (2005) surveyed 148 pollution lawsuits that occurred in America and found that the losses were mainly derived from the legal punishment on the pollution events themselves (i.e. direct economic losses). In China, there are less pollution lawsuits owing to the provisions of the laws for litigation, and the direct economic loss caused by the lawsuits of pollution events cannot be measured from the perspective of the cost of lawsuit settlement. The disclosure of violation brings a significantly negative influence on listed firms. Beside the administrative penalties, the reputational penalties are relatively severe in China.

The relationship between environmental performance and stock price receives substantial attention in the literature while the results are still mixed in the literature. Shane and Spicer (1983) are among the first to study the impact of pollution events on stock prices of listed firms in the U.S. They use environmental reports disclosed by the U.S. Council on Economic Priorities (CEP) from 1970 to 1975, and find negative abnormal returns after the announcement of pollution by CEP, which is more pronounced for firms that are less capable to control pollution.

Violation of environmental protection laws and regulations will lead to lawsuits in developed countries such as the United States and Canada. Lawsuits filing and settlement caused by pollution events can affect the stock price of listed firms. Muoghalu, Robison, and Glascock (1990) examine lawsuits on pollution in the U.S. from 1977 to 1986 and find that the market value suffers a loss of 1.2% on average when listed firms are adjudicated for pollution events, while no effect from the settlement of the lawsuit. Laplante and Lanoie (1994) examine 47 pollution events from 1982 to 1991 in Canada and find that firms suffer an abnormal loss of 1.6% to 2% after the lawsuits and fining on pollutions.

Hamilton (1995) studies the data in toxics release inventory (TRI[2]) by Environmental Protection Agency (EPA), and find that the affected firms have

[2]TRI is a policy tool of the Environmental Protection Agency (EPA) which is designed to release environmental pollution information in company's behaviour. American companies are required to report the emission of over 300 kinds of toxic subsistence which will constitute a danger to human health and the environment. http://www2.epa.gov/toxics-release-inventory-tri-program/.

an average loss of 0.2% to 0.3% when the TRI is released, which is more pronounced for more kinds of toxic substance species. Lanoie, Laplante, and Roy (1998) find that the stock price does not react significantly to the announcement of pollution problems caught by Ministry of Environmental Protection, which may be caused by the difference of capital market and legal systems between the U.S. and Canada. Khanna, Quimio, and Bojilova (1998) examine the market reactions to the TRI releases and find that firms repeatedly exceeding the emission standards have negative abnormal returns, which is related to the domestic and abroad emissions, and environmental performance and environmental R&D investment before the release of TRI.

Rao (1996) treats pollution events as an unethical firm behaviour and finds that the abnormal return is significantly negative, i.e. −5.29% in the month of pollution using 14 pollution events reported by the Wall Street Journal. Bosch et al.(1998) find a negative market reaction if a listed firm becomes the target of EPA enforcement that may violate environmental protection regulations. Klassen and McLaughlin (1996) show that the market value increases by US $80 million on average when the firm is granted an environmental protection award and suffers an average loss of US $390 million for the failure ones.

Dasgupta, Laplante, and Mamingi (2001) examine 39 positive environmental events, and 85 negative environmental events in Argentina, Chile, Philippines, Mexico from 1990 to 1994, and find that the market reacts negatively to the pollution events due to public complaints, and positively to good environmental performances. Lorraine, Collison, and Power (2004) study 23 positive and 9 negative environmental events in the UK and find that there is no significant abnormal return. Gupta and Goldar (2005) study the market reaction to environmental performance rating by Green Rating Program (a program of the CSE in India), and find that the pollution behaviour does harm firms' market value.

Cheung (2011) show positive market reaction when a listed firm is selected as a Dow Jones Sustainability Index, and negative market reaction when it is ruled out from the list during 2002–2008. Capelle-Blancard and Laguna (2010) study 64 chemical disasters from 1990 to 2005, and find the average two-day CARs following the pollution events is −1.3%, and a loss of 12% of the market value over the 6 months period ex-post the event. Endrikat (2016) find an asymmetry pattern between the positive and negative events, i.e. negative events have a more pronounced effect.

From the perspective of Corporate Social Responsibility, Flammer (2013) find that the media report of the efforts on Environmental Corporate Social Responsibility can increase firms' resources and competitiveness. Krüger (2015) study the influence of corporate social responsibility events on shareholder wealth using environment events in the U.S. from 2001 to 2007, i.e. 121 negative events. He finds that the CAR is −1.54% in a 11-day event window [−5, 5], and the events with legal and economic information have a more pronounced market reaction.

Table 1 summarizes the key literature with some basic information as follows:

III. Hypothesis and data

Hypothesis

Market reaction to pollution events

The impact of pollution events on the stock prices in the U.S., Canada and other developed countries

Table 1. Literature summary.

Author(s)	Event and Data Source	Methodology	Country	Time	Result
Hamilton (1995)	Excessive emissions (TRI data)	OLS	U.S.	1989	Negative
Laplante and Lanoie (1994)	47 Violations of environmental law events (Newspapers)	Event Study	Canada	1982–1992	Negative
Dasgupta, Laplante, and Mamingi (2001)	Pollution events (Newspapers)	Event Study	Argentina et al.	1990–1994	Not significant
Lorraine, Collison, and Power (2004)	23 Negative environmental events(Agency reports)	Event Study	U.K.	1995–2000	Not significant
Gupta and Goldar (2005)	Poor environmental ratings (Indian Center for Science and environment)	Event Study	India	1993–2001	Negative
Flammer (2013)	Pollution Events (News from Factiva)	Event Study and OLS	U.S	1980–2009	Negative
Krüger (2015)	Negative environmental News (KLD)	Event Study and OLS	U.S	2001–2007	Negative

seems to be negative in general. However, the mechanism of this negative impact and relevant determinants are mixed in the literature. The market reactions to pollution events in developing countries like China are also mixed in the literature.

Pollution events affect the stock prices of listed firms in the following ways. Firstly, the pollution events provide more information on firms' environmental performance and thus end up in a disclosure effect. After pollution events are reported by the media, the news provided investors with more information on whether the firm reaches the minimum regulatory standard of environmental protection or not (Shane and Spicer 1983). Pollution events provide new information about the environmental performance of listed firms, who can estimate the discrepancy between the environmental performance of listed firms and local environmental regulation.

Secondly, Flammer (2013) shows that environmental protection is a part of corporate social responsibility. Environmental protection has drawn increasingly more attention from the public and has become a kind of social norm recently. Firms will be punished when they pollution and violate this norm. The concept of environmental protection is accepted by more and more people. Therefore, listed firms with pollution events will have negative market reactions.

Therefore, we propose our first hypothesis as follows:

Hypothesis 1: Environmental pollution events have a negative effect on the stock prices of listed firms.

Determinants of the stock market reaction

(1) Administrative penalty and sanction

Administrative penalty is one of the tools through which the government controls environmental pollution. The air, river and forest have public attributes, so pollutions have a negative externality. If the information disclosure is not conducive to the profit, firms are more likely to block the news, which ends up in an asymmetry attribute of environmental information. For example, listed firms know more about their own pollution problems than the uninformed investors. The administrative penalty decisions of regulators provide more validated information on pollution. Moreover, it forces the polluting firms to face the procedures of arbitration and administrative penalties through government regulation.

Karpoff, Lott, and Wehrly (2005) study 478 pollution events from 1980 to 2000 in the U.S., and show that the negative impact of violations of pollution laws and regulations mainly come from regulatory and legal punishment, e.g. fines, compensation for the victims, rectification and pollution clean-up costs.

The new information provided by media reports will have a strong impact on the market value of listed firms. The media may also report the pollution behaviour and administrative penalties if the firm gets punished by environmental protection regulatory authorities. For example, Krüger (2015) finds that the stock price has more significant reactions to pollution events with legal and economic information.

Therefore, we propose our second hypothesis as follows:

Hypothesis 2: Compared with pollution events without sanction information, those with sanction information have a more negative impact on listed firms' stock price.

Administrative punishment of environmental regulatory authorities in China can be categorized into three types, i.e. shutting down production, fines, and order to rectify and reform. Firms need to shut down equipment and production lines which do not comply with environmental protection standards. These halts will cut down their production capacity and sales revenues. Environmental protection regulatory authorities can also impose fines on the polluting firms. The environmental protection regulatory authorities have the power to require firms to make rectification and reform if the firms do not comply with environmental standards.

Thus, we further make the following sub-hypotheses:

Hypothesis 2.1: Compared with pollution events without sanction of shutting-down production, *those with such sanction have a more negative impact on the stock price.*

Hypothesis 2.2: Compared with pollution events without sanction of fines, those with such sanction have a more negative impact on the stock price.

Hypothesis 2.3: Compared with pollution events without sanction of rectification, those with such sanction have a more negative impact on the stock price.

(2) Types of pollution

According to Xu, Zeng, and Tam (2012) and Hamilton (1995), pollution events can be classified into three types, water pollution, air pollution, and other types of pollution including potential existing environment risk. The cost method of cleaning is applied to calculate the hypothesized cleaning up cost, i.e. the cost to recover all the current emissions of pollutants according to existing technology. The water, air and other types of pollution account for 62.9%, 32.1% and 5% of the total hypothesized clean-up costs, respectively. The hypothesized clean-up cost of water pollution is the highest. We will investigate the impact of different pollution types on the market reactions. Xu, Zeng, and Tam (2012) examine pollution events of 57 listed firms and show that there is a more pronounced market reaction to the events with water pollution than other types of pollutions.

We propose our third hypothesis 3 as follows:

Hypothesis 3: Compared with other types of pollution, the stock market has a more negative reaction to pollution events with water pollution.

(3) Ownership types

Social responsibility of state-owned firms is more intriguing as they need to achieve both economic and non-economic goals. Wang and Li (2013) analyse 149 negative environmental events in China that failed to pass the environmental verification, and find more pronounced negative market reactions for state-owned firms than private firms. Investors may have higher expectations on the corporate social responsibility of state-owned firms than private firms.

We propose our fourth hypothesis as follows:

Hypothesis 4: Compared with private firms, the market reaction to pollution events are more negative for state-owned firms.

Data

Pollution events

We investigate the stock market reaction to the pollution events of listed firms in China. We collect pollution events from the media reports. The definition of pollution events is based on Xu, Zeng, and Tam (2012), i.e. events that lead to pollution or imply potential environmental risk due to violating laws and regulations on environmental protection in China.

Source of data

Pollution events are often widely reported by the media (Hamilton 1995). Existing research on pollution events in the US and UK often use reports from well-known newspapers like the *Wall Street Journal* and *the Financial Times*. (Lorraine, Collison, and Power 2004). Using similar methods, we collect the news data from eight influential media in China (*China Securities Journal, Shanghai Securities News, Securities Daily, Securities Times, 21st Century Business Herald, China Business Journal, China Business News, National Business Daily*). The event identification method is based on Flammer (2013). To identify articles about pollutions, we search the keyword pollution using the CNKI news database, which ends up in 15,475 articles. The articles about industry, policy, and non-A-share listed firms are eliminated. Each article is examined to ensure that it contains the pollution event about a listed firm. We reach a sample of 173 pollution events.

For the pollution events collected by the above steps, we search for the sanction information in the environment ministry websites and the firm announcements from CNINF database. The stock price and financial data of listed firm are retrieved from the Wind database.

We choose the sample period according to the data availability and the launch time of environmental regulations for listed firms. China's State Environmental Protection Administration and the China Securities Regulatory Commission enacted *Guiding Opinions on Strengthening the Environmental Protection Supervision and Management of Listed firms* ([2008]24) in February 2008, which clarified the environmental protection requirements of listed firms for the first time. Meanwhile, due to data availability, we select pollution events of listed firms between 2008 and February 2015.

In order to ensure the validity of the sample, events are excluded if they fail to meet the following requirements: (1) The events are close to other significant confounding events during the period before and after 1 day of the event date, such as the profit announcement, merge and acquisition; (2) The events that lack stock price and financial data; (3) Only the first report by the media is included as some pollution events may be reported by several media in different times. Finally, we reach a sample of 145 pollution events, which involve 102 firms in China. Table 2 summarizes the sample selection process as follows:

Methodology

Event study

(1) Definition of the event day

The date when the media reports the pollution is chosen as the event day. If an event is disclosed by several newspapers, the first reported date is treated as the event day. If the event day is not a -trading day or the stock is temporarily suspended for one day due to this event, the following trading day is chosen as the event day. The event day of pollution events is t = 0, and the estimated window is from 180 days to 30 days before the event day.

(2) Event sample

According to the description in section 3.2, we examine 145 pollution events of listed firms from Jan 2008 to Feb 2015. The detailed information is in the appendix.

(3) Normal return model

We choose market model to study the pollution events. Lundgren and Olsson (2010) use a variety of normal return estimation models on pollution events and show that environmental events are not sensitive to the model specifications. We use the CSI300 index as the rate of the market return.

$$R_{it} = \alpha_i + \beta_i R_{mt} + e_{it} \quad (1)$$

t is time; i is the pollution events of listed firms; R_{mt} is the market return calculated by CSI300 index for the day t; α_i is the constant term; β_i is the systematic risk of the stock i. Equation (1) gets the normal returns by calculating the returns from 180 days to 30 days before pollution events and the estimated value of α_i and β_i.

$$\hat{R}_{it} = \widehat{\alpha_i} + \widehat{\beta_i} R_{mt} \quad (2)$$

(4) Estimating the abnormal returns in the event window

The normal return during the event window can be calculated using the estimates of α_i and β_i. The

Table 2. Sample selection process.

Items	Information	Remarks
Time span	7 years	Jan 2008–Feb 2015
Object	A-share listed firms	
News data Source	*China Securities Journal, Shanghai Securities News, Securities Daily, Securities Times, 21st Century Business Herald, China Business Journal, China Business News, National Business Daily*) (CNKI News database)	
Other data source	Wind, CNINF, Ministry of Environmental Protection, IPE	
Original news	15,475	
Total events	173	
Excluded	ST, *ST listed firms	
	Confounding events	
	Data missing	
	Repeating events	Only the first one is kept in case of mutiple events
	Outliers	
Events	145	

difference between the actual return and the predicted normal return or the abnormal return AR is:

$$AR_{it} = R_{it} - \hat{R}_{it} \tag{3}$$

In order to calculate the market reaction of pollution events, the average abnormal return (AAR) for time t is calculated as follows:

$$AAR_t = \frac{1}{N}\sum\nolimits_{i=1}^{N} AR_{it} \tag{4}$$

To test the pollution events' impact in a period of time ($t_2 - t_1$) for each stock i, the CAR is calculated for stock i as follows:

$$CAR_i(T_1, T_2) = \sum\nolimits_{t=T_1}^{T_2} AR_{it} \tag{5}$$

And also the cumulative average abnormal return (CAR) is as follows:

$$CAR(T_1, T_2) = \frac{1}{N}\sum\nolimits_{i=1}^{N} CAR_i(T_1, T_2) \tag{6}$$

We use multivariable regression to further study the impacts of sanction information, pollution type and ownership on the CARs of pollution events (Karpoff, Lott J, and Wehrly 2005; Xu, Zeng, and Tam 2012; Flammer 2013; Krüger 2015). The basic model is as follows:

$$\begin{aligned} CAR_i = {} & \beta_0 + \beta_1 \text{Sanction}_i + \beta_2 \text{Air}_i \\ & + \beta_3 \text{Water}_i + \beta_4 \text{Ownership}_i \\ & + \beta_5 Size_i + \beta_6 \text{ROA}_i + \beta_7 \text{MTB}_i \\ & + \beta_8 \text{Leverage}_i + \beta_9 \text{Shareholder}_i \\ & + \sum \beta_i Industry + \sum \beta_i Region + \varepsilon_i \end{aligned} \tag{9}$$

1. Dependent variable CAR

Considering the significance of CARs around the event day and the dependent variable used by Capelle-Blancard and Laguna (2010), we define the dependent variable as the CAR on the event day and 1 day after the pollution event day (t = [0,1]). We will investigate various factors that may affect the CARs of listed firms with pollution events.

2. Explanatory variables

(1) Sanction

According to Hypothesis 2, the CARs may be more negative when the pollution events contain sanction information, which are retrieved from the content of media reports. In China, the former State Environmental Protection Administration issued the *Environmental Protection Administrative Sanctions Regulation* in August 1999. This file was revised in 2010 (Environmental Protection File No. 2010 [8]). In this regulation, the environmental regulatory authorities could use several methods to punish the companies that violate the environmental regulation, including production shutting down, fine and rectification.

We add the sanction dummy variable, i.e. when the media report contains sanction information, Sanction = 1, and when the media report does not have sanction information, Sanction = 0.

(2) Pollution type (water/air)

The pollution events can be divided into the following three categories according to the types of pollution: First, listed firm discharges untreated polluted water into groundwater, river or ocean, which causes the pollution of water. It is defined as water pollution and expressed as a variable Water = 1. Second, listed firm discharges exhaust gas that harms air quality. It is defined as air pollution and expressed as a variable Air = 1. Third, other pollution type, includes potential pollution risk, construction in advance without permission, lack of pollution control measures, etc.

(3) Ownership

According to the ownership of listed firms, the 145 pollution events are divided into state-owned and private firms. We use a dummy variable Ownership which equals 1 if a listed firm with pollution is a state-owned firm, i.e. central and local state-owned firm, and 0 otherwise.

3. Control variables

(1) Size: The natural logarithm of total assets;
(2) ROA: The net profit over total assets;
(3) MTB: The market value of the equity plus the book value of debt over the book value of total assets;
(4) Leverage: The debt to asset ratio;
(5) Shareholder: The equity shareholding of the top 10 shareholders;
(6) Industry and region dummies.

One of the most important explanatory variables is the sanction information in Equation (9). We further study the impact of sanction by expanding

Sanction into three dummy variables, including production shutting down, fine and rectification.

So the extended model is as follows:

$$CAR_i = \beta_0 + \beta_{11}\text{Stop}_i + \beta_{12}\text{Fine}_i + \beta_{13}\text{Rectify}_i + \beta_2\text{Air}_i + \beta_3\text{Water}_i + \beta_4\text{Ownership}_i + \beta_5 Size_i + \beta_6\text{ROA}_i + \beta_7\text{MTB}_i + \beta_8\text{Leverage}_i + \beta_9\text{Shareholder}_i + \sum \beta_i Industry + \sum \beta_i Region + \varepsilon_i \quad (10)$$

(1) If the pollution event reported by media contains information that the firm should stop production according to environmental regulatory authorities, the variable Stop is 1, and 0 otherwise.

(2) If the pollution event reported by the media contains information that the firm has been fined by environmental regulatory authorities, the variable Fine is 1, and 0 otherwise.

(3) If the media reports that environmental regulatory authorities urge the listed firm with pollution event to take corrective actions, the variable Rectify is 1, and 0 otherwise.

Table 3 summarizes the variable definitions as follows:

IV. Empirical analysis

Sample description

We present the summary statistics for the 145 pollution events for listed firms. Table 4 shows the industry distribution of the 145 pollution events, which cover 17 industries. Twenty-one per cent of the events come from the chemical industry, which is a highly polluted industry due to the production of chemical raw materials and products. Sixteen per cent of the events come from nonferrous metals industry. Fifteen per cent of the events come from the mining industry. Ten per cent of the events come from the biological medicine industry. Eight per cent of the events are from electric power, coal gas, water product and supply. Other industries, such as iron and steel, machinery, construction, textile, also have pollution events in this sample.

Table 5 shows the description of events by pollution type. Pollution events can be divided

Table 4. Description of events by industry.

Industry	No. of Events	Frequency
Mining	22	15%
Iron and steel	4	3%
Nonferrous metals	23	16%
Chemistry	31	21%
Machinery	3	2%
Construction	3	2%
Transportation	2	1%
Medicine, biological products	14	10%
Electric power, coal gas, water product and supply	12	8%
Electron	1	1%
Automobile	3	2%
Textile	3	2%
Light industry	7	5%
Agriculture	6	4%
Trade	1	1%
Food and drink	8	6%
Others	2	1%
Total	**145**	**100%**

Table 3. Variable definitions.

	Name	Literature	Expected Sign	Definition
Dependent Variable	CAR	Muoghalu, Robison, and Glascock (1990), Flammer (2013)		Cumulative abnormal return in the event window
Explanatory Variables	Stop	Karpoff, Lott J, and Wehrly (2005)	-	Equals if the firm needs to stop production, and 0 otherwise
	Fine		-	Equals 1 if the firm has been fined by environmental regulatory authorities, and 0 otherwise
	Rectify		-	Equals 1 if the firm needs to rectify, and 0 otherwise
	Water	Hamilton (1995), Xu, Zeng, and Tam (2012)	-	Equals 1 if the event is related to water pollution, and 0 otherwise
	Air	Hamilton (1995), Xu, Zeng, and Tam (2012)	-	Equals 1 if the event is related to air pollution, and 0 otherwise
	Ownership	Wang and Li (2013)	-	Equals 1 if the firm is a SOE, and 0 otherwise
Control Variables	Size	Krüger (2015)	+	ln(Total Assets)
	ROA	Xu, Zeng, and Tam (2012)	+	ROA
	MTB	Flammer (2013)	±	Market to book ratio
	Leverage	Muoghalu, Robison, and Glascock (1990)	+	Debt to asset ratio
	Shareholder	Liu and Chong (2014)	±	Shareholding ratio of the top ten largest shareholders
	Industry	Wind standards		Industry control variables
	Regions	National Bureau of Statistics of China		Region control variables

Table 5. Description of events by pollution type.

		No. of Events	Frequency
Pollution Type	Water pollution	79	54%
	Air pollution	39	27%
	Others	27	19%

into air, water and others including potential pollution risk, solid waste pollution, etc. Among the 145 pollution events, 54% of them are water pollution events. Twenty-seven per cent of them are air pollution events and 19% are of other types.

Table 6 shows the description of events by ownership. Firms are divided into state-owned and private firms. State-owned firms include central and local state-owned firms. State-owned firms account for 68%, and private firms account for 32% of the 145 pollution events.

Table 7 shows the description of events by sanction information. The events are divided into two categories: one has sanction information in the media report and the other does not. Among the 145 pollution events, 73 of them contain sanction information and 72 do not.

Table 8 shows the distribution of listed firms' locations. Among the 145 pollution events, 61% come from the eastern region. Twenty-one per cent come from the middle region. Six per cent come from the western region. And 13% come from the north-east region.

Stock market reaction to pollution events

The market model is employed to estimate the normal return, where the estimation window is from 180 days to 30 days before the event. Table 9 shows the average abnormal return of the firms before and after pollution events. There are significantly negative abnormal returns on the event day and the following two days.

Before the event day, the firms' stock price fluctuates slightly, but the abnormal returns are not significant. On the event day (t = 0), the average abnormal return is −0.006 (significant at the 5% level). A day after the event (t = 1), the abnormal return is −0.006 (significant at the 1% level). Two days (t = 2) after the event, the abnormal return is −0.004 (significant at the 1% level). On the third and fourth days after the event, there still exist negative abnormal returns but they are not significant.

There are significantly negative abnormal returns after the pollution events, i.e. the pollution events have a negative impact on firms' stock price. As the average abnormal return on the event day and the following day are significantly negative, we use [0,1] as the event window in our main analysis. We also use alternative event windows as a robustness check.

Figure 1 shows the CARs of the 145 pollution events during the event window. Ninety-four pollution events have negative CARs, which are between −0.2 and 0.1. The average CARs is −1.2% (significant at the 1% level) in the event window [0,1]. We also calculate the CARs in three events windows: [0, 1], [−1, 1] and [0, 2] in Table 10. Under the

Table 6. Description of events by ownership.

		No.of Events	Frequency
Ownership	SOE	98	68%
	Private	47	32%

Table 7. Description of events by sanction information.

		No. of Events	Frequency
Sanction	Yes	73	50%
	No	72	50%

Table 8. Description of events by region.

		No. of Events	Frequency
Region	East	88	61%
	Central	30	21%
	West	8	6%
	Northeast	19	13%

Table 9. Average abnormal return before and after the pollution events.

Day	AAR	t statistic
−10	−0.002	−1.168
−9	0.000	0.001
−8	0.000	0.078
−7	0.001	0.628
−6	0.003	1.614
−5	0.001	0.473
−4	−0.002	−1.352
−3	0.003	1.352
−2	0.001	0.323
−1	0.000	0.249
0	−0.006	−2.217 **
1	−0.006	−3.206 ***
2	−0.004	−2.417 **
3	−0.001	−0.625
4	−0.001	−0.532
5	0.000	0.022
6	−0.002	−0.915
7	0.001	0.532
8	0.000	0.137
9	−0.001	−0.86
10	−0.001	−0.757

N = 145, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

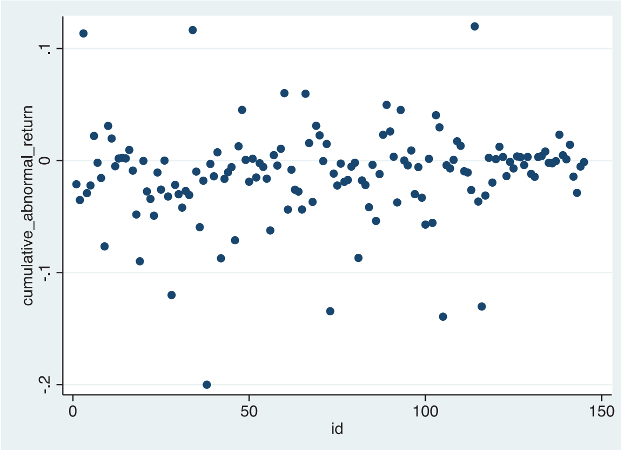

Figure 1. CAR.

Table 10. CAR of different event windows.

Event Window	CAR	*t*-Statistic
(0,1)	−0.0120	−3.52 a
(0,2)	−0.0163	−4.13 a
(−1,1)	−0.0115	−2.85 a

a $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

three events windows, the CARs are all significantly different from zero (at the 1% level). In sum, the stock market reaction to the pollution events is significantly negative. On the event day and following two days after the pollution event, the CAR is −1.6% on average (at the 1% level).

Figure 2 shows the time trend of the CARs 20 days before and after the event day. The stock price of listed firms begins to fall slightly 15 days before the event day. About 10 days before the pollution event, the CAR has a slightly rising trend. One potential reason is that the firm management team may hear about the pollution information and adopts positive measures to reduce potential negative influence, like releasing some positive information. On the event day, the CAR falls sharply, which continues to fall until 10 after the event. After 15 days of ex-post the event, the CAR rises a little. One potential reason is that investors may change their opinions about the pollution event when more information is released. Alternatively, firms may take remedying measures to release positive information to stabilize the stock price. In sum, we find that pollution events have significantly negative impact on the stock price of the firms with pollution events.

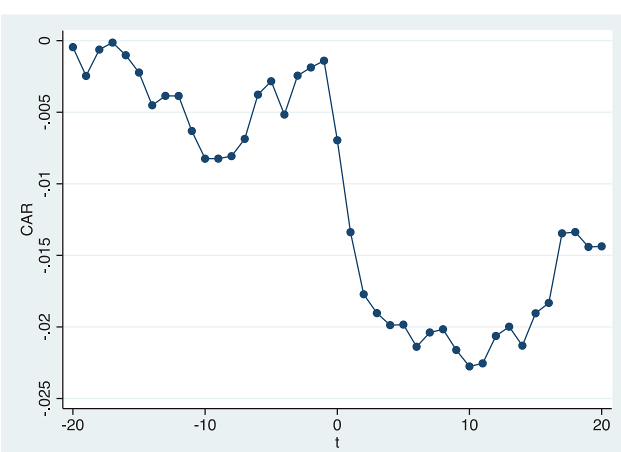

Figure 2. Trend of CAR 20 days before and after the event day.

Determinants of CARs for pollution events

Descriptive statistics

Table 11 shows the descriptive statistics of the variables used in the regression. The average CARs of the 145 pollution events are −1.2%, so the pollution events have a negative impact on the firms' stock prices. There are about 50% of the events contain sanction information, most of which involve water pollution.

Correlation analysis

According to the correlation matrix in the appendix, most of the correlation coefficients of independent variables are less than 0.5. To alleviate the concern of multicollinearity, variance inflation factors (VIF) are further calculated after the regression. The VIF tests show that the average VIF is 1.74 for the baseline model and the VIF for each variable is all less than 4. Thus, there is no serious multicollinearity problem in the model.

Table 11. Descriptive statistics.

	Max	Min	Average	Median	SD
CAR	0.120	−0.200	−0.012	−0.006	0.041
Sanction	1.000	0.000	0.507	1.000	0.502
Water	1.000	0.000	0.542	1.000	0.500
Air	1.000	0.000	0.275	0.000	0.448
Ownership	1.000	0.000	0.690	1.000	0.464
Size	28.480	19.870	23.687	22.905	2.387
ROA	0.351	−0.149	0.043	0.035	0.069
MTB	25.452	0.614	3.261	2.453	2.845
Leverage	0.883	0.015	0.511	0.501	0.193
Shareholder	0.982	0.223	0.636	0.633	0.217

Empirical results

Based on the descriptive statistics, we construct a multivariable regression model to study the factors that may affect the CARs for pollution events. Table 12 shows the result of multivariable regression. The variables related to Hypothesis 2, Hypothesis 3 and Hypothesis 4 are added to the models, respectively. Since the coefficients in Model 1 to Model 5 are qualitatively similar, we use the results in Model 5 to interpret our findings.

The variable Sanction, which equals 1 when the report of the pollution event contains sanction information, has a coefficient of −0.017 (significant at the 1% level). The variable Water, which equals 1 when the event involves water pollution, has a coefficient of −0.285 (significant at the 1% level). The variable Air, which equals 1 when the event involves air pollution, has a coefficient of −0.0152 (t statistic is −1.62, marginally significant). The variable Ownership, which equals 1 when the listed firm with pollution event is a state-owned firm, has a coefficient of −0.0048 (t statistic is −0.450, insignificant).

When sanction information is included in the report of a pollution event, CARs is more negative, which is significant at the 1% level (Hypothesis 2). It also suggests that China's administrative penalties against pollution are effective. Investors may also focus on the direct economic cost brought by administrative penalties.

We also classify the pollution events by pollution types. Water pollution is negative and significant at the 1% level, which supports Hypothesis 3. One potential reason is that these events may pollute large areas of water, which cannot recover in a short period of time, and the clean-up cost is quite substantial. It corroborates the high cost of water pollution recover by Xu, Zeng, and Tam (2012) from 57 pollution events in China.

The coefficient of firms' ownership is −0.0048 but insignificant. The sign of this coefficient supports Hypothesis 4, but opposite to the findings in Wang and Li (2013). State-owned and private firm do not seem to have a significant difference in terms of environmental resource and environmental protection requirements. In addition, the coefficient of Size and ROA is 0.0045 and 0.1532, respectively (significant at the 10% level). It shows that the larger the size and profitability, the less negative influence of pollution events on these firms.

Sanction information has significant influence on the stock price of listed firms with pollution events reported by the media. Pollution events that contain sanction information will cause more negative

Table 12. Regression result (1).

	(1)	(2)	(3)	(4)	(5)
Variables	Car[0,1]	Car[0,1]	Car[0,1]	Car[0,1]	Car[0,1]
Sanction	−0.0177***	−0.0178***	−0.0178***	−0.0174***	−0.0172***
	(−2.910)	(−2.777)	(−2.767)	(−2.742)	(−2.780)
Water		−0.0276***	−0.0279***	−0.0290***	−0.0285***
		(−3.009)	(−3.009)	(−3.062)	(−2.965)
Air		−0.0156*	−0.0155*	−0.0157*	−0.0152
		(−1.670)	(−1.674)	(−1.709)	(−1.624)
Ownership			−0.0077	−0.0061	−0.0048
			(−0.851)	(−0.660)	(−0.450)
Size	0.0059***	0.0052***	0.0060***	0.0049**	0.0045*
	(3.076)	(2.714)	(3.090)	(2.218)	(1.924)
ROA	0.1017**	0.1419***	0.1457***	0.1571***	0.1532***
	(2.295)	(3.319)	(3.296)	(3.198)	(3.161)
MTB	0.0003	0.0002	0.0002	0.0001	0.0001
	(0.891)	(0.505)	(0.672)	(0.458)	(0.302)
Leverage	0.0433*	0.0448*	0.0489**	0.0590**	0.0615**
	(1.817)	(1.964)	(2.054)	(2.105)	(2.218)
Shareholder	−0.0464**	−0.0435**	−0.0432**	−0.0389*	−0.0401*
	(−2.395)	(−2.301)	(−2.229)	(−1.918)	(−1.842)
Constant	−0.1415***	−0.1090***	−0.1254***	−0.0978**	−0.0884*
	(−3.573)	(−2.702)	(−3.163)	(−2.257)	(−1.846)
Industry				Yes	Yes
Region					Yes
Observations	145	145	145	145	145
R-squared	0.182	0.243	0.248	0.263	0.271
N	145	145	145	145	145

Robust t-statistics in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

market reactions. We expand the Sanction into three dummy variables, i.e. production shutting down, fine and rectification. Table 13 shows that all three kinds of sanction information have negative influence on the CARs. The coefficient of shutting down (Stop) is −0.0299 and significant at the 5% level, which supports Hypothesis 2.1. The coefficient of Fine is −0.0219 but not significant. The rectification has negative influence on the CAR with a coefficient of −0.0175 and significant at the 5% level, which supports Hypothesis 2.3. Production shutting down has the largest influence on the firm, followed by fine and rectification. The production shutting down affects the production and sales directly. The fines in related regulation rules are relatively low compared to the revenue of these listed firms. Also, the disclosure of fine sanction alleviates investors' worries about potentially more severe punishment to the firm. The rectification punishment orders the firm to take serious measures to control the pollution in order to comply with the environmental standard. To achieve this goal the firm needs to equip more pollution-control facilities which will require more advanced technology of production and increase the production cost.

Table 13. Regression result (2).

	(1)	(2)	(3)
Variables	Car[0,1]	Car[0,1]	Car[0,1]
Stop	−0.0288**	−0.0301**	−0.0299**
	(−2.101)	(−2.238)	(−2.136)
Fine	−0.0245*	−0.0210	−0.0219
	(−1.688)	(−1.512)	(−1.541)
Rectify	−0.0174***	−0.0173***	−0.0175**
	(−2.641)	(−2.633)	(−2.609)
Water	−0.0246***	−0.0260***	−0.0253***
	(−2.823)	(−2.906)	(−2.812)
Air	−0.0123	−0.0124	−0.0125
	(−1.368)	(−1.398)	(−1.400)
Ownership	−0.0082	−0.0068	−0.0050
	(−0.951)	(−0.769)	(−0.498)
Size	0.0060***	0.0049**	0.0046*
	(3.146)	(2.213)	(1.940)
ROA	0.1473***	0.1597***	0.1634***
	(3.617)	(3.570)	(3.496)
MTB	0.0002	0.0001	0.0001
	(0.715)	(0.501)	(0.443)
Leverage	0.0435**	0.0536**	0.0544**
	(2.103)	(2.220)	(2.231)
Shareholder	−0.0471**	−0.0438**	−0.0474**
	(−2.442)	(−2.162)	(−2.184)
Constant	−0.1193***	−0.0925**	−0.0814
	(−3.130)	(−2.091)	(−1.643)
Industry		Yes	Yes
Region			Yes
Observations	145	145	145
R-squared	0.314	0.327	0.332

Robust t-statistics in parentheses
*** p < 0.01, ** p < 0.05, * p < 0.1.

Sanction information has a negative influence on the CARs of pollution events. Pollution events that contain sanction information have more negative CARs, which supports Hypothesis 2.

Robustness check

(1) Alternative event windows

We choose [0,1] as the event window in our main analysis. However, the news reported by the media may leak out a day earlier than the newspaper. Thus it might be necessary to take the day before the event (t = −1) into consideration. We choose to add column (1) of Table 14 with the alternative event window [−1,1]. We also try the event window [0,2] in the regression model, and we find qualitatively similar results in column (2) of Table 14.

(2) Excluding events with outliers of CARs

Some events with too small or large CARs are excluded from the sample. Among 145 pollution events, there is one event with an absolute value of CAR higher than 0.2. Column (3) of Table 14 shows the estimation after excluding this event from the sample, while we find qualitatively similar results.

V. Conclusion

We study the stock market reaction to pollution events of Chinese A-share listed firms. As the environmental supervisory system is immature in developing countries like China, firms often do not have sufficient motivation to curtail pollution. We collect 145 pollution events that were reported by eight influential newspapers from 2008 till 2015. We find that pollution events lead to negative market reactions of listed firms. Multivariable regressions show that the events with sanction information have more negative market reactions. The ex-post actions by environmental regulatory authorities can also affect the market reaction. Besides, we find that water pollution has the most negative market reactions than other types of pollution.

Table 14. Robustness checks.

	(1)	(2)	(3)
Variables	Car[−1,1]	Car[0,2]	Excluding extreme CARs Car[0,1]
Sanction	−0.0215***	−0.0234***	−0.0158***
	(−2.824)	(−3.354)	(−2.634)
Water	−0.0325***	−0.0287***	−0.0267***
	(−3.076)	(−2.941)	(−2.855)
Air	−0.0207*	−0.0105	−0.0145
	(−1.826)	(−1.073)	(−1.579)
Ownership	−0.0023	0.0002	−0.0083
	(−0.176)	(0.015)	(−0.808)
Size	0.0029	0.0055**	0.0048**
	(0.850)	(2.372)	(2.067)
ROA	0.1584**	0.1327**	0.1416***
	(2.433)	(2.195)	(3.057)
MTB	−0.0005	0.0002	0.0001
	(−0.977)	(0.740)	(0.321)
Leverage	0.0637*	0.0246	0.0463*
	(1.773)	(0.796)	(1.924)
Shareholder	−0.0418	−0.0451**	−0.0363*
	(−1.436)	(−1.991)	(−1.711)
Constant	−0.0424	−0.0975**	−0.0934*
	(−0.626)	(−2.077)	(−1.959)
Industry	Yes	Yes	Yes
Region	Yes	Yes	Yes
Observations	145	145	144
R-squared	0.221	0.261	0.237

Robust t-statistics in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Environment performance has become an increasingly important factor for the long term strategy of listed firms. The listed firms should strengthen pollution control facilities and improve environmental information disclosure. A simple maximization of profits for the shareholders is insufficient to meet the needs of the society. Listed firms with pollution events may face administrative penalties and loss of market value of listed firms. Therefore, listed firms should adopt a more environmentally friendly production process, make their products meet the requirements by regulatory authorities, improve pollution control capabilities, enhance firms' competitiveness and reduce the risk of pollution events. At the same time, listed firms could release their environmental information through CSR reports and environment responsibility reports, and respond to social concerns about their environmental performance.

Environmental laws and regulations should also be strengthened, and the information disclosure for the listed firms should be improved. Currently, media coverage is still a main source for the public to learn about the environmental performance of listed firms. Compared with developed countries, the environmental information disclosure system in China is still weak to some extent, which is often inconsistent among local environmental regulators. When investors learn about the pollution events through the news, the stock price of listed firms may decrease substantially. Thus the environmental information reported by the media may incentivize listed firms to control pollution and enhance environmental performance. When environmental information is fully disclosed by the regulatory authorities, investors can respond to these pollution events in a more efficient way. Thus, enhancing environmental information disclosure will help investors understand the environmental performance of listed firms, and urge these firms to strengthen their environmental protection ex-ante.

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Appendix

Correlation matrix

	CAR	Stop	Fine	Rectify	Air	Water	Ownership	Size	ROA	MTB	Leverage	Shareholder
CAR	1.000											
Stop	−0.269	1.000										
Fine	−0.156	0.089	1.000									
Rectify	−0.143	−0.092	−0.086	1.000								
Air	0.047	0.149	−0.040	0.027	1.000							
Water	−0.177	−0.034	0.158	−0.050	−0.664	1.000						
Ownership	0.194	−0.097	0.027	−0.097	0.154	−0.130	1.000					
Size	0.350	−0.145	0.052	−0.100	0.193	−0.166	0.637	1.000				
ROA	0.038	0.069	0.080	−0.051	0.020	0.149	0.050	0.221	1.000			
MTB	−0.144	0.127	−0.012	−0.048	−0.281	0.163	−0.118	−0.393	0.251	1.000		
Leverage	0.087	−0.060	−0.100	−0.005	0.163	−0.174	0.230	0.142	−0.586	−0.198	1.000	
Shareholder	0.093	−0.213	0.108	−0.082	0.046	0.013	0.378	0.635	0.451	−0.190	−0.149	1.000