Mandatory Pollution Abatement, Corporate Investment and Performance: Theory and Evidence from a U.S. Regulation*

Tri Vi Dang
Columbia University

Youan Wang
The University of Hong Kong

Zigan Wang
The University of Hong Kong

September 2018

Abstract

This paper analyses the effect of mandatory pollution abatement on U.S. corporate investment and performance and provides the following set of theoretical and empirical results. Depending on the type of firms this regulation has different implications for investment behaviors. For financially unconstrained firms, mandatory pollution abatement leads to (1) more current R&D investment, (2) more (voluntary) investment in pollution abatement in the next period, (3) reduces current profit, (4) increases next period's profit and (5) reduces the market value of the firm. However, if firms are financially constrained three of the five consequences are different. It leads to (1') less current R&D investment and (2') less investment in pollution abatement in the next period, and (4') lower profit in the next period.

JEL Classifications: G32, G38, Q58

Keywords: Regulation, Pollution Abatement, R&D Investment, Firm Value

*Tri Vi Dang, td2332@columbia.edu; Youan Wang, markwang@connect.hku.hk; Zigan Wang, wangzg@hku.hk. We are grateful for helpful comments from Ke Na, Fuwei Jiang, Suxiu Yu, Yang Liu, Yang Nan, Meng Miao, Wanli Zhao, Stuart McDonald, Beibei Shen, Wenya Wang, John Wei, Shaojun Zhang, Wenjin Kang and seminar participants at The Hong Kong Polytechnic University, City University of Hong Kong, Delhi School of Economics, Hanqing Advanced Institute of Economics and Finance of Renmin University of China, Shanghai University of Finance and Economics and Shanghai Jiao Tong University. We especially thank Liang Dai for pointing out the potential endogeneity problem of firm lobbying. We also thank Nitesh Yadav and Xin Zhang for excellent research assistance. All errors are ours.

1. Introduction

An interesting question is how regulation affects firms' investment behavior and their stock market performance. This question is also important and relevant since regulation might have consequences for innovation activities of regulated firms. This paper analyses the real effects of environmental regulation, specifically the mandatory pollution abatement regulation or the designation of nonattainment status in the US. When a county is designated as nonattainment, the plants located in that county are required to take actions to comply with the mandatory requirement (Walker, 2011, 2013). Regulatory compliance brings extra cost to the plants, including specific equipment requirements. Under federal guidelines, plants locating in nonattainment counties are required to install the cleanest available technology, supposedly regardless of costs (Becker and Henderson, 1996, 2000). This raises the important question of how this regulation affects the investment behavior of firms and whether pollution abatement spending crowds out R&D investments.

In this paper we provide a theoretical model and an empirical analysis of the effect of mandatory pollution abatement on corporate investment and stock market performance. In the first part of the paper we develop a two-period model to study the mechanism of how regulation affects pollution abatement spending, R&D investments and firm profits in the short and the long run. We show that the implications of mandatory pollution abatement for investment behavior depend on the type of firms and derive the following set of hypotheses. For financially unconstrained firms, mandatory pollution abatement leads to (H1) more current R&D investment, (H2) more (voluntary) investment in pollution abatement in the next period, (H3) reduces current profit, (H4) increases next period's profit and (H5) reduces the market value of the firm. However, for financially constrained firms three of the five consequences are different. The regulation leads to (H1') less current R&D investment, (H2') less investment in pollution abatement in the next period, and (H4') lower profit in the next period.

In order to test this rich set of theoretical implications, we construct a unique dataset by merging various different databases. 1) We hand-collect every county's attainment/nonattainment statuses from the Code of Federal Regulations (CFR) website. 2) A firm's establishment-level information of polluting plant is from the Toxics Release Inventory (TRI) database of the Environmental Protection Agency (EPA). 3) A firm's total

number of establishments is constructed from National Establishment Time-Series (NETS). 4) A firm's environmental awareness is constructed via textual analysis on the 10-K and other filings from the SEC EDGAR. 5) Information about corporate investments is from Compustat. 6) The abnormal stock returns are constructed from CRSP. 7) A firm's lobbying activities on environmental protection policies are hand-collected from the Office of the Clerk of the U.S. House of Representatives, the U.S. Senate Query the Lobbying Disclosure Act Database, and OpenSecrets. This dataset is used to control for a potential endogeneity issue.

Based on these data sources we construct various empirical measures of the theoretical variables in our model. We use the ratio of a firm's number of regulated plants located in *new* nonattainment areas divided by the number of all plants as our main exogenous variable so as to capture the impact of mandatory pollution abatement. Intuitively, if a larger fraction of plants of a firm faces this regulation the firm is arguably more affected. We use the ratio of capital expenditure over total assets, net PP&E over total assets and environmental awareness to measure the pollution abatement spending. The first two measure the spending and the third one measure how much a firm values environment in its operation. For other variables, we use an indicator variable of CEO turnover and the executive turnover rate to measure manager turnover; we use earnings per share (EPS) and the ratio of net income over total assets to measure firm profits, and we use Tobin's Q and cumulative abnormal returns (CARs) to measure firm value.

A main endogeneity concern is lobbying by firms. Regulated firms might be firms that did not lobby against regulation. For whatever reasons they might be different than lobbying firms. Instead of measuring the impact of the regulation on firms' behavior, mandatory pollution abatement captures firm specific effects. Therefore, we conduct our main analysis only using the sample of firms without lobbying. In addition, we use the county-level air quality index (AQI) data to confirm that the change from attainment to nonattainment status cannot be predicted by AQI change so as to mitigate the concern that this regulatory enforcement might not be exogenous.

The main empirical findings in our county-level analysis are largely consistent with the predictions of the model. An increase in the firm's regulated plants ratio leads to an increase of pollution abatement spending in current period. And consistent with the theoretical implications this regulation leads to a decrease in Tobin's Q and CARs in both subsamples of

financially constrained and unconstrained firms (H5). It leads to lower current EPS and net income (H3) for both types of firms. For financially unconstrained firms, current spending on R&D investments as well as spending on PP&E in the next period increase (H1, H2), EPS and net income in next period increase (H4). But for financially constrained firms, spending on current R&D investments, spending on PP&E in the next period and profits in the next period all decrease (H1', H2', H4').

We also provide further nuanced supportive evidences for the two theoretical implications (H3, H5) where mandatory pollution abatement has the same effect on current profit and market value of both types of firms. We show that current EPS and net income drop less for financially constrained firms than unconstrained firms. But the market value of financially constrained firms drops more than for unconstrained firms

These findings also hold in the following robustness tests. 1) We conduct an analysis on the combined sample including both lobbying and non-lobbying firms and conclude that lobbying does not alter the effects of the mandatory pollution abatement on the firm behavior and value in both subsamples with financially constrained and unconstrained firms. 2) We analyze the effectiveness of firm lobbying in influencing the probability of attainment status change. We do find that firm lobbying is significantly and negatively related with the probability of county's change of status. Therefore, we test if firm lobbying affects the effects of implemented change of attainment status by including lobbying firms in our sample and adding an interaction term. We find firm lobbying not affecting the effects in most analyses. 3) One might argue that a firm may self-select the efforts of lobbying activities which further affect the status of its plants' counties. We construct a Heckman correction variable to absorb the potential self-selection factors and include it in a robustness regression. In most regressions, this variable enters insignificantly and the results are similar to what we have in the main analyses. 4) We also test the impact of the designation of nonattainment status on the combined sample of all non-lobbying firms. We find an increasing CEO turnover and executive turnover rate. The effects on the combined sample overall are more similar to the results of the subsample with CEO turnover.

Our paper contributes to the growing literature on how firm behaviors are affected by regulatory enforcement.[1] The most related papers are Walker (2011, 2013) who analyze the effect of the clean air act on the workforce. Our paper is the first one that studies the consequence of pollution abatement regulation on firm capital investment behaviors. In addition, we provide a model to examine the mechanisms and the different investment behaviors contingent on different CEO turnover scenarios.

Our paper also contributes to the large literature on corporate social responsibility (CSR). The study of the relationship between pollution abatement spending and firm performance can trace back to Bragdon and Marlin (1972). Most prior studies examining the relation between pollution abatement spending and firm performance or valuation concluded with a positive correlation (e.g., King and Lenox, 2001, Ferrell, Liang and Renneboog, 2016), with only a few exceptions documenting a concurrent negative correlation between pollution emission and firm performance (e.g., Turban and Greening, 1997). [2] Our paper shows that the overall effect from the mandatory pollution abatement regulation on firm value is negative, while the short-term and long-term profits are affected differently in firms with or without CEO turnover.

Most of those early studies did not identify the causality (see Margolis, Elfenbein, and Walsh, 2007, for a review). The empirical design in our paper contributes to the rising set of pollution abatement research with the effort of establishing causality between the spending and firm value. Some papers use instrumental variables in two-stage least squares regressions (e.g. Deng, Kang and Low, 2013; Di Giuli and Kostovetsky, 2014), experiments (e.g. Elliott, Jackson, Peecher and While, 2013) and regression discontinuity (e.g. Manchiraju and Rajgopal, 2017) to address endeogeneity issues. Manchiraju and Rajgopal (2017), using Indian data, is one of the few studies that pioneer the exploration of a legal enforcement as an exogenous shock of mandatory overall CSR spending for identification purpose. To the best of our knowledge, our paper is the first examining the effect of a regulatory enforcement of a specific type of CSR spending on the firm value using the U.S. data.

[1] An incomplete list of studied regulations in literature include tax (e.g. Tsoutsoura, 2015), minimum wage (e.g. Gan, Hernandez and Ma, 2016), disclosure (e.g. Albring, Banyi, Dhaliwal and Pereira, 2015) and labor protection (e.g. Chaurey, 2015).

[2] An incomplete list includes Bragdon and Marlin (1972); Spicer (1978); Chen and Metcalf (1980); Blacconiere and Patten (1994); Barth and McNichols (1994); Nehrt (1996); Klassen and McLaughlin (1996); Johnson and Greening (1999); Dowell, Hart and Yeung (2000); Konar and Cohen (2001); King and Lenox (2001).

Our theoretical model contributes to a small set of theory papers in the context of CSR. In addition to the existing models that are usually from the point of view of public goods (e.g. Besley and Ghatak, 2007; Baron, 2008), our model explores the mechanism of how firm value is affected by linking pollution abatement spending and financial constraint with firm behaviors such as R&D spending.

The remainder of this paper is organized as follows. Section 2 provides background information about the nonattainment status designation and regulatory enforcement. Section provides a theoretical model and derives the testing hypotheses. Section 4 describes the data sources and variable construction. Section 5 describes the empirical design. Section 6 presents the results. Section 7 concludes.

2. Regulatory Background

The first legislation involving air pollution in the United States was the Air Pollution Control Act of 1955. This Act provided funds for federal research on air pollution. In 1963, the Clean Air Act (CAA) was passed which was the first legislation referring to air pollution control. It established a federal program and provided funds for research on monitoring and controlling air pollution. The Air Quality Act of 1967 was aimed at reducing pollution, but it did not set for any standards, deadlines or enforcement mechanisms. All these acts, however, lacked the power of enforcement and therefore could not bring much change.

The Clean Air Act of 1970 was a groundbreaking legislation for its time. It established the National Ambient Air Quality Standards (NAAQS) for six pollutant criteria. The Environmental Protection Agency (EPA) which was set up in the same year has the mandate to identify and set standards for these six pollutants – carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, particulate matter, and lead. These standards were to be achieved by May 31, 1975. The act also identified two categories of standards – primary standards were to protect public health from harmful effects of pollution; secondary standards were for public welfare protection such as protecting animals, crops, buildings and etc. from pollution. The Act also required states to come up with State Implementation Plans (SIPs) which would be approved by the EPA. For stationary sources, such as steel mills and power plants, the SIPs had to set a specific limit on the pollution that could be discharged. These limits were to be enforced by a group of civil and criminal sanctions. The law, however, failed to reach its standards by the deadlines.

Because of the failure of the 1970 Act to achieve its targets, several amendments were made in 1977 to the CAA. Since then on July 1 each year, Title 40 of the Code of Federal Regulations (CFR) dealing with Protection of the Environment is officially updated with attainment/nonattainment designations of counties. States with counties designated as nonattainment were required to propose SIPs which detailed how they planned to bring the nonattainment areas back to attainment status. Failure to comply with these requirements could lead to withholding of federal grants and ban on construction of new polluting plants in the designated areas. Firms in such areas are required to adopt the "lowest achievable emission rates" (LAER) technologies. These technologies have to be used *irrespective of their cost*. In comparison, in the attainment areas, large polluters (those emitting over 100 tons per year) were to use "best available control technology" (BACT) which impose a lower cost on the firms adopting them as compared to LAER.

The 1977 Amendments also provided for a trade-off policy for new plants in nonattainment areas. An additional polluting unit could be created if it could offset it by reducing the pollution levels from other existing plants (by purchasing pollution offsets) in the area. The amount of new allowed pollution would be lower than the amount of reduction achieved so that the overall level of pollution goes down. Also, polluting plants in nonattainment areas could be required to redesign their production processes, and such redesigns have to be approved by the regulator. This entails an additional cost burden on plants in nonattainment areas. Plants in nonattainment areas also have a higher likelihood of being inspected and fined than those in attainment areas. In comparison, existing plants and small new plants in attainment areas face no such requirements.

The 1990 amendments to the Clean Air Act introduced the permit system. All significant sources of pollution were now required to obtain an operating permit. States issued such permits, but the EPA can veto them in some instances. The amendments also strengthened the enforcement powers of EPA. The EPA could now impose penalties of up to 25,000 US dollars per day for each violation. It made specific criminal penalties more severe and allowed citizen suits against polluting units.[3]

[3] In this paper, the terms "mandatory pollution abatement", "regulatory enforcement", "change of attainment status" and "designation of nonattainment status" all mean that a county's status was designated as attainment and changed to nonattainment, the polluting plants located within the county are required to install or update the pollution abatement equipment with "lowest achievable emission rates" (LAER) technologies.

The Clean Air Act requires the EPA to review the standards for each pollutant every five years and if required, to revise them. With every revision, EPA has to determine once again whether any counties across the country are in attainment or nonattainment of the standards. Yearly revisions of the attainment/nonattainment status of counties in the previous year are published officially on July 1 under Title 40 of the CFR.

3. Theoretical Model and Hypotheses Development

In this section we propose a two-period model to analyze the impact of mandatory pollution abatement on firms' investment in R&D and pollution abatement expenditure as well as the short-term and long-term profit and market value. We use a simple setting to derive a series of testable hypotheses.

a. Model Setup

Consider an economy in which the sales of a firm is given by

$$S_t = S_t(p_t, q_t) = S_t(p_t(R_{t-1}), q_t(\theta_t))$$

where $p_t(R_{t-1})$ is the price that depends on the R&D expenditure given before period 0, $R_{t-1} = \bar{R}_{-1}$, and $q_t(\theta_t)$ is the quantity of goods sold that is affected by the firm's pollution level in period 0, θ_0. We assume that consumers value the firm's pollution abatement effort and R&D increases the sales by allowing the firm to sell more quantity or at a higher price, therefore, $\partial p_t / \partial R_{t-1} > 0$ and $\partial q_t / \partial \theta_t < 0$. We simplify the notation and denote

$$S_t = S_t(\theta_t, R_{t-1})$$

Motivated by the empirical findings in Servaes and Tamayo (2013) who show that customer awareness is an essential factor of firm sales and sales are positively affected by corporate social responsibility, we assume

$$\frac{\partial S_t}{\partial \theta_t} < 0$$

which means that more pollution will reduce the sales, and we assume that R&D investment has a positive effect on the next period's sales:

$$\frac{\partial S_t}{\partial R_{t-1}} > 0$$

Therefore, the firm's profit in period 0 can be represented as

$$\pi_0 = S_0(\theta_0, \bar{R}_{-1}) - C_0(E_0, R_0) \tag{1}$$

where π_0 is firm's profit in period 0, S_0 is the firm's sales in period 0, which depends on two variables, the pollution level in period 0, θ_0, and the R&D expenditure given before period 0, $\bar{R}_{-1}$. C_0 is the firm's cost in period 0, which consists of two components: E_0, the pollution abatement expense and R_0, the R&D expense in period 0 that affects the firm's sales in period 1, S_1. Similarly, in period 1, we have

$$\pi_1 = S_1(\theta_1, R_0) - C_1(E_1, R_1) \tag{2}$$

where π_1 is firm's profit in period 1, S_1 is the firm's sales in period 1, θ_1 is the firm's pollution level in period 1 and R_0 is the R&D expenditure given in period 0. C_1 is the firm's cost in period 1, E_1 is the pollution abatement expense in period 1 and R_1 is the firm's R&D expense in period 1. The key variable to link the two periods is R_0, the input and cost in period 0 which creates more sales in period 1. In addition, we assume that the pollution level θ_t is negatively related to the pollution abatement spending E_t, which means

$$\frac{\partial \theta_t}{\partial E_t} < 0$$

We assume that C_t increases with R_t and E_t:

$$\frac{\partial C_t}{\partial E_t} > 0$$

and

$$\frac{\partial C_t}{\partial R_t} > 0$$

To derive explicit solutions, we assume the following functional forms:

$$\theta_0 = \frac{1}{E_0}$$

$$\theta_1 = \frac{1}{E_0 + E_1}$$

$$C_t = R_t^2 + E_t^2$$

$$S_t = \bar{S} + \frac{R_{t-1}}{\theta_t}$$

where $\bar{S}$ is the fixed part of total sales that is independent of the influence of R&D expense and pollution, it is assumed to be constant. Therefore, the sum of discounted profit (or market value) of the firm is given by

$$V = \pi_0 + \frac{1}{1+r}\pi_1$$
$$= \bar{S} + \bar{R}_{-1}E_0 - E_0^2 - R_0^2 + \frac{1}{1+r}(\bar{S} + R_0(E_0 + E_1) - E_1^2 - R_1^2) \quad (3)$$

where r is the interest rate.

b. Maximization of Firm Value Under No Regulation

We first analyze the case where the firm maximizes the present value of the profits. The set of first-order conditions (FOCs) for the maximization of Equation (3) is given as follows:

$$\frac{\partial V}{\partial E_0} = \bar{R}_{-1} - 2E_0 + \frac{R_0}{1+r} = 0 \Leftrightarrow E_0 = \frac{R_0}{2(1+r)} + \frac{\bar{R}_{-1}}{2} \quad (4)$$

$$\frac{\partial V}{\partial E_1} = \frac{R_0 - 2E_1}{1+r} = 0 \Leftrightarrow E_1 = \frac{R_0}{2} \quad (5)$$

$$\frac{\partial V}{\partial R_0} = -2R_0 + \frac{E_0 + E_1}{1+r} = 0 \Leftrightarrow R_0 = \frac{E_0 + E_1}{2(1+r)} \quad (6)$$

$$\frac{\partial V}{\partial R_1} = -2R_1 = 0 \quad (7)$$

Equation (7) implies that the firm sets $R_1^* = 0$. The reason is intuitive - this model only has two periods, which means the firm needs not to consider its sales thereafter, so choosing $R_1^* = 0$ minimizes its cost in period 1 and maximizes profit. Solving the first-order conditions, we have

$$E_0^* = \frac{(4r^2 + 7r + 3)}{2(4r^2 + 7r + 2)}\bar{R}_{-1}$$

$$E_1^* = \frac{1+r}{2(4r^2 + 7r + 2)}\bar{R}_{-1}$$

$$R_0^* = \frac{1+r}{4r^2+7r+2}\bar{R}_{-1}$$

The investments that maximize the value of the firm or its present value of profits are $(E_0^*, E_1^*, R_0^*, R_1^*)$. It is easy to see that the optimal spending on E_0^*, E_1^* and R_0^* decrease with the interest rate. For the remainder of the analysis, we normalized $r = 0$. Then we have the profit-maximizing investment in pollution abatement $E_0^* = \frac{3}{4}\bar{R}_{-1}$ and $E_1^* = \frac{1}{4}\bar{R}_{-1}$, as well as the optimal investment in R&D, $R_0^* = \frac{1}{2}\bar{R}_{-1}$. The corresponding pollution levels are $\theta_0^* = \frac{4}{3\bar{R}_{-1}}$ and $\theta_1^* = \frac{1}{\bar{R}_{-1}}$, respectively. The profit in period 0 is

$$\pi_0^* = \bar{S} - \frac{1}{16}\bar{R}_{-1}^2$$

The profit in period 1 is

$$\pi_1^* = \bar{S} + \frac{7}{16}\bar{R}_{-1}^2$$

The value of the firm (for $r = 0$) is

$$V^* = \pi_0^* + \pi_1^* = 2\bar{S} + \frac{3}{8}\bar{R}_{-1}^2$$

One implication of this model is that, even without a compulsory requirement of pollution abatement, firms would voluntarily make such investment for profit maximization, reflected by $E_0^* > 0$ and $E_1^* > 0$.

c. Maximization of Firm Value Under Mandatory Pollution Abatement

Now consider the situation that the regulator imposes a mandatory pollution abatement requirement on the firm. For each allowed maximum level of pollution of $\bar{\theta}_0$, there exists a corresponding $\bar{E}_0$. For simplicity, we assume that the government directly requires the firm to invest at least $\bar{E}_0$ on pollution-abatement equipment in period 0. Now there are two cases: if $E_0^* \geq \bar{E}_0$, then regulation does not change the optimal behavior of the firm. Regulation is not binding. If $E_0^* < \bar{E}_0$ and regulation is binding, then it is easy to see that the firm chooses $E_0 = \bar{E}_0$, i.e., the minimum deviation from the unconstrained optimum. Therefore, the firm chooses R_0 and E_1 to maximize the firm value:

$$V^{reg} = \pi_0 + \pi_1 = \bar{S} + \bar{R}_{-1}E_0 - E_0^2 - R_0^2 + \bar{S} + R_0(E_0 + E_1) - E_1^2 - R_1^2$$

$$= 2\bar{S} + \bar{R}_{-1}\bar{E}_0 - \bar{E}_0^2 - R_0^2 + R_0(\bar{E}_0 + E_1) - E_1^2 \tag{8}$$

The FOCs are

$$\frac{\partial V^{reg}}{\partial E_1} = R_0 - 2E_1 = 0 \Leftrightarrow E_1 = \frac{R_0}{2} \tag{9}$$

$$\frac{\partial V^{reg}}{\partial R_0} = -2R_0 + E_1 + \bar{E}_0 = 0 \Leftrightarrow R_0 = \frac{\bar{E}_0 + E_1}{2} \tag{10}$$

Under the regulation, the value-maximizing investments are given as follows,

$$E_1^{reg} = \frac{1}{3}\bar{E}_0$$

$$R_0^{reg} = \frac{2}{3}\bar{E}_0$$

Interestingly, with the mandatory pollution abatement requirement, both E_1 and R_0 are larger compared to the situation without regulation. Note that we are in case $E_0^* < \bar{E}_0$, since $E_0^* = \frac{3}{4}\bar{R}_{-1}$, therefore, $E_1^{reg} = \frac{1}{3}\bar{E}_0 > \frac{1}{3} \times \frac{3}{4}\bar{R}_{-1} = \frac{1}{4}\bar{R}_{-1}$. Similarly, $R_0^{reg} = \frac{2}{3}\bar{E}_0 > \frac{2}{3} \times \frac{3}{4}\bar{R}_{-1} = \frac{1}{2}\bar{R}_{-1}$. E_1 increases by $\frac{1}{3}\bar{E}_0 - \frac{1}{4}\bar{R}_{-1}$ and R_0 increases by $\frac{2}{3}\bar{E}_0 - \frac{1}{2}\bar{R}_{-1}$. The rationale behind the increasing R_0 is as follows. Regulation implies more E_0 which increases the marginal benefit of R&D spending, R_0, on sales in period 1. Note, a higher E_0 also reduces pollution in period 1 (i.e. θ_1 goes down) which leads to higher sales in period 1, ceteris paribus. While the marginal cost of R&D spending is the same as under no regulation, but the marginal benefit increases, therefore the firm invests more in R&D. Formally, Equation (10) shows that R_0 increases with E_0.

Although not immediately obvious, the reason why the firm voluntarily spends more on pollution abatement in period 1 (E_1) is also intuitive. A higher E_0 leads to a higher R_0, which increases the marginal benefit of E_1 on sales in period 1. Since the marginal cost of E_1 is the same with or without regulation but the marginal benefit increases, therefore the firm invests more in E_1. See Equation (9). The profit in period 0 is

$$\pi_0^{reg} = \bar{S} + \bar{R}_{-1}\bar{E}_0 - \frac{13}{9}\bar{E}_0^2 < \bar{S} - \frac{1}{16}\bar{R}_{-1}^2 = \pi_0^*$$

and is smaller than without regulation. The profit in period 1 is

$$\pi_1^{reg} = \bar{S} + \frac{7}{9}\bar{E}_0^2 > \bar{S} + \frac{7}{16}\bar{R}_{-1}^2 = \pi_1^*$$

because $\bar{E}_0 > E_0^* = \frac{3}{4}\bar{R}_{-1}$. The value of the firm under regulation is

$$V^{reg} = 2\bar{S} + \bar{R}_{-1}\bar{E}_0 - \frac{2}{3}\bar{E}_0^2 < 2\bar{S} + \frac{3}{8}\bar{R}_{-1}^2 = V^*$$

The firm value drops under mandatory pollution abatement requirement. This is intuitive since V^* is the unconstrained optimum. Any $E_0 \neq E_0^*$ reduces market value. Now we summarize our findings as a proposition.

Proposition 1: A mandatory extra pollution abatement spending leads to (i) more voluntary spending on pollution abatement in period 1; (ii) more R&D investment in period 0; (iii) reduced profit in period 0; (iv) increased profit in period 1; and (v) lower value of the firm.

d. Mandatory Pollution Abatement and Financial Constraint

In this section, we discuss the case when the regulated firm is financially constrained. We assume the maximum amount of spending the firm can finance is its first best investment under no regulation, i.e. $K = R_0^* + E_0^* = \frac{1}{2}\bar{R}_{-1} + \frac{3}{4}\bar{R}_{-1} = \frac{5}{4}\bar{R}_{-1}$. If $\bar{E}_0 > E_0^*$, then the firm has to reduce its R&D investment at least by the amount $\Delta = \bar{E}_0 - E_0^*$. So the value of the firm is

$$V^{fincon} = \pi_0 + \pi_1 = 2\bar{S} + \bar{R}_{-1}\bar{E}_0 - \bar{E}_0^2 - R_0^2 + R_0(\bar{E}_0 + E_1) - E_1^2 \qquad (8')$$

as in equation (8) but with the additional constraint that

$$R_0 + \bar{E}_0 \leq \frac{5}{4}\bar{R}_{-1}$$

Note, a financially unconstrained firm chooses $R_0^{reg} = \frac{2}{3}\bar{E}_0$. Since $\bar{E}_0 > E_0^* = \frac{3}{4}\bar{R}_{-1}$,

$$R_0^{reg} + \bar{E}_0 > \frac{5}{4}\bar{R}_{-1}$$

It is easy to see that a financial constrained firm chooses the smallest deviation from R_0^{reg}, i.e.

$$R_0^{fincon} = R_0^{reg} - \Delta = \frac{2}{3}\bar{E}_0 - \Delta.$$

From the FOC, $\frac{\partial V^{fincon}}{\partial E_1} = 0$, the optimal investment in pollution spending in period 1 is

$$E_1^{fincon} = \frac{1}{2} R_0^{fincon}.$$

Note that $\pi_0^{fincon} < \pi_0^*$ since we assume that pollution abatement is binding (i.e. $\bar{E}_0 > \frac{3}{4}\bar{R}_{-1}$). Furthermore, $\pi_0^{fincon} > \pi_0^{reg}$ (i.e. the profit of unconstrained firms under regulation) since the constrained firm spends less on R&D. Also, $\pi_1^{fincon} < \pi_1^{reg}$, since the firm has invested less in R&D in period 0 which reduces the profit in period 1. The value of the firm is $V^{fincon} < V^{reg}$, since V^{reg} is the financially constrained maximum given regulation. Now we summarize these results as the second proposition.

Proposition 2: When the firm is financially constrained, a mandatory extra pollution abatement spending leads to (i) less spending on pollution abatement in period 1; (ii) less R&D investment in period 0; (iii) less profit in period 0; (iv) less profit in period 1; and (v) lower value of the firm.

The implications of mandatory pollution abatement for current profit and market value are the same for both types of firms. Profits in period 0 as well as market value decline. But our model also makes a prediction about the magnitude. From the above analysis, we have the following results.

Corollary 1: When there is a mandatory extra pollution abatement spending, profits in period 0 of financially constrained firms drops less than for unconstrained firms.

Corollary 2: When there is a mandatory extra pollution abatement spending, the market value of financially constrained firms drops more than unconstrained firms.

Table 1 summarizes the set of testable hypotheses.

Table 1	Variable	Unconstrained Firms (Prop 1)	Constrained Firms (Prop 2)
Pollution abatement spending in period 0	E_0	$+$	$+$
Pollution abatement spending in period 1	E_1	$+$	$-$
R&D spending in period 0	R_0	$+$	$-$
Profit in period 0	π_0	$--$	$-$
Profit in period 1	π_1	$+$	$-$
Firm value	V	$-$	$--$

4. Empirical Design

In this section we provide an empirical test of the theory. Section 4.a desrcibes the empirical measures of the variables in the model. Section 4.b explains the sample construction. Section 4.c describes the empirical specifications.

a. Measures of Variables

i. Variables that measure firm behavior and performance

We use three proxies to measure the short-term pollution abatement expenditure, E_0. The first two are capital expenditure/total assets ratio and net PP&E/total assets ratio. We study the effect of the change to nonattainment status designation on these two variables to examine whether the mandatory pollution abatement will cause the firms to spend more on new equipment as discussed in Becker and Henderson (2000) and Greenstone, List, and Syverson (2012). There is a valid concern that these two proxies also include the capital expenditure and net PP&E that are not related to pollution abatement, so we use a third proxy, environmental awareness, defined as the frequency of mentioning environment-related words in its filings in 10-K, 10-K405, 10KSB and 10KSB40, to measure the firm's attention on environment and pollution. We use the three proxies in three years (t+3) to measure the long-term pollution abatement expenditure, E_1.[4]

We use the variable of R&D expenditure divided by the total assets to measure the short-term R&D spending, R_0. We use earnings per share (EPS) and net income/total assets ratio to measure the short-term firm profit, π_0, and the two variables in three years to measure the long-term firm profit, π_1.

[4] The results are robust with these variables in four and five years and available upon request, we present the results of three years because they have a large sample size.

We use Tobin's Q and cumulative abnormal returns (CARs) to measure the firm value, V. We define Tobin's Q as the market value of assets divided by book value of assets. We also construct 1-, 3- and 4-factor CARs on window (-2, 2) and (-5, 5), where day 0 is the publishing date of the nonattainment status of each county, which is July 1 in each year.

ii. The variable that reflects the change of attainment status

We construct the main exogenous variable as follows. We use the proportion of plants being affected by the mandatory pollution abatement requirement for each firm-year observation to measure the change of attainment status. More specifically, we are not using the percentage of plants in all (old and new) nonattainment areas as our explanatory variable. For identification purpose, we are using the *additional* percentage of plants in *new* nonattainment areas as our explanatory variable, which is the *"% Plant in New Nonattainment Area*". For each firm-year observation, the shock that we employ is the counties that appear in the *new* nonattainment status announcement list in each year *t* and not in nonattainment list in year *t-1*.

For example, if a firm has four plants A, B, C and D in four different counties. A, B and C release pollutants while D does not. A is in a county that was in attainment status in year *t-1* but in nonattainment status in year *t*, B is in a county that was in nonattainment status in both year *t-1* and year *t*, C is in a county that was in attainment status in both year *t-1* and year *t*, and D is not regulated. The value of our measure in this case is 1/4, indicating that only 25% of its plants (plant A) is affected by the regulation.

iii. Variables that may affect pollution abatement regulation:

The main concern is that there might be factors that could undermine the exogeneity of pollution abatement regulation. The regulation may be anticipated and affected by firm-lobbying and county-level air quality. We construct a firm-year level dummy variable indicating whether a firm has been involved in lobbying activities on environmental issues, and exclude all firms with lobbying activities in our primary analyses. We use the air quality index data at county-level from the EPA to measure the air quality.

iv. Firm-year level control variables:

We control for the firm's financial leverage, cash flow volatility and operating cash flow ratio following existing literature. We also control for total assets and sales growth

because the two variables are correlated with CSR based on prior research such as McGuire, Sundgren and Schneeweis (1988). For the other variables used in literature such as assets growth and operating income growth, we do not control them because they are highly correlated with the five controls that we already have in our regression models.

In addition, we control for firm fixed effects. MSA-year and industry-year fixed effects are included to capture differences in firm financials and abnormal returns across different geographical regions, different industrial sectors and over time. Though not presented in the tables, the results are also robust when MSA, industry, and year fixed effects are all or partially included.

b. Data Sources and Sample Construction

The data used in this paper are derived from eight different sources. Because the plant-level data on the EPA website start from 1987, we construct our data first by starting with a complete list of U.S. firms in Compustat between 1987 and 2016, a database that contains detailed firm level accounting and financial information for each firm-year observation. We have from 10,708 to 12,558 firms each year.

We then match the list with CRSP, a database containing all publicly traded firms' stock prices. To estimate the impact of nonattainment status announcement on the stock return, we compute each firm's cumulative abnormal return (CAR) around July 1 (or the next trading day when July 1 is a non-trading day) in each year. As explained in Regulatory Background, July 1 of each year is the publishing date of each county's nonattainment status. We obtain each firm's daily stock price data from CRSP and use them to compute 5-day CAR during the window (-2, +2) or 11-day CAR during the window (-5, +5), where day 0 is the publishing date of the nonattainment status of each county. We define abnormal returns by using the difference between actual and projected returns, where we estimate projected returns as follows: (1) regress the daily stock return on the returns on the CRSP value-weighted market portfolio over the 200-day period from the 210th trading day through the 11th trading day before the publishing date of the nonattainment status and collect the estimated coefficients and (2) use the estimated coefficients to compute the projected returns during the 5-day window (-2, +2) or 11-day window (-5, +5). The 3-factor and 4-factor

models' factors data are from the website of Kenneth R. French.[5]. Most of Compustat firms can be matched with CRSP in this step.

The Environmental Protection Agency (EPA) records a full list of toxics releasing plants emitting pollutants above a certain level and each plant's parent firm. Therefore, we can manually match our sample with EPA Toxics Release Inventory (TRI) database using firm names and obtain each firm's list of subsidiary toxics releasing plants and their location in each year. Moreover, we obtain the list of pollutants that each plant emits. Moreover, we collect the air quality data of each county from EPA to estimate the effect of lobbying on the change of attainment status.

In the next step, we hand-collect each county's attainment and nonattainment status of the regulated pollutants from Title 40 of the Code of Federal Regulations (CFR). For the accurate statuses in early years, we check the scanned copies of the reports. Combining the information from the EPA and the CFR, we count each firm's number of plants that are located in new nonattainment areas in each year. Combined with the total number of plants that each firm owns every year in the dataset National Establishment Time-Series (NETS), we are able to calculate the proportion of plants being affected by the announcement for each firm-year observation.

More specifically, we are not using the percentage of plants in all (old and new) nonattainment areas as our explanatory variable. For identification purpose, we are using the *additional* percentage of plants in *new* nonattainment areas as our explanatory variable, which is the *"% Plant in New Nonattainment Area*". For each firm-year observation, the shock that we employ is the counties that appear in the *new* nonattainment status announcement list in each year *t* and not in nonattainment list in year *t-1*. Because many Compustat firms do not have any toxics releasing plants and therefore are not regulated by the EPA and CFR, after the matching process we obtain 1,071 firms and 15,005 firm-year observations with plants under potential regulation.

[5] We are unable to verify if the information of nonattainment status designation was upload online in the early 1990s and became immediately available to the investors after its release on July 1st. We are more certain that the information was required to be upload online after 2002 because of the Section 207(f)(2) of the E-Government Act of 2002. This act requires all federal agencies to develop an inventory of information to be published on their websites, establish a schedule for publishing information, make those schedules available for public comment, and post the schedules and priorities on their websites. We did a robustness test for CAR using the subsample after 2002, the results remain consistent and are available upon request.

Moreover, we construct a variable to measure environmental awareness, defined as the frequency of mentioning environment-related words in its filings. The construction largely follows four steps. First, we download all 10-K filings from Securities and Exchange Commission (SEC) EDGAR database from 1987 to 2016, also including 10-K405, 10KSB and 10KSB40 but excluding amended filings. Second, we remove ASCII-encoded segments (e.g., graphics files, etc.), HTML tags (e.g., <DIV>, <TR>, <TD>, etc.), tables and other unrelated elements, and obtained the cleaned text. Third, we count the number of times that the environment-related words appear in the cleaned text. The environment-related words are with the stem "environ-" such as "environment" and "environmental", and the words with the stem "pollut-" such as "polluting" and "pollutant." Fourth, we divide the above number by the total number of words in the cleaned text to generate the frequency, which is our measure. This variable has positive value for most EPA-matched Compustat firms.

To examine how our empirical results may be affected by firm lobbying, we also collect the lobbying data from the Office of the Clerk of the U.S. House of Representatives, the U.S. Senate Query the Lobbying Disclosure Act Database, and cross-check with OpenSecrets. We construct a firm-year level dummy variable indicating whether a firm has been involved in lobbying activities on environmental issues, and exclude all firms with lobbying activities in our primary analyses, which further reduces our observation numbers by around 19%. To estimate the effect of lobbying on the change of attainment status, we also construct a county-year variable measuring the intensity of lobbying from the firms with plants operating in the county.

Definitions of all variables that we use in our analyses are detailed in Table 1 in the Appendix. Table 2 presents all variables' summary statistics, including each variable's observations, mean, standard deviation and distribution in quantiles. Some variables have extreme values. We test the robustness of our results by winsorizing these values at 1% and 5% level. The results are robust.

[Insert Table 2]

c. Empirical Specifications

We use the following baseline empirical specification to examine the effects of mandatory pollution abatement on the various dependent variables of interest,

$$Dep_{ft} = \alpha + \beta ratio_{ft} + \chi_{ft} + \Phi_{MSA,t} + \Phi_{industry,t} + \Phi_f + \epsilon_{ft} \quad (12)$$

where Dep_{ft} measures firm performance and firm investment in our model. $ratio_{ft}$ is the variable that reflects the regulatory shock. For each firm *f* in year *t*, $ratio_{ft}$ is defined as the number of regulated plants located in *new* nonattainment areas divided by the total number of all plants of the firm. The *new* nonattainment counties that those with attainment status in year *t-1* and nonattainment status in year *t*. χ_{ft} are the firm-year control variables, $\Phi_{MSA,t}$ is the MSA-year fixed effects, $\Phi_{industry,t}$ is the industry-year fixed effects, and Φ_f is the firm fixed effects.

Because the nonattainment status of each county in year *t* is designated in every year, $ratio_{ft}$ is typically regarded exogenous in previous literature (Walker, 2011 and 2013). Nevertheless, lobbying might give rise to an important endoegneity issue. For example, the non-lobbying firms are different from the lobbying firms because they do not have enough resources to lobby. Or the non-lobbying firms purposely choose not to lobby and expect the regulation to be implemented.

We use two specifications to address this. First, we only use the subsample of firms which do not lobby at all in our analyses of Equation (12). In a second specification, we use the full sample of firms and run the following regression that includes an interaction term of lobbying with $ratio_{ft}$:

$$\begin{aligned} Dep_{ft} = \alpha + \beta_1 ratio_{ft} * lobbying_{ft} + \beta_2 ratio_{ft} + \beta_3 lobbying_{ft} \\ + \chi_{ft} + \Phi_{MSA,t} + \Phi_{industry,t} + \Phi_f + \epsilon_{ft} \end{aligned} \quad (13)$$

where $lobbying_{ft}$ is a dummy variable indicating if a firm f lobbies on environmental policies in year t. If the effects of mandatory pollution abatement are not different for the lobbying and non-lobbying firms, the estimated coefficient of the interaction term $\beta_1$should not be different from zero.

Propositions 1 and 2 distinguish between two types of firms and provide the main testing hypotheses of the paper. Depending on whether the firm is financially constrained or not, three variables are affected by mandatory pollution abatement in opposite directions: (i) pollution abatement spending in period 1, (ii) R&D spending in period 0, and (iii) profit in period 1.

Therefore, we run Equation (12) as well as (13) separately on the subsample of firms which are not financially unconstrained and the subsample of firms which are financially consrtained. These provide the baseline empirical test of Propositions 1 and 2. In order to test Corollaries 1 and 2, we conduct the following analysis using the full sample of firms and control for turnover as follows:

$$Dep_{ft} = \alpha + \beta_1 ratio_{ft} * fincon_{ft} + \beta_2 ratio_{ft} + \beta_3 fincon_{ft} + \chi_{ft} + \Phi_{MSA,t} + \Phi_{industry,t} + \Phi_f + \epsilon_{ft} \quad (14)$$

where Dep_{ft} are the measures of the aforementioned three variables. $fincon_{ft}$ is a dummy variable that equals one if a firm's is financially constrained in year *t*.

In Section 6 we consider a number of alternative specifications and control for other factors that might affect our results. In our sample, it is very rare that a county experiences twice the status changes from attainment to nonattainment. In unreported tests using only the first-time change of status, all results hold almost the same.

5. Empirical Results

This section provides evidences for the predictions of the model. The results in section 5.a are based on the sample of firms without any lobbying activities. Similar results are obtained in section 5.b where we use the full sample of firms and control for lobbying activities. Propositions 1 and 2 are consistent with the empirical findings. Section 5.c provides supportive empirical evidences for Corollaries 1 and 2.

a. Evidence for Propositions 1 and 2 (based on sample of firms without lobbying)

Table 3 provides empirical support for Proposition 1. The empirical specification follows Equation (12) and the sample only contains firms without CEO turnover and excludes all lobbying firms. The independent variable, *% Plant in New Nonattainment Area* is defined as the number of regulated plants located in *new* nonattainment areas divided by the total number of all plants. Firm-year controls include total assets, sales growth, leverage, cash flow volatility and operating cash flow ratio. We control for MSA-year, industry-year and firm fixed effects in all regressions. Robust t-statistics are clustered at MSA level.

Regressions (1) - (6) show that the estimated coefficients are all significantly positive, indicating that a firm increases capital expenditure ratio and net PP&E ratio, and mention

environment more in its filings when more of its plants are subject to regulation (i.e., when more plants' county status changes from attainment to nonattainment in a year).

Estimated coefficients of other regressions are largely significant and consistent with the predictions of Proposition 1. The economic magnitude is also sizeable. For example, regression (12) implies a 4.48%*0.095 = 0.43% drop in net income ratio when there is a 9.5% (one standard deviation) increase in newly regulated plants. Note that the mean of net income ratio is merely 3.8%, which means that the ratio drops by 11.2%. Regression (20) implies a 1.5477*0.095 = 0.15-dollar increase of future EPS when there is an increase of newly regulated plants by one standard deviation. The mean of EPS in three years is 1.582 dollars, which means that the ratio drops by 9.5%.

For the sample of non-lobbying firms without CEO turnover, a 9.5% (one standard deviation) increase in the firm's regulated plants ratio leads to (i) a significant increase by 4.6% in capital expenditure ratio (the absolute increase is 0.2%, and the mean capex ratio is 4.3%), 1% increase in net PP&E ratio, and 1.4% increase in environmental awareness in the current year; (ii) 4.9% increase in capital expenditure ratio, 2.4% increase in net PP&E ratio, and 4.1% increase in environmental awareness in three years; iii) 3% increase in R&D spending in the current period; (iv) 5% decrease in EPS and 11.2% decrease in net income ratio in the current period; and (v) 9.5% increase in EPS and 14% increase in net income ratio in three years.

[Insert Table 3]

Table 4 provides empirical support for Proposition 2. The empirical specification follows Equation (12) and the sample excludes lobbying firms. The only difference is that this subsample only tests the non-lobbying firms with CEO turnover.

The estimated results are also largely consistent with the model predictions. The only exception is the insignificant estimate of long-run pollution abatement spending. Though insignificant, the negative signs of coefficients are consistent with Proposition 2(i). The economic magnitudes are also meaningful. For example, regression (20) implies a 2.0758*0.095 = 0.197 dollar drop of future EPS when there is an increase of newly regulated plants by one standard deviation. Note that the mean of EPS in three years is 1.582 dollars, which means that the ratio drops by 12.5%. The results are consistent with Proposition 2(iv).

In the sample of non-lobbying firms with CEO turnover, a 9.5% increase in the firm's regulated plants ratio leads to (i) insignificant increase in capital expenditure ratio, 9% increase in net PP&E ratio (the absolute increase is 2.82% and the mean of capex ratio is 29.6%), and 2.5% increase in environmental awareness in the current year; (ii) insignificant decrease in capital expenditure ratio, net PP&E ratio and environmental awareness in three years; iii) 3.4% decrease in R&D spending in the current period; (iv) mixed findings in EPS net income ratio in the current period; and (v) 12.5% decrease in EPS and 11.9% decrease in net income ratio in three years.

[Insert Table 4]

b. Evidence for Propositions 1 and 2 (based on sample or all firms)

Table 5 and 6 show that the results in the previous section are robust.

[Insert Table 5 and 6]

c. Evidence for Corollaries 1 and 2

A further set of subtle differences regarding the effects of regulation on corporate investments and performance is about the magnitude of changes when both Propositions 1 and 2 predict the same sign. In this section we provide empirical support that the drop is current profit is smaller for firms with CEO turnover and the drop in market value is larger for firms with CEO turnover.

[Insert Table 7]

6. Robustness

a. Lobbying Reconsidered

An additional question regarding firm lobbying on environmental policies is whether it effectively reduces the possibility of a county's change of attainment status. To address this question, we run the following regression on a sample at county-level:

$$Change\_status_{ct} = \alpha + \beta_1 num\_lobbying_{ct} + \beta_2 \Delta AQI_{ct} + \Phi_c + \Phi_t + \epsilon_{ct} \qquad (15)$$

Where $Change\_status_{ct}$ is a dummy variable that equals one if a county c is designated as attainment in year $t-1$ but as nonattainment in year t. $num\_lobbying_{ct}$ is the number of lobbying firms with at least one polluting plant in county c. $\Delta AQI_{ct} = AQI_{ct} - AQI_{c,t-1}$ is the change of average air quality indices of all monitors in county c between year t and $t-1$, respectively. Φ_c and Φ_t are county and firm fixed effects, respectively. We admit that this is not a perfect test of the effect of firm lobbying on a county's change of attainment status – a possible reverse causality is that the message of status change is leaked before the announcement and firm lobbying activities are reversely affected by regulators' potential decision of changing attainment status. Though important, testing the causal effect of lobbying is beyond the scope of this paper because no matter a randomly assigned lobbying is effective or not, our empirical tests of the effects of attainment status change on firm performance and behavior in Equation (12) remain valid as long as the effects are indifferent on the lobbying and non-lobbying firms when the decision of attainment status change is determined and mandatory pollution abatement requirement is implemented.

Another possibility is that the non-lobbying firms purposely choose not to lobby and expect the regulation to be implemented. For example, a firm already with LAER technology equipment may expect an implementation of mandatory pollution requirement that increases the cost of its local competitors. If it is such a case, the change of attainment status is then self-selected. To address the potential self-selection problem, we conduct a Heckman two-stage least squares estimation for correction. In the first stage, we run Equation (15) using the air quality index and the lobbying data and estimate the probability that a county's status is changed from attainment to nonattainment. We use the predicted probability of a county's status change to compute the inverse Mills ratio IMR_{ct}. Because the IMR absorbs the hidden factors that may affect a county's implementation of regulation, a firm's ratio of regulated plants is affected by the hidden factors in all counties with its polluting plants. To account for these factors' effect on each firm, we then compute firm-year level weighted average Heckman correction variable HC_{ft} using the following formula:

$$HC_{ft} = \frac{\sum_{c=1}^{C} NumPlant_{fct} * IMR_{ct}}{\sum_{c=1}^{C} NumPlant_{fct}}$$

Where $NumPlant_{fct}$ is the number of plants that firm f has in county c in year t. In the second stage, we include the Heckman correction variable in our primary analysis and run the following regression:

$$Dep_{ft} = \alpha + \beta ratio_{ft} + \chi_{ft} + \Phi_{MSA,t} + \Phi_{industry,t} + \Phi_f + HC_{ft} + \epsilon_{ft} \qquad (16)$$

Table 8 presents the results of Probit regressions showing how the AQI change and the number of lobbying firms are related to the probability of a county's attainment status change. The dependent variable is a dummy indicating whether a county experiences a status change from attainment to nonattainment. The independent variables include a county's change (Columns 1-2) or percentage change (Columns 3-4) of yearly maximum AQI, or the yearly maximum AQI in the current year and last year (Columns 5-6). We use the yearly maximum AQI instead of the average AQI because the EPA website states that the nonattainment status designation is partially based on the highest level of AQI in a year. We also use the 90% highest percentile of AQI and the results remain robust. In Columns 2, 4 and 6, we include the number of environment-lobbying firms with at least one polluting plant in the county. We control for county and year dummies in all regressions.

In Table 8, all independent variables related to AQI enter insignificantly. However, the variable of lobbying enters significantly negatively in the regressions. This finding indicates that the firm lobbying is negatively correlated with the change of a county's attainment status. Therefore, the possibility of self-selection may exist. We construct county-year level inverse Mills ratio and firm-year level Heckman correction variable HC_{ft}.

Table 8 presents the results of Equation (16) with Heckman correction included. Panel A and B present the effects of regulation on firms without and with CEO turnover, respectively. The presented results are similar to the main results in Table 3 and 4, and are consistent with Proposition 1 and 2. The variable of Heckman correction enters insignificantly in 19 of the 26 regressions, indicating that the self-selection problem is not a major concern in most analyses. Even for the regressions with significant Heckman correction term, the estimated coefficients of the main variable of interest are also consistent with the two propositions, therefore, our empirical results are robust after the correction for potential self-selection.

b. The Possibility of Foreseeing the Change of Attainment Status

A related question is whether a county's attainment status and the change of attainment status can be foreseen before its announcement, and how this possibility may affect our empirical design. This regulation aims to improve air quality, so a plausible predictor of a county's attainment status is its air quality index (AQI). Moreover, testing AQI is meaningful because the county-level index can be regarded as exogenously determined: Air quality indicators are recorded objectively by air monitors and that of a county is affected by multiple factors beyond the county itself, such as neighboring counties' air and a year's wind direction. In our data, a higher AQI means more polluted air.

We use Equation (15) to test the exogeneity of the change of attainment status. Although it is not a perfect design to test the effect of lobbying on the change of status, it is a good one to test AQI because of the reason above. A significant (and reasonably positive because a higher AQI change indicates worsened air) estimate of $\Delta AQI_{ct} = AQI_{ct} - AQI_{c,t-1}$ in Equation (15), or β_2, means that the status that changes from attainment to nonattainment can be foreseen if the air is worsened. An insignificant estimate of β_2 in Equation (15) at least partially supports the exogeneity of the regulation – not all counties with worsened air are determined to be designated as nonattainment. In fact, the EPA states that its final designations are based on 1) air quality monitoring data, 2) recommendations submitted by the states and tribes, and 3) other technical information. Therefore, air quality monitoring data is merely one of the factors and simply looking at it does not guarantee an accurate prediction of designation. Other factors that lack clear threshold add to the exogenous nature of attainment status designation.

The more important question is whether the possibility for a firm to foresee the status change alters the effects of the attainment status change. Will a firm that foresees the change alter its behaviors before the announcement? First, we argue that it is unlikely: If the regulatory requirement of pollution abatement exceeds the voluntarily chosen level, the firm has no reason to implement it in advance because 1) our model predicts that any deviation from the voluntary level lowers the short-term profit and firm market value, and 2) there may be a chance that the regulator changes the decision before announcement, so it is optimal for the firm to maintain the current operation until the mandatory requirement is determined.

c. Multivariate multiple regression

In our separate OLS regressions, a few of the regressions generate insignificant results. To test if the model predictions as a whole hold in general, we use two subsamples with no missing values in any outcome variable to conduct two joint tests for Proposition 1 and 2. Appendix Table A3 presents the F-values of multivariate analysis of variance (MANOVA) and multivariate multiple regressions on two subsamples: the firms with and without CEO turnover. The main independent variable of interest is the interaction between *% Plant in New Nonattainment Area*. In all analyses we control for firm-year total assets, sales growth, leverage, cash flow volatility and operating cash flow ratio in all regressions. We also control for MSA-year, industry-year and firm dummies in all regressions. Unreported signs of all independent variables are consistent with the predictions of Proposition 1 and 2. Table A3 shows that the F-values for both joint tests and for all but two equations are large enough to be significant at 10% level. The results confirm our findings in main analyses that the model as a whole is largely supported by the data.

To jointly estimate a single regression model with more than one outcome variable and more than one independent variable, we employ the multivariate multiple regression[6]. Compared to a multivariate multiple regression, separate OLS regression analyses for each outcome variable produces the same individual coefficients as well as their standard errors, but the OLS regressions do not produce multivariate results or allow for testing of coefficients across equations that a multivariate multiple regression does. We do not use a multivariate multiple regression in our main analysis because of its two disadvantages. First, it drops all observations with any missing value in any outcome variable. We test 15 outcome variables in separate OLS regression analyses, but the subsample with no missing values for all 15 outcome variables has less than a half of observations compared to the separate OLS regression analyses, especially when we include two variables with many missing values: the CEO resignation dummy and the executive turnover rate. Second, the STATA software for the multivariate multiple regression does not allow for standard deviation clustering. Due to the above two reasons, we only report F-values to indicate the significance of the joint tests at the end of the Empirical Results section instead of employing the multivariate multiple regression in our main analysis.

[6] The coding instruction of multivariate multiple regression using STATA is given by UCLA's Institute for Digital Research and Education: https://stats.idre.ucla.edu/stata/dae/multivariate-regression-analysis/

7. Conclusion

In this paper we a provide theoretical and empirical analysis and show that depending on the types of firms mandatory pollution abatement regulation has different implications for corporate investments and performance. For financially constrained firms, mandatory pollution abatement leads to less R&D investment and less pollution abatement spending in the next period. But for financially unconstrained firms, this regulation leads to more R&D investments and more (voluntary) spending on pollution abatement in the next period. This empirical result shows that environmental regulation does not necessarily crowds out but can actually stimulates investment in innovations.

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Figure 1A: Counties with Nonattainment Status in 2003

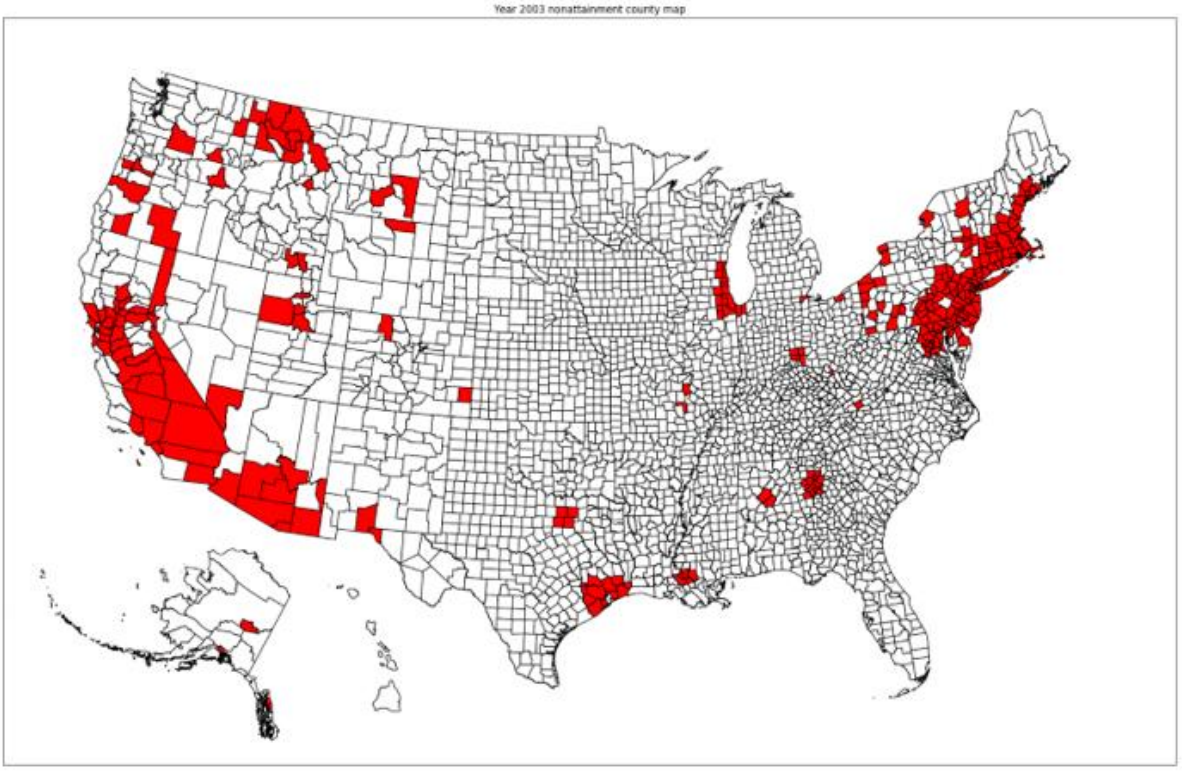

Figure 1B: Counties with Nonattainment Status in 2004

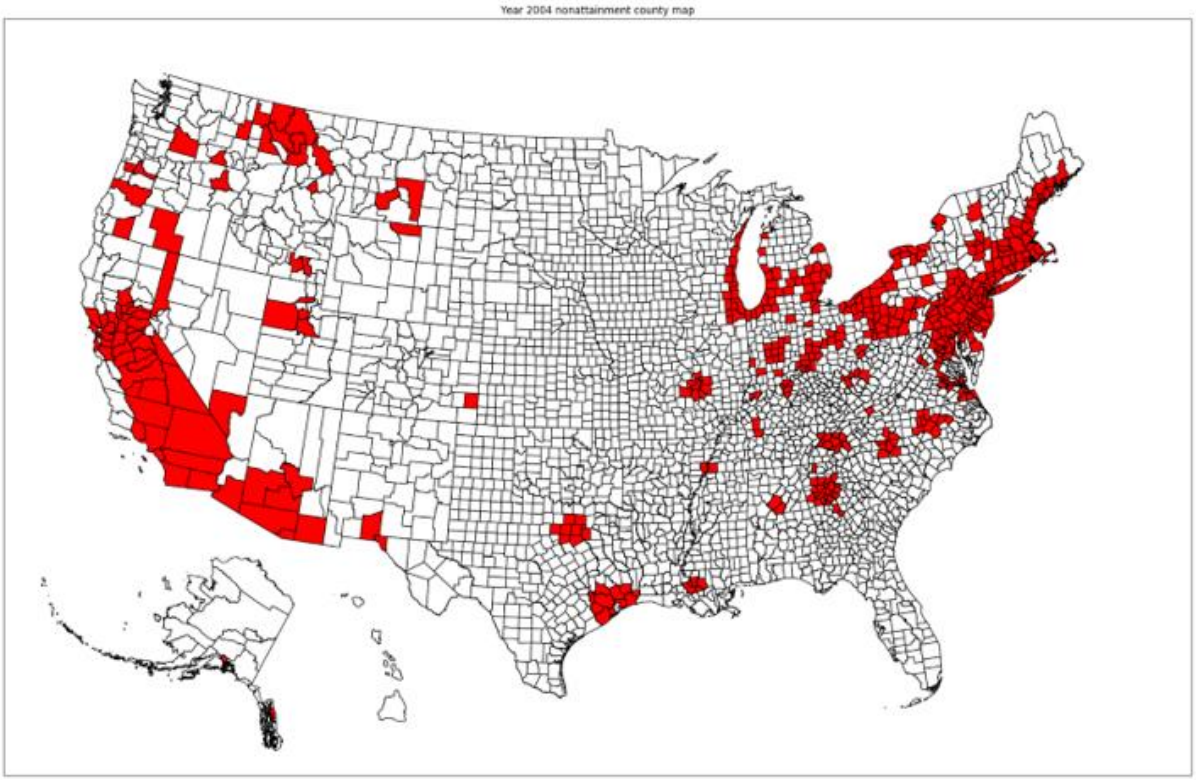

Table 2: Summary Statistics

	Obs	Mean	Std. Dev	0.25	Median	0.75
	Dependent Variables					
Cumulative abnormal return (CAR)						
1 Factor CAR (-2, 2)	7079	0.001	0.055	-0.021	0.001	0.024
3 Factor CAR (-2, 2)	7079	0.004	0.077	-0.031	0.004	0.040
4 Factor CAR (-2, 2)	7079	0.001	0.055	-0.021	0.000	0.023
1 Factor CAR (-5, 5)	7079	-0.001	0.077	-0.035	0.000	0.034
3 Factor CAR (-5, 5)	7079	0.001	0.055	-0.022	0.000	0.024
4 Factor CAR (-5, 5)	7079	0.000	0.078	-0.035	0.001	0.035
Environmental Awareness	7409	0.071	0.059	0.028	0.057	0.099
Environmental Awareness in 3 years	5421	0.073	0.057	0.031	0.060	0.102
CapEx Ratio	7380	0.043	0.031	0.021	0.035	0.056
CapEx Ratio in three years	5320	0.041	0.029	0.020	0.033	0.053
Dummy(CEO Resignation)	4922	0.107	0.309	0	0	0
EPS	7319	1.429	2.363	0.284	1.323	2.489
EPS in 3 Years	5303	1.582	2.394	0.346	1.467	2.680
Executive Turnover Rate	4901	0.136	0.147	0	0.143	0.2
Net Income Ratio	7377	0.038	0.075	0.012	0.046	0.079
Net Income Ratio in 3 Years	5337	0.041	0.073	0.015	0.048	0.080
Net PP&E Ratio	7381	0.296	0.179	0.157	0.256	0.396
Net PP&E Ratio in three years	5251	0.288	0.179	0.148	0.246	0.384
R&D Ratio	7228	0.018	0.027	0	0.008	0.023
Tobin's Q	7407	3.251	2.521	1.699	2.452	3.775
	Independent Variable					
% Plant in New Nonattainment Area	7454	0.017	0.095	0	0	0
	Control Variables					
Cash Flow Volatility	7454	0.073	0.275	0.052	0.084	0.118
Leverage	7454	0.566	0.337	0.424	0.562	0.690
Operating Cash Flow Ratio	7454	0.088	0.073	0.052	0.087	0.124
Sales Growth	7454	0.114	2.365	-0.033	0.054	0.157
Total Assets	7454	5830	17066	512	1489	4303
	County-level Variables					
AQI Change	34300	-0.001	0.017	-0.008	-0.001	0.006
AQI Change Percentage	34295	0.012	0.303	-0.116	-0.016	0.092
AQI Current Year	36410	0.074	0.034	0.051	0.068	0.093
AQI Last Year	34610	0.076	0.033	0.052	0.070	0.096
Dummy(Status Change from Attainment to Nonattainment): Scaled by Multiplying 100	49815	1.588	12.501	0	0	0
Number of Lobbying Firms Current Year	49815	0.402	1.221	0	0	0

Table 3: The effects of regulation on non-lobbying firms without CEO turnover

This table presents the OLS regression estimates of the behavior and performance measures of non-lobbying firms without CEO turnover. The independent variable, *% Plant in New Nonattainment Area*, is the number of regulated plants located in new nonattainment areas divided by the total number of all plants. Firm-year controls include total assets, sales growth, leverage, cash flow volatility and operating cash flow ratio. We control for MSA-year, industry-year and firm fixed effects in all regressions. Robust t-statistics are clustered at MSA level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% statistical significance.

		Model-predicted Sign	Dependent Variable	% Plant in New Nonattainment Area	t-statistics	Firm-year Controls	Fixed Effects	Obs	R-squared
(1)	E_0	+	CapEx Ratio	0.0193***	(3.4334)	No	Yes	2,801	0.86
(2)				0.0197***	(3.3803)	Yes	Yes	2,749	0.87
(3)			Net PP&E Ratio	0.0288**	(2.2346)	No	Yes	2,809	0.97
(4)				0.0266**	(2.1546)	Yes	Yes	2,755	0.97
(5)			Environmental Awareness	0.0124*	(1.9550)	No	Yes	2,820	0.91
(6)				0.0128*	(1.8796)	Yes	Yes	2,765	0.91
(7)	R_0	+	R&D Ratio	0.0062	(1.6150)	No	Yes	2,696	0.97
(8)				0.0060*	(1.6903)	Yes	Yes	2,641	0.97
(9)	π_0	-	EPS	-0.7065*	(-1.8376)	No	Yes	2,768	0.81
(10)				-0.6853*	(-1.6603)	Yes	Yes	2,738	0.82
(11)			Net Income Ratio	-0.0515***	(-3.1158)	No	Yes	2,744	0.82
(12)				-0.0448***	(-2.8287)	Yes	Yes	2,714	0.85
(13)	E_1	+	CapEx Ratio in 3 Years	0.0197*	(1.8870)	No	Yes	1,773	0.91
(14)				0.0201*	(1.6851)	Yes	Yes	1,733	0.91
(15)			Net PP&E Ratio in 3 Years	0.0692	(1.5714)	No	Yes	1,719	0.98
(16)				0.0748*	(1.9329)	Yes	Yes	1,679	0.99
(17)			Environmental Awareness in 3 Years	0.0316*	(1.7675)	No	Yes	1,791	0.96
(18)				0.0345*	(1.7101)	Yes	Yes	1,751	0.96
(19)	π_1	+	EPS in 3 Years	1.4738*	(1.8258)	No	Yes	1,748	0.99
(20)				1.5477**	(2.2199)	Yes	Yes	1,720	0.99
(21)			Net Income Ratio in 3 Years	0.0596**	(2.0654)	No	Yes	1,757	0.83
(22)				0.0547**	(2.0804)	Yes	Yes	1,729	0.83
(23)	V	-	Tobin's Q	-0.8791**	(-2.1246)	No	Yes	2,763	0.90
(24)			Tobin's Q	-0.8986**	(-2.2322)	Yes	Yes	2,709	0.93
(25)			1 Factor CAR (-2, 2)	-0.0431***	(-2.6761)	Yes	Yes	2,575	0.75
(26)			1 Factor CAR (-5, 5)	-0.0417***	(-2.6414)	Yes	Yes	2,575	0.74
(27)			3 Factor CAR (-2, 2)	-0.0408***	(-2.6719)	Yes	Yes	2,575	0.74
(28)			3 Factor CAR (-5, 5)	-0.0459*	(-1.7490)	Yes	Yes	2,575	0.72
(29)			4 Factor CAR (-2, 2)	-0.0515*	(-1.9616)	Yes	Yes	2,575	0.71
(30)			4 Factor CAR (-5, 5)	-0.0469*	(-1.7459)	Yes	Yes	2,575	0.70

Table 4: The effects of regulation on non-lobbying firms with CEO turnover

This table presents the OLS regression estimates of the behavior and performance measures of non-lobbying firms with CEO turnover. The independent variable, *% Plant in New Nonattainment Area*, is the number of regulated plants located in new nonattainment areas divided by the total number of all plants. Firm-year controls include total assets, sales growth, leverage, cash flow volatility and operating cash flow ratio. We control for MSA-year, industry-year and firm fixed effects in all regressions. Robust t-statistics are clustered at MSA level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% statistical significance.

		Model-predicted Sign	Dependent Variable	% Plant in New Nonattainment Area	t-statistics	Firm-year Controls	Fixed Effects	Obs	R-squared
(1)	E_0	+	CapEx Ratio	0.0086	(1.4169)	No	Yes	4,579	0.79
(2)				0.0088*	(1.6596)	Yes	Yes	4,553	0.79
(3)			Net PP&E Ratio	0.0278*	(1.7549)	No	Yes	4,572	0.94
(4)				0.0282*	(1.8154)	Yes	Yes	4,549	0.94
(5)			Environmental Awareness	0.0167**	(2.1442)	No	Yes	4,589	0.84
(6)				0.0164**	(2.0747)	Yes	Yes	4,562	0.84
(7)	R_0	-	R&D Ratio	-0.0065**	(-2.1325)	No	Yes	4,484	0.94
(8)				-0.0060*	(-1.7874)	Yes	Yes	4,457	0.94
(9)	π_0	-	EPS	0.0174	(0.0470)	No	Yes	4,526	0.69
(10)				-0.4088	(-0.9245)	Yes	Yes	4,508	0.81
(11)			Net Income Ratio	0.0095	(0.6938)	No	Yes	4,575	0.67
(12)				-0.0016	(-0.2177)	Yes	Yes	4,557	0.92
(13)	E_1	-	CapEx Ratio in 3 Years	-0.0049	(-0.8884)	No	Yes	3,547	0.82
(14)				-0.0050	(-0.8805)	Yes	Yes	3,525	0.82
(15)			Net PP&E Ratio in 3 Years	-0.0074	(-0.3985)	No	Yes	3,532	0.96
(16)				-0.0051	(-0.2633)	Yes	Yes	3,515	0.96
(17)			Environmental Awareness in 3 Years	-0.0066	(-0.7141)	No	Yes	3,630	0.87
(18)				-0.0060	(-0.6526)	Yes	Yes	3,608	0.86
(19)	π_1	-	EPS in 3 Years	-2.0279***	(-3.1286)	No	Yes	3,526	0.72
(20)				-2.0758***	(-3.1745)	Yes	Yes	3,509	0.73
(21)			Net Income Ratio in 3 Years	-0.0504***	(-3.7823)	No	Yes	3,548	0.70
(22)				-0.0510***	(-3.6701)	Yes	Yes	3,531	0.70
(23)	V	-	Tobin's Q	-0.9800**	(-2.0661)	No	Yes	4,594	0.82
(24)			Tobin's Q	-0.8403**	(-2.1559)	Yes	Yes	4,567	0.88
(25)			1 Factor CAR (-2, 2)	-0.0356***	(-3.6285)	Yes	Yes	4,435	0.57
(26)			1 Factor CAR (-5, 5)	-0.0329***	(-3.0077)	Yes	Yes	4,435	0.56
(27)			3 Factor CAR (-2, 2)	-0.0331***	(-3.0567)	Yes	Yes	4,435	0.57
(28)			3 Factor CAR (-5, 5)	-0.0468***	(-4.1386)	Yes	Yes	4,435	0.56
(29)			4 Factor CAR (-2, 2)	-0.0465***	(-3.3775)	Yes	Yes	4,435	0.55
(30)			4 Factor CAR (-5, 5)	-0.0466***	(-3.4698)	Yes	Yes	4,435	0.55

Table 5: The effect of regulation on all (lobbying and non-lobbying) firms without CEO turnover

This table presents the results of OLS regressions showing how the effects of the percentage of newly regulated plants in nonattainment areas on behaviors of all firms without CEO turnover. The main independent variable of interest is the interaction between *% Plant in New Nonattainment Area* and an indicator variable of firm lobbying. The two standalone variables also included. We control for firm-year total assets, sales growth, leverage, cash flow volatility and operating cash flow ratio, and MSA-year, industry-year and firm fixed effects in all regressions. Robust t-statistics are clustered at MSA level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% statistical significance.

			% Plant in New Nonattainment Area	t-stat	Dummy (Lobbying)	t-stat	% Plant in New Nonattainment Area*Dummy (Lobbying)	t-stat	Firm-year Controls and Fixed Effects	Obs	R-squared
(1)		CapEx Ratio	0.0186***	(3.5121)	-0.0048	(-1.0936)	0.0005	(0.0148)	Yes	3,033	0.86
(2)	E_0	Net PP&E Ratio	0.0197**	(2.2972)	-0.0268*	(-1.8121)	-0.0071	(-0.1065)	Yes	3,042	0.97
(3)		Environmental Awareness	0.0092	(1.0216)	-0.0102*	(-1.6857)	-0.0532	(-1.1111)	Yes	3,044	0.90
(4)	R_0	R&D Ratio	0.0043	(1.4610)	0.0006	(0.3666)	-0.0047	(-0.2074)	Yes	2,930	0.96
(5)	π_0	EPS	-0.6812*	(-1.9320)	0.1342	(0.5281)	3.4297	(1.3231)	Yes	3,025	0.83
(6)		Net Income Ratio	-0.0388***	(-2.7792)	0.0051	(0.2981)	-0.0028	(-0.0314)	Yes	3,002	0.83
(7)		CapEx Ratio in 3 Years	0.0204**	(2.0860)	0.0055	(1.2863)	0.0239	(0.4961)	Yes	1,924	0.91
(8)	E_1	Net PP&E Ratio in 3 Years	0.0815**	(2.3667)	-0.0021	(-0.1660)	0.0409	(0.6304)	Yes	1,872	0.99
(9)		Environmental Awareness in 3 Years	0.0199	(0.9424)	0.0051	(0.8878)	-0.0181	(-0.2848)	Yes	1,945	0.95
(10)	π_1	EPS in 3 Years	0.9290*	(1.7760)	0.1689	(0.3796)	0.6536	(0.2252)	Yes	1,879	0.90
(11)		Net Income Ratio in 3 Years	0.0412	(1.5579)	0.0063	(0.8318)	0.0715	(0.8055)	Yes	1,909	0.83
(12)	V	Tobin's Q	-1.0021***	(-3.1971)	0.0805	(0.3673)	-0.5926	(-0.4737)	Yes	2,995	0.92
(13)		1 Factor CAR (-2, 2)	-0.0406**	(-2.5149)	0.0073	(1.4448)	0.0828	(1.0561)	Yes	2,858	0.73

Table 6: The effect of regulation on all (lobbying and non-lobbying) firms with CEO turnover

This table presents the results of OLS regressions showing how the effects of the percentage of newly regulated plants in nonattainment areas on behaviors of all firms with CEO turnover. The main independent variable of interest is the interaction between *% Plant in New Nonattainment Area* and an indicator variable of firm lobbying. The two standalone variables also included. We control for firm-year total assets, sales growth, leverage, cash flow volatility and operating cash flow ratio, and MSA-year, industry-year and firm fixed effects in all regressions. Robust t-statistics are clustered at MSA level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% statistical significance.

			% Plant in New Nonattainment Area	t-stat	Dummy (Lobbying)	t-stat	% Plant in New Nonattainment Area*Dummy (Lobbying)	t-stat	Firm-year Controls and Fixed Effects	Obs	R-squared
(1)		CapEx Ratio	0.0104**	(2.3776)	0.0024	(1.2381)	-0.0062	(-0.7091)	Yes	5,925	0.78
(2)	E_0	Net PP&E Ratio	0.0275*	(1.6936)	0.0029	(0.4496)	0.0188	(0.7346)	Yes	5,919	0.95
(3)		Environmental Awareness	0.0088	(1.0697)	-0.0014	(-0.4869)	-0.0154	(-0.8142)	Yes	5,978	0.82
(4)	R_0	R&D Ratio	-0.0056*	(-1.6967)	0.0002	(0.2986)	-0.0006	(-0.1600)	Yes	5,887	0.94
(5)	π_0	EPS	-0.6322	(-1.3901)	-0.1489	(-1.1336)	0.2457	(0.2380)	Yes	5,920	0.79
(6)		Net Income Ratio	-0.0032	(-0.4507)	0.0016	(0.8573)	-0.0129	(-1.0179)	Yes	5,975	0.91
(7)		CapEx Ratio in 3 Years	-0.0108*	(-1.6923)	-0.0004	(-0.2111)	0.0092	(0.7497)	Yes	4,629	0.80
(8)	E_1	Net PP&E Ratio in 3 Years	-0.0212	(-1.0166)	0.0051	(1.0478)	0.0367*	(1.7043)	Yes	4,651	0.96
(9)		Environmental Awareness in 3 Years	-0.0084	(-1.1231)	-0.0009	(-0.4459)	-0.0130	(-1.0856)	Yes	4,748	0.84
(10)	π_1	EPS in 3 Years	-1.4847***	(-2.6659)	-0.0898	(-0.5070)	-0.6130	(-0.7066)	Yes	4,632	0.71
(11)		Net Income Ratio in 3 Years	-0.0342***	(-2.6953)	0.0003	(0.0622)	0.0114	(0.3947)	Yes	4,639	0.67
(12)	V	Tobin's Q	-0.6125**	(-1.9984)	0.0612	(0.4860)	0.4624	(0.5764)	Yes	5,956	0.86
(13)		1 Factor CAR (-2, 2)	-0.0233***	(-2.9636)	0.0030	(1.1249)	-0.0144	(-0.7523)	Yes	5,826	0.51

Table 7: The effects of regulation on non-lobbying firms with and without CEO turnover

This table presents the results of OLS regressions showing how the effects of the percentage of newly regulated plants in nonattainment areas on firm behaviors are affected by CEO resignation. The main independent variable of interest is the interaction between *% Plant in New Nonattainment Area* and an indicator variable of CEO resignation. The two standalone variables are also included. We control for firm-year total assets, sales growth, leverage, cash flow volatility and operating cash flow ratio in regressions of even numbers. We control for MSA-year, industry-year and firm fixed effects in all regressions. Robust t-statistics are clustered at MSA level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% statistical significance.

		Model-predicted Sign	Dependent Variable	% Plant in New Nonattainment Area*Dummy(CEO Change)	t-stat	% Plant in New Nonattainment Area	t-stat	Dummy(CEO Change)	t-stat	Firm-year Controls	Fixed Effects	Obs	R-squared
(1)	R_0	-	R&D Ratio	-0.0134**	(-2.4105)	-0.0056*	(-1.7936)	-0.0001	(-0.3488)	No	Yes	4,753	0.94
(2)				-0.0145**	(-1.9904)	-0.0048	(-1.4420)	-0.0002	(-0.5289)	Yes	Yes	4,726	0.95
(3)	π_0	+	EPS	4.3735***	(3.2177)	-0.6103	(-1.3885)	-0.2114*	(-1.7863)	No	Yes	4,783	0.69
(4)				3.2282**	(2.1111)	-0.6095	(-1.4454)	-0.1225	(-1.1916)	Yes	Yes	4,769	0.82
(5)			Net Income Ratio	0.0943	(1.4174)	-0.0051	(-0.3964)	-0.0061	(-1.5610)	No	Yes	4,840	0.66
(6)				0.0686**	(2.0198)	-0.0002	(-0.0502)	-0.0038**	(-2.3818)	Yes	Yes	4,826	0.93
(7)	E_1	-	CapEx Ratio in 3 Years	-0.0251	(-1.0481)	0.0070	(1.5572)	-0.0005	(-0.5523)	No	Yes	4,753	0.94
(8)				-0.0276	(-1.1579)	0.0079*	(1.7478)	-0.0002	(-0.2420)	Yes	Yes	4,726	0.95
(9)			Net PP&E Ratio in 3 Years	-0.0968*	(-1.8354)	0.0023	(0.1684)	-0.0050**	(-2.1180)	No	Yes	4,783	0.69
(10)				-0.1037**	(-2.0018)	0.0056	(0.3752)	-0.0049**	(-2.0795)	Yes	Yes	4,769	0.82
(11)			Environmental Awareness in 3 Years	-0.0530*	(-1.9583)	0.0016	(0.1846)	-0.0010	(-0.6733)	No	Yes	4,840	0.66
(12)				-0.0562**	(-2.1741)	0.0022	(0.2683)	-0.0010	(-0.7308)	Yes	Yes	4,826	0.93
(13)	V	-	EPS in 3 Years	-9.8655**	(-2.0821)	-1.0075	(-1.5007)	-0.1578	(-1.5590)	No	Yes	3,637	0.74
(14)				-9.4668**	(-2.0244)	-1.0312	(-1.5136)	-0.1516	(-1.4965)	Yes	Yes	3,621	0.74
(15)			Net Income Ratio in 3 Years	-0.3329**	(-2.3636)	-0.0289**	(-2.0035)	-0.0020	(-0.5493)	No	Yes	3,658	0.71
(16)				-0.3145**	(-2.2784)	-0.0288*	(-1.8858)	-0.0022	(-0.6203)	Yes	Yes	3,642	0.72

Table 8: Change of attainment status

This table presents the results of Probit regressions showing how the AQI change and the number of lobbying firms are related to the probability of a county's attainment status change. The unit of analysis is county-year. The dependent variable is a dummy indicating whether a county experiences a status change from attainment to nonattainment. The independent variables include a county's change (Columns 1-2) or percentage change (Columns 3-4) of AQI, or the AQI in the current year and last year (Columns 5-6). In Columns 2, 4 and 6, we include the number of environment-lobbying firms with at least one polluting plant in the county. We control for county and year dummies in all regressions. Robust t-statistics are clustered at county level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% statistical significance.

	(1)	(2)	(3)	(4)	(5)	(6)
	Dummy(Status Change from Attainment to Nonattainment): Scaled by Multiplying 100					
AQI Change	-0.2341	-0.2188				
	(-0.0632)	(-0.0591)				
AQI Change Percentage			-0.1249	-0.1234		
			(-0.6188)	(-0.6115)		
AQI Current Year					4.9614	4.7418
					(1.1960)	(1.1426)
AQI Last Year					4.7873	4.5689
					(1.1823)	(1.1279)
Number of Lobbying Firms Current Year		-0.1164**		-0.1165**		-0.1054*
		(-1.9649)		(-1.9656)		(-1.7751)
County Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observations	34,225	34,225	34,225	34,225	34,225	34,225
R-squared	0.43	0.43	0.43	0.43	0.43	0.43

Table 9: Including Heckman Correction

This table presents the results of OLS regressions of behaviors and performance of all (lobbying and non-lobbying) firms without CEO turnover (Panel A) or with CEO turnover (Panel B). The independent variable, *% Plant in New Nonattainment Area* is defined as the number of regulated plants located in new nonattainment areas divided by the total number of all plants. We control for firm-year total assets, sales growth, leverage, cash flow volatility and operating cash flow ratio, and also MSA-year, industry-year and firm fixed effects in all regressions. A Heckman correction variable is included. Robust t-statistics are clustered at MSA level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% statistical significance.

Panel A: Effects of regulation on firms without CEO turnover

			% Plant in New Nonattainment Area	t-stat	Heckman correction	t-stat	Firm-year Controls and Fixed Effects	Obs	R-squared
(1)		CapEx Ratio	0.0099**	(2.0034)	-0.0264	(-1.4025)	Yes	4,263	0.85
(2)	E_0	Net PP&E Ratio	0.0328*	(1.8618)	0.0266	(0.5905)	Yes	4,268	0.96
(3)		Environmental Awareness	0.0170*	(1.9617)	-0.0522	(-1.5657)	Yes	4,284	0.89
(4)	R_0	R&D Ratio	0.0060**	(2.1337)	0.0012	(0.0761)	Yes	4,216	0.95
(5)	π_0	EPS	-0.6714***	(-2.6750)	-0.4096	(-0.7919)	Yes	4,264	0.87
(6)		Net Income Ratio	-0.0299***	(-2.9877)	0.0026	(0.1704)	Yes	4,227	0.91
(7)		CapEx Ratio in 3 Years	0.0245**	(2.0029)	-0.0242	(-1.0955)	Yes	2,844	0.88
(8)	E_1	Net PP&E Ratio in 3 Years	0.0527**	(2.0013)	-0.0136	(-0.3297)	Yes	2,850	0.98
(9)		Environmental Awareness in 3 Years	0.0424**	(2.0178)	0.0142	(0.4189)	Yes	2,947	0.91
(10)	π_1	EPS in 3 Years	1.9076**	(2.5957)	-1.4071**	(-2.2648)	Yes	2,830	0.90
(11)		Net Income Ratio in 3 Years	0.0225	(0.8196)	-0.0225	(-0.7074)	Yes	2,837	0.84
(12)	V	Tobin's Q	-0.7765**	(-2.2079)	1.1113*	(1.8396)	Yes	4,250	0.91
(13)		1 Factor CAR (-2, 2)	-0.0382**	(-2.2229)	-0.0041	(-0.1300)	Yes	4,053	0.74

Panel B: Effects of regulation on firms with CEO turnover

			% Plant in New Nonattainment Area	t-stat	Heckman correction	t-stat	Firm-year Controls and Fixed Effects	Obs	R-squared
(1)		CapEx Ratio	0.0106**	(2.0250)	-0.0004	(-0.0628)	Yes	8224	0.76
(2)	E_0	Net PP&E Ratio	0.0221*	(1.8089)	0.0176	(0.7984)	Yes	8273	0.93
(3)		Environmental Awareness	0.0099*	(1.9132)	0.0014	(0.1140)	Yes	8330	0.78
(4)	R_0	R&D Ratio	-0.0085**	(-2.0397)	0.0055*	(1.7915)	Yes	8198	0.92
(5)	π_0	EPS	-0.8337**	(-2.5002)	-0.2658	(-0.6824)	Yes	8245	0.74
(6)		Net Income Ratio	-0.0068	(-1.4601)	-0.0086**	(-2.2417)	Yes	8274	0.89
(7)		CapEx Ratio in 3 Years	-0.0124**	(-2.4002)	0.0049	(0.6324)	Yes	6916	0.77
(8)	E_1	Net PP&E Ratio in 3 Years	-0.0411**	(-2.4063)	-0.0004	(-0.0167)	Yes	6952	0.94
(9)		Environmental Awareness in 3 Years	-0.0159**	(-2.4398)	0.0186	(1.3908)	Yes	7043	0.79
(10)	π_1	EPS in 3 Years	-1.2969**	(-2.4061)	-0.0336	(-0.0862)	Yes	6942	0.65
(11)		Net Income Ratio in 3 Years	-0.0265**	(-2.0282)	-0.0205***	(-2.8869)	Yes	6981	0.65
(12)	V	Tobin's Q	-0.6034**	(-2.2050)	-0.6437*	(-1.8655)	Yes	8,329	0.82
(13)		1 Factor CAR (-2, 2)	-0.0205***	(-3.0952)	0.0141*	(1.7318)	Yes	8,186	0.48

Table 10: Multivariable Multiple Regression

This table presents the F-values of multivariate analysis of variance (MANOVA) and multivariate multiple regressions on two subsamples with no missing value in any variable: the firms without CEO turnover and the firms with CEO turnover. The main independent variable of interest is the interaction between *% Plant in New Nonattainment Area*. In all analyses we control for firm-year total assets, sales growth, leverage, cash flow volatility and operating cash flow ratio in regressions of even numbers. We also control for MSA-year, industry-year and firm dummies.

	Only no CEO turnover firms				Excluding no CEO turnover firms			
MANOVA Joint Test F-value			F-value	p-value			F-value	p-value
			3.7217	0.0000			3.1217	0.0000
Multivariate Multiple Regressions								
	Obs	R-squared	F-value	p-value	Obs	R-squared	F-value	p-value
CapEx Ratio	1,293	0.1200	7.8748	0.0000	1,019	0.0986	5.4585	0.0000
Net PP&E Ratio	1,293	0.0567	3.4678	0.0000	1,019	0.0209	1.0671	0.3793
Environmental Awareness	1,293	0.0714	4.4387	0.0000	1,019	0.0454	2.3738	0.0006
R&D Ratio	1,293	0.0593	3.6400	0.0000	1,019	0.0700	3.7579	0.0000
EPS	1,293	0.2391	18.1400	0.0000	1,019	0.4359	38.5618	0.0000
Net Income Ratio	1,293	0.3922	37.2472	0.0000	1,019	0.8250	235.3026	0.0000
CapEx Ratio in 3 Years	1,293	0.0592	3.6305	0.0000	1,019	0.0593	3.1475	0.0000
Net PP&E Ratio in 3 Years	1,293	0.0402	2.4156	0.0003	1,019	0.0073	0.3675	0.9952
Environmental Awareness in 3 Years	1,293	0.0806	5.0607	0.0000	1,019	0.0311	1.6030	0.0451
EPS in 3 Years	1,293	0.3367	29.3057	0.0000	1,019	0.0465	2.4331	0.0004
Net Income Ratio in 3 Years	1,293	0.2001	14.4409	0.0000	1,019	0.1824	11.1345	0.0000
Tobin's Q	1,293	0.3351	29.0956	0.0000	1,019	0.5631	64.3170	0.0000
1 Factor CAR (-2, 2)	1,293	0.0618	3.8012	0.0000	1,019	0.0753	4.0661	0.0000

Table 11: Effect of regulation on non-lobbying firms with and without CEO turnover

This table presents the OLS regression estimates of the behavior and performance measures of all non-lobbying firms. The independent variable, *% Plant in New Nonattainment Area*, is the number of regulated plants located in new nonattainment areas divided by the total number of all plants. Firm-year controls include total assets, sales growth, leverage, cash flow volatility and operating cash flow ratio. We control for MSA-year, industry-year and firm fixed effects in all regressions. Robust t-statistics are clustered at MSA level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% statistical significance.

		Dependent Variable	% Plant in New Nonattainment Area	t-statistics	Firm-year Controls	Fixed Effects	Obs	R-squared
(1)	E_0	CapEx Ratio	0.0080*	(1.8054)	No	Yes	7,380	0.76
(2)			0.0086**	(2.0651)	Yes	Yes	7,302	0.75
(3)		Net PP&E Ratio	0.0234**	(2.0171)	No	Yes	7,381	0.94
(4)			0.0245**	(2.1753)	Yes	Yes	7,304	0.94
(5)		Environmental Awareness	0.0133**	(2.1662)	No	Yes	7,409	0.83
(6)			0.0133**	(2.1848)	Yes	Yes	7,327	0.83
(7)		Dummy(CEO Change)	0.1383**	(2.4163)	No	Yes	4,922	0.46
(8)			0.1407**	(2.4377)	Yes	Yes	4,894	0.46
(9)		Executive Turnover Rate	0.0874**	(2.5744)	No	Yes	4,901	0.49
(10)			0.0845**	(2.4151)	Yes	Yes	4,873	0.50
(11)	R_0	R&D Ratio	-0.0042**	(-2.0567)	No	Yes	7,180	0.94
(12)			-0.0039*	(-1.9442)	Yes	Yes	7,098	0.94
(13)	π_0	EPS	-0.1093	(-0.3907)	No	Yes	7,294	0.66
(14)			-0.0763	(-0.3012)	Yes	Yes	7,246	0.70
(15)		Net Income Ratio	-0.0059	(-0.5418)	No	Yes	7,319	0.66
(16)			-0.0028	(-0.3141)	Yes	Yes	7,271	0.74
(17)	E_1	CapEx Ratio in 3 Years	-0.0021	(-0.4539)	No	Yes	5,320	0.79
(18)			-0.0021	(-0.4360)	Yes	Yes	5,258	0.79
(19)		Net PP&E Ratio in 3 Years	-0.0265	(-1.5738)	No	Yes	5,251	0.95
(20)			-0.0247	(-1.4677)	Yes	Yes	5,194	0.95
(21)		Environmental Awareness in 3 Years	-0.0073	(-1.0785)	No	Yes	5,421	0.87
(22)			-0.0073	(-1.0820)	Yes	Yes	5,359	0.87
(23)	π_1	EPS in 3 Years	-1.1374**	(-2.1001)	No	Yes	5274	0.72
(24)			-1.1458**	(-2.1426)	Yes	Yes	5229	0.72
(25)		Net Income Ratio in 3 Years	-0.0322*	(-1.8662)	No	Yes	5,305	0.69
(26)			-0.0332**	(-2.0176)	Yes	Yes	5,260	0.69
(27)	V	Tobin's Q	-0.8797***	(-2.7865)	No	Yes	7,357	0.81
(28)		Tobin's Q	-0.8957***	(-3.0957)	Yes	Yes	7,276	0.86
(29)		1 Factor CAR (-2, 2)	-0.0438***	(-6.3488)	Yes	Yes	7,010	0.55
(30)		1 Factor CAR (-5, 5)	-0.0391***	(-5.7919)	Yes	Yes	7,010	0.54
(31)		3 Factor CAR (-2, 2)	-0.0393***	(-6.1038)	Yes	Yes	7,010	0.54
(32)		3 Factor CAR (-5, 5)	-0.0520***	(-4.2784)	Yes	Yes	7,010	0.51
(33)		4 Factor CAR (-2, 2)	-0.0502***	(-4.5059)	Yes	Yes	7,010	0.50
(34)		4 Factor CAR (-5, 5)	-0.0492***	(-4.4326)	Yes	Yes	7,010	0.49

Table A1: Variable Definition

Variable Name	Definition	Source
Environmental Awareness	Firm-year level variable. The combined frequency of the words with the stem "environ-" such as "environment" and "environmental", and the words with the stem "pollut-" such as "polluting" and "pollutant" in a firm-year's 10-K filing.	Constructed from SEC EDGAR
CapEx Ratio	Firm-year level variable. Capital Expenditure (CAPX in Compustat) divided by total book assets (AT).	Compustat
Cumulative Abnormal Return (CAR)	Firm-year level variable. 5-day CAR during the window (-2, +2), where day 0 is the publishing date of the nonattainment status of each county. We define abnormal returns by using the difference between actual and projected returns, where we estimate projected returns as follows: (1) regress the daily stock return on the returns on the CRSP value-weighted market portfolio over the 200-day period from the 210th trading day through the 11th trading day before the publishing date of the nonattainment status and collect the estimated coefficients and (2) use the estimated coefficients to compute the projected returns during the 5-day window (-2, +2) or 11-day window (-5, +5). The 3-factor and 4-factor models' factors data are from the website of Kenneth R. French.	CRSP, Kenneth R. French website
Dummy(CEO Change)	Firm-year level variable. A dummy indicating with the firm's CEO is different in year t+1 than in year t.	ExecuComp
Dummy(Lobbying)	Firm-year level variable. A dummy indicating with the firm lobbying on environmental policies in year t.	The Office of the Clerk of the U.S. House of Representatives, the U.S. Senate Query the Lobbying Disclosure Act Database, and OpenSecrets
EPS	Firm-year level variable. Earnings per share, calculated as the net income (NI) divided by the number of outstanding shares (CSHO).	Compustat
AQI Change	County-year level variable. The value difference of the county's air quality index between year t and year t-1.	EPA
AQI Change Percentage	County-year level variable. The percentage difference of the county's air quality index between year t and year t-1.	EPA
AQI Current Year	County-year level variable. The county's air quality index in year t.	EPA
AQI Last Year	County-year level variable. The county's air quality index in year t-1.	EPA

Dummy(Status Change from Attainment to Nonattainment)	County-year level variable. Equals one if a county's status is attainment in year t-1 and becomes nonattainment in year t, and zero otherwise. In regression it is scaled by multiplying 100.	EPA, CFR
Number of Lobbying Firms Current Year	County-year level variable. The number of lobbying firms with at least one polluting plant in county c in year t.	The Office of the Clerk of the U.S. House of Representatives, the U.S. Senate Query the Lobbying Disclosure Act Database, and OpenSecrets
Executive Turnover Rate	Firm-year level variable. The number of resigning executives divided by the total number of executives in a firm-year observation.	ExecuComp
Net Income Ratio	Firm-year level variable. Net income (NI) divided by total book assets(AT).	Compustat
Net PP&E Ratio	Firm-year level variable. The cost, less accumulated depreciation, of tangible fixed property used in the production of revenue (PPENT) divided by total book assets (AT).	Compustat
R&D Ratio	Firm-year level variable. Research and development expense (XRD) divided by total book assets(AT).	Compustat
Tobin's Q	Firm-year level variable. Market value of assets (MKVALT + LT) divided by book value of assets (BKVLPS + LT).	Compustat
% Plant in New Nonattainment Area	Firm-year level variable. The number of plants newly regulated by PM10 program divided by the total number of all toxics releasing plants of firm in that year.	EPA, CFR
Cash Flow Volatility	Firm-year level variable. Cash flow is total earnings before extraordinary items (IBC) plus equity's share of depreciation (DP). Cash flow volatility is the variance of past five years' cash flow/total assets (AT) ratio.	Compustat
Leverage	Firm-year level variable. Total liabilities (LT) divided by total book assets (AT).	Compustat
Operating Cash Flow Ratio	Firm-year level variable. The operating cash flow (OANCF) divided by total book assets (AT).	Compustat
Sales Growth	Firm-year level variable. The sales (SALE) in year t minus the sales in year t - 1 then divided by the sales in year t - 1.	Compustat
Total Assets	Firm-year level variable. The value of total assets reported on the balance sheet (AT).	Compustat