Mandatory Pollution Abatement, Financial Constraint and Firm Investment

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ABSTRACT

This paper provides a theoretical and empirical analysis of how pollution abatement regulation or the designation of nonattainment status affects corporate investment and performance. If consumers value environmental awareness, spending on mandatory pollution abatement and other investment are complements for financially unconstrained firms but substitutes for financially constrained firms. Financially unconstrained firms invest more, have lower current profits but higher future profits while constrained firms invest less, have stable current profits and lower long-term profits. This paper shows that consumer environmental awareness and firms' financial resources are determinants of whether environmental regulation crowds out or stimulates R&D investment and capital expenditure. (JEL: G32, G38, Q58)

Keywords: Mandatory Pollution Abatement, Financial Constraint, R&D, Capital Expenditure

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1. Introduction

A controversial question about environmental regulation is whether spending on mandatory pollution abatement crowds out other investment and adversely affects the competitiveness of regulated firms and their market performance. The U.S. Environmental Protection Agency (EPA) states that "The costs of complying with Clean Air Act requirements through the 1970 to 1990 period affected patterns of industrial production, capital investment, productivity, consumption, employment, and overall economic growth" (U.S. EPA, 1997). This paper focuses on one specific aspect of the Clean Air Act and analyses how the designation of nonattainment status affects capital expenditure and R&D investment of financially constrained and unconstrained firms. When a county is designated as nonattainment, the plants located in that county are required to take actions to comply with the mandatory requirement. Regulatory compliance brings extra costs to the plants, including specific equipment requirements. Under federal guidelines, plants located in nonattainment counties are required to install the cleanest available technology (Becker and Henderson, 2000; Greenstone, List, and Syverson, 2012).

It is an important question to study because firms in the U.S. are required and have spent a significant amount of resources on pollution abatement. For example, the total pollution control capital investment in the U.S. was $41 billion or 2.8% of total capital investment in 1990 (U.S. EPA, 1990). Total costs for all pollution control activities in the U.S. were $115 billion or 2.1% of Gross National Product in 1990 (U.S. EPA, 1990). The direct costs of implementing the Clean Air Act from 1970 to 1990, including annual compliance expenditures in the private sector and program implementation costs in the public sector, totaled $628 billion (U.S. EPA, 1997). In 2005, $3.88 billion of pollution abatement capital expenditures was attributed to just air emissions abatement. Only in the food manufacturing industry, pollution abatement operating costs amounted to $1.52 billion in the same year (Table 1, U.S. Bureau of Census, 2008).

In this paper, we conduct a theoretical and empirical analysis of how the designation of nonattainment status affects corporate investment and performance on the firm level. We first show that under the requirement of mandatory pollution abatement, financially unconstrained firms experience significant decline in short-

term profitability, measured by profit margin and return to assets. The profit declines more when the fraction of plants of the firm, which faces mandatory pollution abatement, is larger. But for financially constrained firms, their profits do not experience such a decline. Furthermore, we document that both types of firms significantly increase their pollution abatement effort.

As a potential explanation for the different implications of this regulation on firms' profits, we show that financially constrained firms reduce their current capital expenditure and R&D investment. In contrast, financially unconstrained firms increase their current investment.[1] So why do financially unconstrained firms increase their current investment when they face mandatory pollution abatement effort? In order to better understand the (to some extent surprising) empirical consequences of this regulation for investment and profits, we build a simple two-period model. We provide an economic mechanism that can rationalize such behavior of both types of firms. In addition, the model derives further testable implications about the future voluntary pollution abatement effort and future profitability of firms.

The main assumption of the model is that the consumers value the environmental awareness of firms so that pollution abatement effort increases sales. See Servaes and Tamayo (2013) for empirical evidence. Under this assumption, we show that spending on pollution abatement and investment constitute complements for financially unconstrained firms, but they are substitutes for financially constrained firms. In other words, spending on mandatory pollution abatement crowds out other investment of financially constrained firms, but such spending stimulates more R&D investment and capital expenditure by financially unconstrained firms. Also, the model shows that current profits of a financially unconstrained firm decline because it invests more in both pollution abatement and R&D while current profits of a financially constrained firm are stable since it scales back R&D investment when facing increased pollution abatement spending.

Besides offering an economic mechanism for understanding the impact of regulation on current R&D investment and profitability, our model derives a set of

[1] Throughout the rest of the paper, the term "investment" captures both capital expenditure and R&D spending.

additional testable hypotheses. For financially unconstrained firms, this nonattainment status leads to more future investment in pollution abatement (H1), higher future profits (H2), and lower market value of the firm (H3). However, for financially constrained firms the first two consequences are different. This regulation leads to (H1') less future investment in pollution abatement, and (H2') lower future profits. Furthermore, for the cases where the implications (H3) are the same for both types of firms, the model predicts that the firm value (Tobin's Q) drops more for financially constrained firms. These predictions of the model are supported by the empirical findings.

In order to conduct the empirical analysis, we construct a dataset by merging eight different databases with county and firm-plant level information. The U.S. EPA records a full list of toxics releasing plants emitting pollutants above a certain level and each plant's parent firm in its Toxics Release Inventory (TRI) database. Based on this we create a sample 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 to identify whether it is regulated by the certain mandatory pollution abatement requirement. We hand-collect each county's attainment and nonattainment status of the regulated pollutants from Title 40 of the Code of Federal Regulations (CFR) from 1987 to 2016.

Based on the information, from the EPA and the CFR, we count each firm's number of plants that are located in nonattainment areas in each year. Combined with the total number of plants that each firm owns every year in the National Establishment Time-Series (NETS) dataset, we are able to calculate the proportion of plants being affected by the announcement for each firm-year observation. We use the ratio of a firm's number of regulated plants located in nonattainment areas divided by the number of all plants as our main exogenous variable to capture the impact of nonattainment status designation. Intuitively, if a larger fraction of plants of a firm faces this regulation, the firm is arguably more affected. Moreover, we obtain the employee number data from the NETS database so that we are able to construct an employee-number-weighted regulated plants ratio. The robustness tests using this weighted ratio confirm our results based on the unweighted ratio used in the main analyses.

We obtain information about pollution abatement investment from the MSCI ESG database. As a proxy for financial constraint, we adopt the financial constraint index proposed by Bodnaruk, Loughran, and McDonald (2015) based on the frequency of financial-constraint-related words in its 10-K filings. Then we sort firms according to their financial constraint index. Firms are defined as financially constrained if their financial constraint index is in the top 1/3 (the top tertile). Firms in the bottom tertile are defined as financially unconstrained. Our results remain robust for other financial constraint proxies.

The yearly designation of nonattainment status of counties is typically regarded as exogenous in the existing literature (Walker, 2011, 2013). Nevertheless, an endogeneity concern is firm lobbying. Regulated firms might be firms that did not lobby against regulation and for various potential reasons they might be different than lobbying firms. 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, but we do find that firm lobbying is significantly and negatively correlated with the probability of a county's change of status. We conduct our main analysis only using the sample of firms without lobbying. The results also hold when we conduct the analysis using (1) the combined sample of lobbying and non-lobbying firms and (2) the full sample (i.e. including lobbying and non-lobbying as well as the middle 1/3 of firms based on the financial constraint measure) with Heckman correction.

Our paper contributes to various strands of literature on the effects and consequences of environmental regulatory enforcement. Becker and Henderson (2000) is among the early studies that described the nonattainment designation: "A key regulatory tool since 1978 is the annual designation of county air quality attainment status. Nonattainment status triggers specific equipment requirements, with the severity and enforcement of regulations rising with plant size." Walker (2011, 2013) conducts a county-level analysis to study the effects of nonattainment status designation on the employment and job flow components. Greenstone et al. (2012) find that the nonattainment designation is associated with a 2.6% decline in measured total factor productivity (TFP) among plants that emit the targeted pollutants.

Different from but complementing the existing literature, our paper analyzes the effects of nonattainment designation on firm-level investment behavior and profitability and provides a set of novel and nuanced results. This paper shows that mandatory pollution abatement regulation affects financially constrained and unconstrained firms very differently regarding investment as well as current and future profitability. While mandatory pollution abatement spending crowds out investment of financially constrained firms, it stimulates R&D investment and capital expenditure of financially unconstrained firms.

Our paper also contributes to the literature on innovation and firm investment which shows that R&D investment and capital expenditures are affected differently by various economic factors, such as financial market development, stock liquidity, and short selling (Becker-Blease and Paul, 2006; Brown, Martinsson, and Petersen, 2013; Fang, Tian, and Tice, 2014; Grullon, Michenaud, and Weston, 2015). Dang and Xu (2018) show that market sentiment has different effects on investment of financially constrained firms and unconstrained firms. They show that financially constrained firms invest more in R&D when market sentiment is high while unconstrained firms' investment is not responsive. In our paper we show that financially unconstrained firms invest more in R&D when they face nonattainment status designation while constrained firms reduce investment.

Furthermore, our paper is related to the large literature on corporate social responsibility (CSR). Pollution abatement effort can be interpreted as a special form of corporate social responsibility. The study of the relationship between pollution abatement effort and firm performance can trace back to Bragdon and Marlin (1972). Most prior studies examining the relationship between pollution abatement effort and firm performance or valuation concluded with a positive correlation (e.g., Ferrell, Liang, and Renneboog, 2016; King and Lenox, 2001), 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 of the nonattainment status designation on firm value is negative, while the

[2] See also Barth and McNichols (1994); Blacconiere and Patten (1994); Chen and Metcalf (1980); Di Giuli and Kostovetsky (2014); Dowell, Hart, and Yeung (2000); Elliott, Jackson, Peecher, and White (2014); Klassen and McLaughlin (1996); Konar and Cohen (2001); Manchiraju and Rajgopal (2017); Nehrt (1996); Spicer (1978).

short-term and long-term profits are affected differently for financially constrained and unconstrained firms.

Our theoretical model contributes to a small set of theory papers in the context of CSR. Besley and Ghatak (2007) and Baron (2008) model CSR investment as having public good features. Our model explores the mechanism of how the investment and value of the firm are affected by mandatory pollution abatement regulation as a special form of CSR for financially constrained and unconstrained firms. We show that if consumers value environmental awareness, mandatory pollution and investment are complements for financially unconstrained firms, but they are substitutes of constrained firms. In addition, we provide indicative evidence for the model assumption by showing that regulated firms which spend more on pollution abatements communicate more about their environmental awareness to consumers and investors in their corporate filings.

The remainder of this paper is organized as follows. Section 2 provides background information about the nonattainment status designation and regulatory enforcement. Section 3 describes the data sources and sample, and Section 4 describes variable construction. Section 5 presents some initial empirical findings that are surprising to some extent. Section 6 provides a theoretical model to explain these findings and derives additional testable hypotheses. Section 7 presents empirical tests of the hypotheses that Section 6 drives. Section 8 shows additional robustness checks on cross-section analysis and endogeneity issues. Section 9 concludes.

2. Background

The history of the U.S. air protection legislation dates back to 1955 when the first federal air pollution law, the Air Pollution Control Act of 1955, was enacted. This Act also provided funds for federal research on air pollution. The first federal regulation that aimed to control air pollution is the Clean Air Act of 1963, and later the Air Quality Act of 1967 was made to expand the federal government activities, but these acts didn't set any standards, deadlines, or enforcement mechanisms and therefore lacked the power of enforcement.

The 1970 Clean Air Act (CAA) established a framework for the attainment and maintenance of clean and healthful air quality level and contained a number of key provisions. First, the Environmental Protection Agency (EPA) was set up and directed to establish National Ambient Air Quality Standards (NAAQS) for six pollutant criteria (carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, particulate matter, lead). Second, it 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. Third, the 1970 Act forced new sources to meet standards based on the best available technology. Fourth, it addressed hazardous pollutants and automobile exhausts.

The CAA was later amended twice in 1977 and in 1990. Since the 1977 Clean Air Act Amendments (1977 CAAA), on July 1 each year, Title 40 of the Code of Federal Regulations (CFR) is officially updated with attainment/nonattainment designations of counties. The 1977 CAAA required states with counties designated as nonattainment 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) are to use "best available control technology" (BACT) which impose a lower cost on the firms adopting them as compared to LAER.

The 1977 CAAA also provided 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. 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 Clean Air Act Amendments considerably strengthened the earlier versions of the Act. The biggest regulatory procedural change in the Act is the new permit program where all major emitting sources are 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]

The CAA 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.

As an illustration, we hand-collect the nonattainment status of each county in every year and use the data in 2003 and 2004 to generate Figure 1, which shows the U.S. counties with different attainment and nonattainment status in 2003 and 2004. The counties in white color are attainment areas in both years. The red color represents nonattainment counties in both years. The counties in yellow are attainment areas in 2003 and switch to nonattainment in 2004, while the counties in green are in nonattainment status in 2003 and switch to attainment in 2004.

Some nonattainment counties change to attainment status after one or two years, while some counties in Southern California can remain nonattainment status for over a decade. Our data show that it is very rare for a county to be designated as nonattainment for the second time after it changes from the nonattainment to attainment status.

[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.

[Insert Figure 1]

3. Data Sources and Sample Construction

The data used in this paper are obtained from eight different databases. 1) We hand-collect every county's attainment/nonattainment status from the Code of Federal Regulations (CFR). 2) A firm's establishment-level information of polluting plant is from the Toxics Release Inventory (TRI) database of the Environmental Protection Agency (EPA).[4] 3) The total number of plants and the employee number of each plant are from National Establishment Time-Series (NETS). 4) Information about pollution abatement investment is from MSCI ESG. 5) Information about R&D investment and capital expenditure is from Compustat. 6) Stock returns data are from CRSP. 7) A firm's financial constraint index and environmental awareness are constructed via textual analysis of the 10-K and other filings from SEC EDGAR. 8) 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. The lobbying dataset is used to control for a potential endogeneity issue.

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 then match the list with CRSP, a database containing all publicly traded firms' stock prices. Most of the 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

[4] In this study, we only use the TRI database to identify polluting plants but not use its self-reported pollution data, which are widely criticized on the pollution measurement accuracy (De Marchi and Hamilton, 2006; Koehler and Spengler, 2007).

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 the 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. Because many Compustat firms do not have any toxics releasing plants and therefore are not regulated by the EPA and CFR, they cannot be matched with the EPA TRI dataset by name. After the matching process, we obtain 1,071 firms and 10,082 firm-year observations with plants under potential regulation.

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 main analyses.

4. Variable Construction

a. Variables that Measure Firm Investment, Pollution Abatement Effort and Profit

We use the ratio of R&D expenditure to total assets (R&D) and the ratio of capital expenditure to total assets (Capex) to capture firm investment behaviors. To proxy pollution abatement investment, we employ two indicators from the MSCI ESG database, which is a widely used to measure corporate social responsibility (CSR). One indicator variable, "Pollution Reduction" (ENV-STR-B in KLD), indicates whether firms have active programs and performance in reducing toxic emissions.

The other indicator, “Clean Energy Investment” (ENV-STR-D in KLD), equals one if the firm proactively invests in clean technologies.

Apart from the above two indicators, we also define the environmental awareness index as the frequency of mentioning environment-related words in its filings in 10-K, 10-K405, 10KSB and 10KSB40, to measure the firm’s communication on environment and pollution issues. See Dhaliwal, Li, Tsang, and Yang (2011) and Dhaliwal, Radhakrishnan, Tsang, and Yang (2012). The construction has four steps. First, we download all 10-K filings from the Securities and Exchange Commission (SEC) EDGAR database from 1994 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 a positive value for most EPA-matched Compustat firms.

We use profit margin and ROA to measure the firm profits. The firm value is measured by Tobin’s Q and cumulative abnormal returns (CARs). 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 the windows (-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. 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. 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.

b. The Variable that Reflects the Change of Attainment Status

We construct the main exogenous independent variable as follows. We use the proportion of plants being affected by the nonattainment status designation for each firm-year observation to measure the effect of attainment status. More specifically, we construct the percentage of plants in nonattainment counties of a firm, *Regulated_Plant_Ratio,* as the number of toxics releasing (regulated) plants located in nonattainment areas divided by the total number of plants, i.e.

$$ratio_{ft} = \frac{\sum_{i=1}^{N_{ft}} r_{fit}}{N_{ft}}$$

where r_{fit} is a dummy variable that equals one if plant i of firm f is a toxics releasing plant and located in a nonattainment county in year t and zero otherwise; N_{ft} is the total number of plants of firm f in year t. Note, suppose firm f has many toxic releasing plants $\{i\}$, but if none of them are located in counties designated as nonattainment areas in year t, then $ratio_{ft}$=0. Or if a firm has ten plants and two of them are toxics releasing plants and both are located in a county designated as nonattainment area in year t, then $ratio_{ft}$=0.2. This ratio is calculated for each firm in each year. In Section 8c, we describe the construction of the ratio weighted by plant's employee number (*Regulated_Plant_Ratio_Weighted*), and the ratio of regulated plants' number to toxics releasing inventory (TRI) plants only (*Regulated_Plant_Ratio_TRI*). Online Appendices C and D show that all results are similar and robust when using the alternative measures.

c. The Variable that Measures Financial Constraint

The literature has proposed various proxies for financial constraints. Following Bodnaruk et al. (2015), we construct the financial constraint index as the frequency of financial-constraint-related words in 10-K filings. The construction follows four steps. First, we download all 10-K filings from the SEC EDGAR database from 1987 to 2016, also including 10-K405, 10KSB, 10KSB40 and 10-KSB 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 defined in Bodnaruk et al. (2015), obtained the cleaned text. Third, we count the number of times that the financial-constraint-related words appearing in the cleaned text. The list of 184 financial-constraint-related words is given in Bodnaruk et al. (2015). Fourth, we divide the above number by the total number of words in the cleaned text to generate the frequency, which is our constructed financial constraint index. Nessa (2017) validates the predictive power of this financial constraint measure. Our results also hold for other measures of financial constraint.[5]

d. Variables that May Affect Pollution Abatement Regulation

The nonattainment status of each county in year t is designated in every year and $ratio_{ft}$ is typically regarded as exogenous in the literature of environmental economics (Walker, 2011, 2013). Nevertheless, a 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 index. Those factors will be more thoroughly discussed in the later section. 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.

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. 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.

[5] In unreported analysis we use the following proxies for financial constraint, namely firm size (Erickson and Whited, 2000), dividend payout ratio (Fazzari, Hubbard, and Petersen, 1988), Size-Age Index (Hadlock and Pierce, 2010), and WW index (Whited and Wu, 2006). The results are available upon request.

e. 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. Though not presented in the tables, the results are also robust when Metropolitan State Area (MSA), industry, and year fixed effects are all or partially included.

f. Summary Statistics of Variables

The definitions of all variables in our analyses are detailed in Appendix Table A1. Table 1 presents summary statistics of the variables for the full sample and the subsamples of firms that do not lobby and are either financially constrained or unconstrained (i.e. top or bottom 1/3 of firms ranked by financial constraint index). As discussed in Section 3, our sample only includes firms with at least one toxic releasing plant, i.e. firms that can face potential regulation. The full sample contains 1,071 firms and 10,082 firm-year observations.

In the full sample, lobbying firms constitute 19.2% of total firm-year observations. So our main analysis is based on 80.8% of available observations. It is worth mentioning that for all variables, the number of observations for non-lobbying financially unconstrained firms is smaller than for non-lobbying financially constrained firms. The reason is the following. The ranking of the financial constraint index of firms is based on the full sample. The number of observations is smaller because there are fewer non-lobbying firms in the bottom 1/3 of the financial constraint index ranking (unconstrained) than there are in the top 1/3 of the ranking (constrained). In other words, financially constrained firms engage less in lobbying activities so there are more of them in the subsample of non-lobbying firms. Also, there is variation in the number of observations among the variables. The count of

observations in the subsample for each variable is constructed as an intersection of three characteristics (lobbying ∩ financial constraint ∩ variable of interest).

A key variable in our analysis is the independent variable, *ratio*. In the main analysis we use *Regulated_Plant_Ratio* defined as the number of regulated plants divided by the total number of plants of a firm in a given year. Table 1 shows the average ratio is between 2% and 2.4% in the four different samples. This means that on average around 2% of plants are subject to regulation each year. Note, this is the unconditional mean and includes ratio=0 for all firms without any plants at all in counties designated as nonattainment counties in a year. Conditional on a plant of a firm being regulated this ratio (i.e. average[ratio| ratio>0]) has an average that ranges from 9.3% to 10.8% in the four different samples and is significantly larger than the unconditional average.

In robustness tests, we use *Regulated_Plant_Ratio_Weighted* defined as the employment-weighted number of regulated plants divided by the total number of plants of a firm in a given year. Table 1 shows that this (unconditional) ratio ranges from 3.5% to 4.5% for the different samples. For *Regulated_Plant_Ratio_TRI* defined as the number of regulated plants divided by the total number of TRI (Toxics Release Inventory) plants of a firm in a given year, this ratio is between 27.2% and 28.2% in the different samples. Using these two alternative ratios as an independent variable yields similar results. See Online Appendix C.

[Insert Table 1]

5. The Effect of Mandatory Pollution Abatement on Current Profits and Investment

In this section, we first analyze how mandatory pollution abatement affects the current profits of the firm and its current spending on pollution reduction, capital expenditure and R&D.

a. Empirical Specifications

We use the following baseline empirical specification to examine the effects of nonattainment status designation on the various dependent variables of interest,

$$Dep_{ft} = \alpha + \beta ratio_{ft} + \chi_{ft} + \Phi_t + \Phi_f + \epsilon_{ft} \quad (1)$$

where Dep_{ft} measures firm profitability in Table 2 (profit margin and return on assets), pollution abatement efforts in Table 3 (pollution reduction and clean energy investment), or firm investment in Table 4 (R&D and capital expenditure). $ratio_{ft}$ is the variable that reflects the exogenous regulatory shock. For each firm f in year t, $ratio_{ft}$ is defined as the number of regulated plants divided by the total number of all plants of the firm f in year t. Regulated plants means toxics releasing plants located in counties with nonattainment status in a given year. χ_{ft} represents the firm-year control variables, including total assets, sales growth, leverage, cash flow volatility and operating cash flow ratio. Φ_t is the year fixed effects and Φ_f is the firm fixed effects.

b. Current Profitability

We use profit margin and ROA as a measure of firm profitability and dependent variable in Equation (1). Table 2 presents the results. The two samples are non-lobbying firms that are financially constrained (Columns 1-4) or unconstrained (Columns 5-8). Note that the sample size is smaller than the full sample since it only includes firms that do not lobby and are financially constrained (i.e. top 1/3 of firms ranked by financial constraint index) or unconstrained (i.e. bottom 1/3 of firms according to that index). The independent variable, *Regulated_Plant_Ratio*, is $ratio_{ft}$ in Equation (1). Robust t-statistics are clustered at the firm level.

Table 2 shows that financially constrained firms do not experience a statistically significant decrease in profitability when their regulated plant ratio increases, while the financially unconstrained firms' profitability decreases with their fraction of regulated plants. This is reflected by the insignificant estimates of the *Regulated_Plant_Ratio* in Columns 1-4 for the constrained firms and the significantly negative estimates in Columns 5-8 for the unconstrained firms. The results are similar when we use either profit margin or ROA as proxy for profitability and are consistent when we include or exclude the firm-year controls.

[Insert Table 2]

c. Pollution Abatement Compliance Efforts

When facing mandatory pollution abatement requirement, why do current profits of financially unconstrained firms decline but profits of financially constrained firms are stable? One reason might be that financially constrained firms do not comply with the regulation due to limited resources. Table 3 tests this conjecture and presents the estimated results when the dependent variables are measures of pollution abatement efforts. We use two indicators from MSCI ESG database, pollution reduction and clean energy investment. Except for the dependent variables, other parts of the empirical setting like the independent variable, control variables and fixed effects are the same as in Table 2. Note, Table 3 has fewer observations than in Table 2 because we lose some firms in the process of matching our sample with the MSCI ESG database.

The results show that both financially constrained and unconstrained firms significantly increase their efforts in pollution abatement. The results are consistent when using either pollution reduction or clean energy investment as the dependent variable and are consistent when we include or exclude the firm-year controls.

The economic magnitude is also sizable. For example, regression (6) in Table 3 implies a 0.1292*0.084 = 0.01 increase in *Pollution Reduction* index when there is a 0.084 (one standard deviation) increase in *Regulated_Plant_Ratio* for the non-lobbying, unconstrained firm sample. Note that the mean of *Pollution Reduction* index is merely 0.061, which means that the index increases by 18% (=0.01/0.061). The economic magnitude is even larger for the non-lobbying and financially constrained firm sample. Regression (2) implies a 0.0973*0.106 = 0.01 increase in *Pollution Reduction* index when there is a 0.106 (one standard deviation) increase in *Regulated_Plant_Ratio* for the non-lobbying, constrained firm sample. Since the mean of *Pollution Reduction* index is merely 0.029 for this subsample, it means that the index increases by 35.6% (=0.01/0.029).

[Insert Table 3]

d. Firm Investment

Since both financially constrained and unconstrained firms increase pollution abatement effort, we investigate if this regulation crowds out other investment. We analyze spending on R&D investment and capital expenditure. The empirical specification is the same as before.

Table 4 shows opposite firm investment behaviors when facing the nonattainment status designation. Financially constrained firms experience a significant decrease in both R&D investment and capital expenditure when their regulated plant ratio increases, while financially unconstrained firms' R&D investment and capital expenditure increase with the fractions of their plants being regulated. This is reflected by the significantly negative estimates of the *Regulated_Plant_Ratio* in Columns 1-4 for the constrained firms and the significantly positive estimates in Columns 5-8 for the unconstrained firms.

These observations can explain why the profits of financially constrained firms do not decline (statistically significantly). These firms reduce R&D investment and capital expenditure. Since financially unconstrained firms do not scale back other investment, their current profits decline. But this raises another puzzle. Why do financially unconstrained firms increase their investment when facing mandatory pollution requirement? The next section provides a model that can rationalize such behavior. In addition, it derives several other testable implications.

[Insert Table 4]

6. Economic Rationale and Hypotheses

In this section, we propose a simple two-period model to analyze optimal spending on pollution abatement and investment of a firm. This model highlights an economic mechanism that can rationalize the documented behavior of financially constrained and unconstrained firms when they face pollution abatement regulation. In addition, the model derives additional testable predictions regarding the future (voluntary) pollution abatement spending, future profits and the market value of regulated firms.

a. Model Setup

Consider a firm that sells a good and only exists for two periods (t=0,1). The quality of the good depends on (R&D and capital) investment, R. The quantity demand and price a consumer is willing to pay depend on the quality as well as how the good is produced. The production of the good causes pollution, θ. If the firm spends more on pollution abatement E, it reduces the pollution level, i.e. $\partial\theta_t/\partial E_t < 0$. The revenue or sales of the firm in period t is given by

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

where $R_{t-1}$is investment in period *t-1* and θ_t is the pollution level of production. If the firm spends more on investment in the previous period, this leads to better quality output in next period, and thus sales is higher ceteris paribus, i.e. $\partial S_t/\partial R_{t-1} > 0$.

The main assumption of the model is environmental awareness of consumers which is 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 interpret pollution abatement spending as a specific kind of social corporate responsibility. So we assume that higher level of pollution reduces sales, i.e. $\partial S_t/\partial\theta_t < 0$. The firm's profits in period t is given by

$$\pi_t = S_t(\theta_t, R_{t-1}) - C_t(E_t, R_t)$$

where the costs C_t increase in R_t and E_t. To derive explicit solutions, we assume that sales is given by

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

where $\bar{S}$ is the fixed part of sales that is independent of the influence of investment and pollution level and the variable part of sales increases with investment but decreases in emitted pollution. Furthermore, we assume that cost is given by $C_t = R_t^2 + E_t^2$; and emitted pollution is given by $\theta_0 = 1/E_0$; $\theta_1 = 1/(E_0 + E_1)$. Higher spending on pollution abatement reduces emitted pollution. So the profit of the firm in period 0 and 1 is given by

$$\pi_0 = \bar{S} + R_{-1} \cdot E_0 - E_0^2 - R_0^2$$

$$\pi_1 = \bar{S} + R_0 \cdot (E_0 + E_1) - E_1^2 - R_1^2$$

respectively, where R_{-1} is investment in period t-1 and exogenous. The market value (i.e. the sum of discounted profits) is given by

$$V = \pi_0 + \frac{\pi_1}{1+r}$$

where r is the interest rate. For expositional simplicity, we set $R_{-1} = 1$ and $r = 0$ in the following analysis. The Online Appendix A derives the results without these two simplifying assumptions and contains detailed proof steps. The value of the firm is

$$V = \bar{S} + E_0 - E_0^2 - R_0^2 + \bar{S} + R_0 \cdot (E_0 + E_1) - E_1^2 - R_1^2 \quad (2)$$

b. Maximization of Firm Value Under No Regulation

We first analyze the case where the firm chooses $(E_0^*, E_1^*, R_0^*, R_1^*)$ to maximize the market value without any constraint. Solving the set of first-order conditions (FOCs) for the maximization of Equation (2), we obtain:

$$E_0^* = 3/4;\ E_1^* = 1/4;\ R_0^* = 1/2;\ R_1^* = 0;$$

$$\pi_0^* = \bar{S} - 1/16;\ \pi_1^* = \bar{S} + 7/16;\ V^* = 2\bar{S} + 3/8$$

Note that $R_1^* = 0$ because this is a two-period model so investment in period 1 generates no future value. One implication of this model is that, even without a compulsory requirement of pollution abatement, firms would voluntarily make such effort for profit maximization, reflected by $E_0^* > 0$ and $E_1^* > 0$.[6]

c. Maximization of Firm Value Under Mandatory Pollution Abatement

Now we consider the situation where 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. The firm chooses $R_1^* = 0$ and (R_0, E_0, E_1) to maximize the firm value $V = \pi_0 + \pi_1$ subject to the constraint $E_0 \geq \bar{E}_0$. Denote E_0^* as the value maximizing level of pollution abatement spending. 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

[6] This implication is consistent with previous literature's empirical findings on the positive correlation between voluntary pollution abatement effort and firm value (e.g., King and Lenox, 2001).

binding. But if $E_0^* < \bar{E}_0$ and regulation is binding, then it is optimal for the firm to choose $E_0 = \bar{E}_0$, i.e., the minimum deviation from the unconstrained optimum. So, the firm (only) chooses R_0 and E_1 to maximize the firm value:

$$V^{reg} = \pi_0 + \pi_1 = 2\bar{S} + \bar{E}_0 - \bar{E}_0^2 - R_0^2 + R_0(\bar{E}_0 + E_1) - E_1^2 \qquad (3)$$

From the FOCs of equation (3), the optimal investment (R_0^{reg}, E_1^{reg}) under regulation are given by

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

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

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 $\bar{E}_0 > E_0^* = \frac{3}{4}$, therefore, $E_1^{reg} = \frac{1}{3}\bar{E}_0 > \frac{1}{3} \times \frac{3}{4} = \frac{1}{4} = E_1^*$. Similarly, $R_0^{reg} = \frac{2}{3}\bar{E}_0 > \frac{2}{3} \times \frac{3}{4} = \frac{1}{2} = R_0^*$. Note, E_1 increases by $\frac{1}{3}\bar{E}_0 - \frac{1}{4}$ and R_0 increases by $\frac{2}{3}\bar{E}_0 - \frac{1}{2}$.

In this sense regulation stimulates investment and more subsequent spending on pollution abatement. The rationale behind the increasing R_0 is as follows. Regulation implies more E_0 (than the value maximizing E_0^*) and this increases the marginal benefit of investment, 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 investment is the same as under no regulation, but the marginal benefit increases, therefore the firm invests more. Formally, the FOC of $\partial V^{reg}/\partial R_0 = 0$ 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.

Under binding regulation (i.e. $\bar{E}_0 > E_0^* = 3/4$), the profits and market value of the regulated firm are given as follows:

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

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

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

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

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

The prediction (*i*) is consistent with the findings in Table 4 and prediction (*ii*) is consistent with the findings in Table 2. Section 7 conducts an empirical test of predictions (*iii*) to (*v*). The derived results above also reconcile the seemly opposite results in the CSR literature if we replace the pollution abatement for the general CSR spending: the voluntary CSR increases the firm value (Servaes and Tamayo, 2013) while the mandatory CSR decreases it (Manchiraju and Rajgopal, 2017).

d. Mandatory Pollution Abatement and Financial Constraint

In this section, we discuss the case when the regulated firm is financially constrained. We assume that the maximum amount of spending the firm can finance in period 0 and 1 is K_0 and K_1, respectively. To facilitate comparison, we assume the firm can finance its first best investment under no regulation, i.e. $K_0 = R_0^* + E_0^*$ =5/4 and $K_1 = E_1^* = \frac{1}{4}$.[7] If $\bar{E}_0 > E_0^*$, then the firm has to reduce its investment in period 0 at least by the amount $\Delta = \bar{E}_0 - E_0^*$. So, the maximization problem of the firm is the same as in equation (3)

$$V^{fincon} = \pi_0 + \pi_1 = 2\bar{S} + \bar{E}_0 - \bar{E}_0^2 - R_0^2 + R_0(\bar{E}_0 + E_1) - E_1^2$$

but there are the additional constraints that

$$R_0 + \bar{E}_0 \leq 5/4; E_1 \leq 1/4$$

[7] The qualitative results in this section hold for any $K_0, K_1 > 0$.

Note, the above analysis shows that a financially unconstrained firm optimally chooses $R_0^{reg} = \frac{2}{3}\bar{E}_0$. Since $\bar{E}_0 > E_0^* = \frac{3}{4}$, we have $R_0^{reg} + \bar{E}_0 > \frac{5}{4}$. So regarding investment in period 0, it is optimal for a financially constrained firm to choose the smallest deviation from R_0^{reg}, i.e.

$$R_0^{fincon} = R_0^{reg} - \Delta = \frac{2}{3}\bar{E}_0 - \Delta = \frac{2}{3}\bar{E}_0 - (\bar{E}_0 - E_0^*) = E_0^* - \frac{1}{3}\bar{E}_0 = \frac{3}{4} - \frac{1}{3}\bar{E}_0.$$

Under binding regulation ($\bar{E}_0 > E_0^* = 3/4$), we have the following comparative results of regulation and financial constraint for investment

$$R_0^{fincon} < \frac{1}{2} = R_0^* < R_0^{reg}.$$

From the FOC of Equation (3), $dV^{fincon}/dE_1 = 0$, the optimal pollution abatement spending in period 1 is

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

Since $R_0^{fincon} < 1/2$, we have

$$E_1^{fincon} < \frac{1}{4}E_1^* < E_1^{reg}.$$

The profit of the financially constrained firm in period 0 is

$$\pi_0^{fincon} = \bar{S} + \bar{E}_0 - \bar{E}_0^2 - (\frac{3}{4} - \frac{1}{3}\bar{E}_0)^2$$

Note, $5/4 = K_0 \geq \bar{E}_0 > E_0^* = 3/4$. Depending on $\bar{E}_0$, the profit in period 0 can be either larger or smaller than π_0^*=$\bar{S} - 1/16$. Comparing the formulas of π_0^{fincon} and π_0^* and solving out the quadratic equation of $\bar{E}_0$, we obtain the conditions:

$$\pi_0^{fincon} > \pi_0^*, \text{ if } 0.6 < \bar{E}_0 < 0.75$$

$$\pi_0^{fincon} < \pi_0^*, \text{ if } \bar{E}_0 > 0.75 \text{ or } \bar{E}_0 < 0.6$$

However, since regulation is binding ($\bar{E}_0 > E_0^* = 0.75$), the model predicts that $\pi_0^{fincon} < \pi_0^*$. But $\pi_0^{fincon} > \pi_0^{reg}$.

The intuition is that the financially constrained firm invests less in period 0 than a financially unconstrained firm while both firms choose $E_0 = \bar{E}_0$. So, the effect

on profits in period 0 is ambiguous. The profit of the financially constrained firm in period 1 is

$$\pi_1^{fincon} = \bar{S} + (\tfrac{3}{4} - \tfrac{1}{3}\bar{E}_0)\left(\bar{E}_0 + \tfrac{3}{8} - \tfrac{1}{6}\bar{E}_0\right) - \left(\tfrac{3}{8} - \tfrac{1}{6}\bar{E}_0\right)^2$$

Since $\bar{E}_0 > E_0^* = \frac{3}{4}$, we have

$$\pi_1^{fincon} < \pi_1^* < \pi_1^{reg}$$

Intuitively, since $R_0^{fincon} < R_0^* < R_0^{reg}$, the firm has invested less in R&D in period 0 which leads to lower demand in period 1 and thus less profit in period 1. For the value of the firm, we have

$$V^{fincon} < V^{reg} < V^*.$$

The value of the firm is $V^{fincon} < V^{reg}$, since V^{reg} is the financially unconstrained maximum given regulation. We summarize these results as the second proposition.

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

The prediction (*i*) is consistent with the findings in Table 4 and prediction (*ii*) is consistent with the findings in Table 2. 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 effort, profits in period 0 of financially constrained firms drop less than for financially unconstrained firms.

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

Table 5 summarizes the set of testable hypotheses. The next section tests the predictions of the model for future investemnt in pollution abatement, future profits and the market value of regulated firms.

[Insert Table 5]

7. Environmental Awareness, Future Abatement Efforts and Profits

In this section, we use a similar empirical design to test the additional predictions (*iii*) to (*v*) in Propositions 1 and 2 as well as Corollaries 1 and 2. Furthermore, this section provides indicative evidence for the main assumption of the model that when consumer values environmental awareness, firms communicate more about their pollution abatement effort.

a. Communication of Firms Environmental Awareness

If consumer values environmental friendly products and clean technology, do firms communicate their environmental spending and awareness to consumers and investors? We test if firms' environmental awareness increases in response to a higher ratio of regulated plants. The results are presented in Table 6. The dependent variable is the environmental awareness index, 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 communication on environment and pollution issues. Except for the dependent variables, other empirical settings like the independent variable, control variables and fixed effects are the same as in Table 2. The subsamples are again the firms that do not lobby and are either financially constrained (i.e. top 1/3 of firms ranked by financial constraint index) or unconstrained (i.e. bottom 1/3 of firms ranked by financial constraint index).

The results show a higher environmental awareness index when constrained and unconstrained firms face the mandatory pollution abatement regulation. Both financially constrained and unconstrained firms experience a significant increase in the environmental awareness index when their regulated plant ratio increases,

reflected by the significantly positive estimates of the *Regulated_Plant_Ratio* in all columns.

[Insert Table 6]

b. Future Pollution Abatement Efforts and Environmental Awareness

The Proposition 1 (*iii*) and Proposition 2 (*iii*) predict opposite voluntary pollution abatement efforts (E_1) for financially constrained and unconstrained firms. Table 7 tests these predictions. The dependent variables are the pollution reduction in 3 years, clean energy investment in 3 years (both from the MSCI ESG database), and the environmental awareness index in 3 years (constructed from the SEC EDGAR).[8] The subsamples are again the firms that do not lobby and are either financially constrained (i.e. top 1/3 of firms ranked by financial constraint index) or unconstrained (i.e. bottom 1/3 of firms ranked by financial constraint index). All regressions control for the year fixed effects and the firm fixed effects.

As predicted by the model, Table 7 shows opposite results for constrained and unconstrained firms. The financially constrained firms experience a significant decrease in their future pollution abatement efforts and environmental awareness when their regulated plant ratio increases, while the financially unconstrained firms' increase their future pollution abatement efforts and environmental awareness. This is reflected by the significantly negative estimates of the *Regulated_Plant_Ratio* in Columns 1-3 for the constrained firms and the significantly positive estimates in Columns 4-6 for the unconstrained firms. In Online Appendix B, Table B1 shows that the results are similar if we do not control for firm characteristics (e.g. leverage, total assets).

[Insert Table 7]

c. Future Profitability

The Proposition 1 (*iv*) and Proposition 2 (*iv*) predict opposite future profitability (π_1) for financially constrained and unconstrained firms. We test this

[8] 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 larger sample size.

prediction in Table 8. The dependent variables are the profit margin and ROA in 3 years. The subsamples are again the firms that do not lobby and are either financially constrained (i.e. top 1/3 of firms ranked by financial constraint index) or unconstrained (i.e. bottom 1/3 of firms ranked by financial constraint index).

Consistent with the predictions of the model, the results in Table 8 show opposite results for constrained and unconstrained firms. The financially constrained firms experience a significant decrease in their future profitability when their regulated plant ratio increases, while the financially unconstrained firms' profitability increases. This is reflected by the significantly negative estimates of the *Regulated_Plant_Ratio* in Columns 1-4 for the constrained firms and the significantly positive estimates in Columns 5-8 for the unconstrained firms.

[Insert Table 8]

d. Tobin's Q and Cumulative Abnormal Return

The Proposition 1 (v) and Proposition 2 (v) predict that both financially constrained and unconstrained firms' value (V) decrease when facing mandatory pollution abatement regulation. We test this prediction in Table 9. The dependent variables are Tobin's Q, 1-, 3- and 4-factor cumulative abnormal return (CAR) of window (-2, +2) around nonattainment status announcement.[9] The subsamples are again the firms that do not lobby and are either financially constrained (i.e. top 1/3 of firms ranked by financial constraint index) or unconstrained (i.e. bottom 1/3 of firms ranked by financial constraint index).

Consistent with the predictions of the model, the results show that both constrained and unconstrained firms experience a significant decrease in their Tobin's Q and CARs when their regulated plant ratio increases, reflected by the significantly negative estimates of the *Regulated_Plant_Ratio* in all columns. In

[9] 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 CARs using the subsample after 2002, the results remain consistent and are available upon request.

Online Appendix B, Table B2 shows that the results are similar if we do not control for firm characteristics (e.g. leverage, total assets).[10]

[Insert Table 9]

e. Testing Corollaries 1 and 2

Depending on whether the firm is financially constrained or not, three variables are affected by mandatory pollution abatement in opposite directions: (i) pollution abatement effort in period 1, (ii) capital expenditure and R&D investment in period 0, and (iii) profit in period 1. These provide the baseline empirical test of Propositions 1 and 2. Two nuanced implications of the model concern the magnitude of changes when both Propositions 1 and 2 predict the same sign. Corollary 1 states that under regulation profits in period 0 of financially constrained firms drops less than for unconstrained firms. Corollary 2 states that under regulation the market value of financially constrained firms drops more than unconstrained firms.

Therefore, we run the following regression using the pooled sample of all non-lobbying firms including financially constrained and unconstrained firms as well as the middle 1/3 firms:[11]

$$Dep_{ft} = \alpha + \beta_1 ratio_{ft} * fincon_{ft} + \beta_2 ratio_{ft} + \beta_3 fincon_{ft} + \chi_{ft} + \Phi_t + \Phi_f + \epsilon_{ft} \quad (4)$$

where Dep_{ft} are the measures of the aforementioned variables. $fincon_{ft}$ is a dummy variable that equals one if a firm's is financially constrained in year t (i.e. top 1/3 of firms ranked by financial constraint index). In addition to the independent variable used in previous tables, we add an interaction term between *Regulated_Plant_Ratio* ($ratio_{ft}$) and the financial constraint *Dummy* ($fincon_{ft}$). The main coefficient of interest is β_1. Observations with financial constraint index in the middle 1/3 are included but results remain robust when they are excluded.

[10] The results for 1-, 3- and 4-factor CARs of windows (-5, +5) are similar and presented in Online Appendix B Table B2.

[11] In unreported analysis, we also run regressions on the pooled sample of constrained and unconstrained firms, but not including the middle 1/3 firms. The results are similar and signs and can be obtained upon request.

The results in the difference-in-difference type of analysis provide further empirical evidence for the model and especially the nuanced predictions of Corollaries 1 and 2. In Table 10, the estimated coefficients of the interaction term on the measures for the current year's firm investment (R_0) in column (1) and (2); the next period's pollution abatement effort (E_1) in columns (5) to (7); and future firm profits (π_1) in column (8) and (9) are all negative. This is consistent with the theory and the previous empirical observations since the effects of regulation on these variables have opposite signs for financially constrained and unconstrained firms.

Furthermore, columns (3) and (4) show that the estimated coefficients of the interaction term on current profits (π_0) are positive. This means, financially constrained firms with more plants subject to pollution abatement regulation have relatively higher current profits than other firms. This is consistent with Corollary 1 which states that the profits of these firms drop less. Columns (10) to (11) show that the estimated coefficient of the interaction term on firm value (V) is negative (though insignificant). This means, financially constrained firms with more plants subject to pollution abatement regulation have relatively lower Tobin's Q and market value than other firms. This is consistent with Corollary 2. In Online Appendix B, Table B3 shows that all results are similar if we do not control for firm characteristics (e.g. leverage, total assets).

[Insert Table 10]

8. Robustness Checks

In this section we conduct several further analyses and show that the main results are robust to various specifications.

a. Analysis using Sample with both Lobbying and Non-Lobbying Firms

In the above analyses, we exclude all firms that lobby on the environmental issues because of an endogeneity concern. In this section we conduct the analysis using the sample that includes lobbying firms. We run the following regression that

includes an interaction term of lobbying with $ratio_{ft}$ to test if firm lobbying has a significant impact on the effect of regulation on firm investment and performance:

$$Dep_{ft} = \alpha + \beta_1 ratio_{ft} * lobbying_{ft} + \beta_2 ratio_{ft} + \beta_3 lobbying_{ft} + \chi_{ft} + \Phi_f + \Phi_t + \epsilon_{ft} \quad (12)$$

where $lobbying_{ft}$ is a dummy variable indicating if a firm f lobbies on environmental policies in year t, and the main independent variable of interest is the interaction between *Regulated_Plant_Ratio* ($ratio_{ft}$) and the lobbying *Dummy (lobbying)*. Specifically, we run Equation (12) separately on the two subsamples of financially unconstrained and constrained firms. We also run the regression on a combined sample regardless of financial constraint. 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 be indifferent from zero.

Table 11 contains three panels and show that the interaction term enters insignificantly in all but two regressions in Panel A (financially unconstrained firms), in all but two regressions in Panel B (financially constrained firms), and in all regressions in Panel C (all firms). In Panel C we combine the subsamples of financially constrained and unconstrained firms, plus the firms with their financial constraint index falling in the middle 1/3 (the middle tertile). The observation number in each regression in Panel C is higher than three times of observations in Panels A and B because this sample also includes firms with missing values of financial constraint index.

More importantly, the signs of *Regulated_Plant_Ratio* in all panels are consistent with Propositions 1 and 2 of the model predictions and many of the estimated coefficients remain significant with the interaction term included. In particular, the results are also consistent with Corollaries 1 and 2. For example, the estimated signs of the coefficient in regressions (4) and (5) (R&D and Capex) are opposite and significant for financially unconstrained firms (Panel A) and constrained firms (Panel B). The results show that the lobbying activities on environmental policies in general do not have a significant impact on the regulatory effects.

[Insert Table 11]

b. Endogeneity Issues due to Possible Prediction of Attainment Status Change

The nonattainment status of each county in year t is designated in every year and $ratio_{ft}$ is typically regarded as exogenous in the literature of environmental economics (Walker, 2011, 2013). Nevertheless, a question is whether a county's attainment status change can be foreseen before its announcement, and how this possibility may affect our empirical design. 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. The latter two factors can be affected by lobbying. Therefore, we consider two variables that may be useful in predicting a county's attainment status change: air quality index (AQI) and firm lobbying.

We run the following regression on a county-level sample to estimate the possibility of prediction:

$$Change\_status_{ct} = \alpha + \beta_1 num\_lobbying_{ct} + \beta_2 \Delta AQI_{ct} + \Phi_c + \Phi_t + \epsilon_{ct} \qquad (13)$$

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. In our data, a higher AQI means more polluted air. A significant estimate of $\Delta AQI_{ct} = AQI_{ct} - AQI_{c,t-1}$ in Equation (13), or β_2, means that the status change from attainment to nonattainment can be foreseen if the air is worsened. An insignificant estimate of β_2 in Equation (13) at least partially supports the exogeneity of the regulation – not all counties with worsened air are determined to be designated as nonattainment.

In Online Appendix B, Table B4 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. In Table B4, 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. We provide a more detailed discussion of this in the Online Appendix B. Note, Table 11 in the previous section shows that the lobbying activities on environmental policies do not have a significant impact on the regulatory consequences.

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 this is the 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 (13) 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 construct the firm-year level weighted average Heckman correction variable HC_{ft} using county-year level IMR_{ct}:

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

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:

$$Dep_{ft} = \alpha + \beta ratio_{ft} + \chi_{ft} + \Phi_f + \Phi_t + HC_{ft} + \epsilon_{ft} \quad (14)$$

In Online Appendix B, Table B5 presents the results. They are similar to the main results and are consistent with Propositions 1 and 2. The variable of Heckman

correction enters insignificantly in all but one regressions, indicating that the self-selection problem is not a major concern in these analyses. Therefore, our empirical results are robust after the correction for potential self-selection.

c. Alternative Regulated Plant Ratio

One potential concern in our main analysis is that the independent variable *Regulated_Plant_Ratio* does not reflect the relative importance of a firm's different plants. Therefore, we construct another independent variable for robustness checks, *Regulated_Plant_Ratio_Weighted*. It measures the employee-number-weighted number of regulated plants located in nonattainment areas divided by the total employee number of the firm, represented by the following formula,

$$ratio_{ft} = \frac{\sum_{i=1}^{N_{ft}} r_{fit} \cdot e_{fit}}{\sum_{i=1}^{N_{ft}} e_{fit}}$$

where r_{fit} is a dummy variable that equals one if plant i of firm f is a toxics releasing plant and located in a nonattainment county in year t and zero otherwise; e_{fit} is the number of employees in plant i of firm f in year t; N_{ft} is the total number of plants of a firm f in year t. The employee number is obtained from the NETS database. In Online Appendix C, we redo Tables 2 to 11 and show that all previous results are robust when using this measure as independent variable.

As a third measure of the independent variable we use is *Regulated_Plant_Ratio_TRI*, which is defined as

$$ratio_{ft} = \frac{\sum_{i=1}^{N_{ft}} r_{fit}}{N_{ft}^{TRI}}$$

where r_{fit} is a dummy variable that equals one if plant i of firm f is a toxics releasing plant and located in a nonattainment county in year t and zero otherwise; N_{ft} is the total number of plants of firm f in year t; and N_{ft}^{TRI} is the total number of toxics releasing plant (TRI) plants of a firm f in a year t. We confirm that all previous results are robust when using this measure as independent variable, and the results are available upon request.

d. Alternative Fixed Effects and Winsorization

In unreported results, the direction of the signs and the statistical significance are the same when we control for the MSA-year, industry-year and firm fixed effects in all regressions and cluster the standard deviation by firm. The results are available upon request.

Another potential concern is that some variables in our analyses may have extreme values. We test the robustness of our results by winsorizing all dependent variables' values at 1% and 5% level. We additionally winsorize all dependent and independent variables. All those robustness tests generate consistent and significant results and are available upon request.

9. Conclusion

On the one hand, the opponents of environmental regulation typically argue that mandatory pollution abatement spending crowds out other investment and thus reduces the competitiveness of regulated firms. On the other hand, proponents of such regulation tend to point out that it can induce profit-maximizing firms to invest more, especially in innovation, than they would otherwise do. This paper conducts a theoretical and empirical analysis of this question and provides a differentiated answer to these conflicting views.

This paper uses a unique mandatory pollution abatement regulation setting in the U.S., the designation of nonattainment status, to study its effects on capital expenditure and R&D investment as well as profits of financially constrained and unconstrained firms. When a county is designated as nonattainment, the plants located in that county are required to take actions to comply with the mandatory requirement which increase pollution abatement cost. Consistent with the theoretical predictions, this paper documents that environmental regulation crowds out the capital expenditure and R&D investment of financially constrained firms, but stimulates more R&D investment, capital expenditure and future voluntary pollution abatement spending by financially unconstrained firms. If consumers value

environmental awareness of firms, pollution abatement spending and investment are complements for financially unconstrained firms.

This paper shows that environmental awareness and firms' financial resources are important determinants of how environmental regulation affects corporate investment behavior. Therefore, policy discussions and proposals about environmental regulation should take these two factors into account.

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Figure 1: Counties with nonattainment status in 2003 and 2004

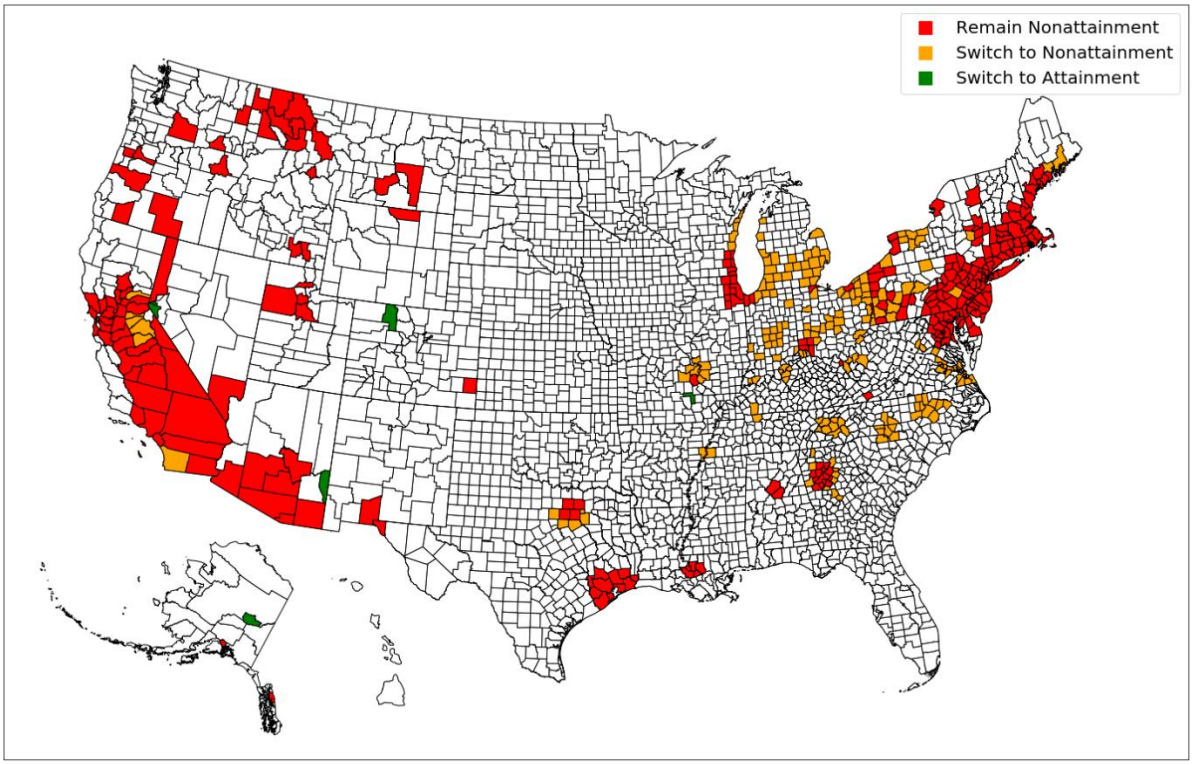

Table 1: Summary statistics

Table 1 presents summary statistics of the variables for the full sample and the subsamples of firms that do not lobby and are either financially constrained or unconstrained (i.e. top or bottom 1/3 of firms ranked by financial constraint index). The sample period is from 1987 to 2016. Note that the non-lobbying financially constrained and unconstrained subsamples are created according to the ranking of the financial constraint index based on the full sample. The numbers of observations in the subsamples are not necessarily 1/3 of the total number of observations of non-lobbying firms. Because less financially constrained firms engage in lobbying, the number of observations in the sample of non-lobbying financially constrained firms is larger than that of the non-lobbying financially constrained subsample for all variables.

	Full Sample			Non-Lobbying Firms			Non-Lobbying Constrained Firms			Non-Lobbying Unconstrained Firms		
	Obs	Mean	Std. Dev	Obs	Mean	Std. Dev	Obs	Mean	Std. Dev	Obs	Mean	Std. Dev
Dependent Variables												
1 Factor CAR (-2, 2)	9,670	0.002	0.051	6,316	0.001	0.054	2,231	0.003	0.059	1,689	0.002	0.048
1 Factor CAR (-5, 5)	9,694	0.004	0.074	6,316	0.004	0.078	2,231	0.002	0.082	1,689	0.009	0.073
3 Factor CAR (-2, 2)	9,694	0.001	0.051	6,316	0.001	0.054	2,231	0.003	0.059	1,689	0.001	0.051
3 Factor CAR (-5, 5)	9,694	0.000	0.073	6,316	-0.002	0.077	2,231	-0.002	0.080	1,689	0.002	0.073
4 Factor CAR (-2, 2)	9,694	0.001	0.051	6,316	0.001	0.055	2,231	0.003	0.059	1,689	0.001	0.051
4 Factor CAR (-5, 5)	9,694	0.001	0.074	6,316	0.000	0.078	2,231	0.000	0.082	1,689	0.001	0.072
Capex	9,890	0.049	0.034	6,507	0.043	0.031	2,316	0.043	0.031	1,713	0.046	0.031
Clean Energy Investment	6,424	0.140	0.347	4,360	0.101	0.301	1,538	0.088	0.283	997	0.082	0.275
Clean Energy Investment in 3 Years	5,751	0.150	0.357	3,874	0.113	0.317	1,205	0.099	0.298	1,150	0.091	0.288
Dummy(Lobbying)	8,259	0.192	0.394	6,674	0.000	0.000	2,381	0.000	0.000	1,796	0.000	0.000
Environmental Awareness	9,897	0.080	0.058	6,523	0.076	0.055	2,317	0.080	0.055	1,716	0.068	0.055
Environmental Awareness in 3 Years	7,477	0.079	0.057	4,731	0.075	0.054	1,504	0.082	0.055	1,435	0.065	0.051
Pollution Reduction	6,523	0.073	0.260	4,458	0.047	0.212	1,570	0.029	0.169	1,032	0.061	0.240
Pollution Reduction in 3 Years	5,825	0.074	0.262	3,946	0.047	0.211	1,223	0.039	0.194	1,167	0.042	0.201
Profit Margin	9,835	0.189	10.798	6,481	0.300	0.184	2,304	0.273	0.178	1,705	0.330	0.162
Profit Margin in 3 Years	8,334	0.305	0.168	5,313	0.302	0.163	1,732	0.275	0.153	1,559	0.324	0.165
R&D	9,706	0.018	0.027	6,323	0.018	0.027	2,231	0.014	0.024	1,679	0.021	0.027
ROA	9,887	0.043	0.070	6,530	0.040	0.075	2,336	0.027	0.078	1,724	0.053	0.070
ROA in 3 Years	7,387	0.043	0.069	4,641	0.043	0.071	1,476	0.036	0.070	1,398	0.047	0.072
Tobin's Q	9,832	2.894	2.393	6,450	3.340	2.508	2,261	2.804	1.953	1,715	3.919	3.073
Independent Variables												
Regulated_Plant_Ratio	10,082	0.024	0.113	6,674	0.023	0.106	2,381	0.022	0.106	1,796	0.020	0.084
Regulated_Plant_Ratio_Weighted	10,082	0.042	0.143	6,674	0.041	0.140	2,381	0.035	0.133	1,796	0.045	0.140
Regulated_Plant_Ratio_TRI	10,082	0.284	0.339	6,674	0.276	0.343	2,381	0.272	0.351	1,796	0.282	0.340
Control Variables												
Cash_Flow	10,080	0.080	0.243	6,673	0.074	0.289	2,381	0.064	0.105	1,795	0.081	0.530
Leverage	10,076	0.580	0.308	6,670	0.563	0.348	2,380	0.604	0.226	1,795	0.522	0.563
OCF	10,063	0.091	0.074	6,662	0.089	0.073	2,373	0.080	0.070	1,792	0.102	0.072
Sales_Growth	10,049	0.114	2.051	6,648	0.113	2.489	2,370	0.096	0.791	1,789	0.078	0.288
Total_Assets	10,080	10096.690	38675.594	6,673	4907.872	12503.846	2,381	4219.225	8742.639	1,795	5434.763	16652.355

Table 2: The effects of mandatory pollution abatement regulation on profit margin and ROA

This table presents the OLS regression estimates of the profit margin and ROA of non-lobbying, financially constrained and unconstrained firms. The sample period is from 1987 to 2016. The sample only includes firms that do not lobby and are financially constrained (i.e. top 1/3 of firms ranked by financial constraint index) or unconstrained (i.e. bottom 1/3 of firms ranked by financial constraint index). The independent variable, *Regulated_Plant_Ratio*, is the number of regulated plants located in nonattainment areas divided by the total number of plants. Robust t-statistics are clustered at the firm level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% significance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Constrained				**Unconstrained**			
	Profit Margin		**ROA**		**Profit Margin**		**ROA**	
Regulated_Plant_Ratio	-0.0137	-0.0108	-0.0019	-0.0006	-0.0360**	-0.0387**	-0.0247***	-0.0242***
	(-1.1900)	(-1.1333)	(-0.1792)	(-0.1438)	(-2.2374)	(-2.3711)	(-2.8502)	(-2.9790)
Cash_Flow		0.3438***		0.6331***		0.0096		0.1274***
		(3.1929)		(14.1416)		(0.2615)		(4.1645)
Leverage		0.0535		-0.0217**		0.0093		0.1110***
		(1.5751)		(-2.0285)		(0.2522)		(3.5220)
OCF		0.2471***		0.0783***		0.1942***		0.3137***
		(3.5946)		(2.6907)		(3.3541)		(6.3938)
Sales_Growth		-0.0051		0.0061		0.0274**		0.0311**
		(-0.3205)		(1.4396)		(2.4155)		(2.5333)
Total_Assets		0.0000		-0.0000		0.0000		-0.0000
		(0.5188)		(-1.3431)		(0.2733)		(-1.4100)
Intercept	0.2604***	0.1876***	0.0252***	-0.0068	0.1970***	0.1849***	0.0465***	-0.0334*
	(85.9280)	(7.3485)	(9.2195)	(-0.9307)	(49.6890)	(9.3669)	(13.7129)	(-1.7565)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Observations	2304	2299	2336	2328	1723	1722	1724	1720
R-squared	0.72	0.74	0.55	0.88	0.67	0.69	0.77	0.83

Table 3: The effects of mandatory pollution abatement regulation on pollution abatement investment index

This table presents the OLS regression estimates of the pollution reduction index and clean energy investment index of non-lobbying, financially constrained and unconstrained firms. The sample period is from 1987 to 2016. The sample only includes firms that do not lobby and are financially constrained (i.e. top 1/3 of firms ranked by financial constraint index) or unconstrained (i.e. bottom 1/3 of firms ranked by financial constraint index). The independent variable, *Regulated_Plant_Ratio*, is the number of regulated plants located in nonattainment areas divided by the total number of plants. Robust t-statistics are clustered at the firm level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% significance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Constrained				**Unconstrained**			
	Pollution Reduction		**Clean Energy Investment**		**Pollution Reduction**		**Clean Energy Investment**	
Regulated_Plant_Ratio	0.0957**	0.0973**	0.1330***	0.1116**	0.1263***	0.1292***	0.1846***	0.1907***
	(2.0726)	(2.1504)	(2.6758)	(2.2071)	(2.6205)	(2.6573)	(3.1389)	(3.2855)
Cash_Flow		-0.0073		0.1003		0.1659		-0.0108
		(-0.0962)		(0.8145)		(0.8803)		(-0.0513)
Leverage		0.0736		0.0179		-0.1116		0.0853
		(1.3282)		(0.2103)		(-0.6750)		(0.4669)
OCF		0.0177		-0.0642		-0.0728		0.2091
		(0.1705)		(-0.4349)		(-0.4440)		(0.9066)
Sales_Growth		0.0124		-0.0331		-0.0097		-0.0690
		(0.8819)		(-1.1806)		(-0.2435)		(-1.2015)
Total Assets		0.0000		0.0000**		0.0000**		0.0000**
		(0.5256)		(2.1062)		(2.2538)		(2.5016)
Intercept	-0.0060	-0.0469	-0.0608	-0.0516	0.0830	0.1344	-0.1048**	-0.1233
	(-0.3661)	(-1.0946)	(-1.0009)	(-0.5313)	(1.6232)	(1.3570)	(-2.5115)	(-1.1123)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Observations	1570	1564	1538	1534	1032	1031	997	996
R-squared	0.59	0.59	0.63	0.64	0.61	0.62	0.66	0.67

Table 4: The effects of mandatory pollution abatement regulation on R&D investment and capital expenditure

This table presents the OLS regression estimates of the R&D investment and capital expenditure of non-lobbying, financially constrained and unconstrained firms. The sample period is from 1987 to 2016. The sample only includes firms that do not lobby and are financially constrained (i.e. top 1/3 of firms ranked by financial constraint index) or unconstrained (i.e. bottom 1/3 of firms ranked by financial constraint index). The independent variable, *Regulated_Plant_Ratio*, is the number of regulated plants located in nonattainment areas divided by the total number of plants. Robust t-statistics are clustered at the firm level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% significance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Constrained				**Unconstrained**			
	R&D		**Capex**		**R&D**		**Capex**	
Regulated_Plant_Ratio	-0.0036***	-0.0031**	-0.0062**	-0.0072**	0.0067***	0.0061***	0.0136***	0.0121**
	(-2.8530)	(-2.2907)	(-2.1936)	(-2.4734)	(2.9211)	(2.6281)	(2.6697)	(2.3089)
Cash_Flow		-0.0086**		0.0110		0.0041		-0.0063
		(-2.0470)		(1.4231)		(0.9286)		(-0.3610)
Leverage		0.0016		-0.0163**		0.0038		-0.0082
		(0.8131)		(-2.3279)		(0.8710)		(-0.4733)
OCF		-0.0011		0.0214		0.0123		0.0489*
		(-0.1359)		(1.5433)		(1.4406)		(1.8196)
Sales_Growth		-0.0009		0.0002		0.0005		0.0059*
		(-0.8248)		(0.0784)		(0.3346)		(1.7452)
Total_Assets		-0.0000		0.0000		-0.0000		-0.0000**
		(-1.1654)		(0.0654)		(-1.4906)		(-2.2692)
Intercept	0.0010	0.0009	0.0420***	0.0499***	0.0002	-0.0025	0.0298***	0.0331***
	(0.6958)	(0.4680)	(7.5930)	(7.8977)	(0.3467)	(-0.8704)	(16.8961)	(2.9991)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Observations	2231	2216	2316	2304	1679	1671	1713	1726
R-squared	0.96	0.96	0.90	0.90	0.97	0.97	0.90	0.91

Table 5: Tabulating the predictions of the model

Notes: The sign "+" indicates that the model predicts an increase in the variable after the nonattainment status is designated (e.g. the mandatory pollution abatement regulation is implemented). The sign "-" indicates a decrease, and the sign "- -" indicates a decrease in greater magnitude than "-".

	Variable	Fin. unconstrained Firms (Proposition 1)	Fin. constrained Firms (Proposition 2)
Pollution abatement effort in period 0	E_0	$+$	$+$
Pollution abatement effort in period 1	E_1	$+$	$-$
Investment (R&D and CAPEX) in period 0	R_0	$+$	$-$
Profit in period 0	π_0	$--$	$-$
Profit in period 1	π_1	$+$	$-$
Firm value	V	$-$	$--$

Table 6: The effects of mandatory pollution abatement regulation on environmental awareness index

This table presents the OLS regression estimates of the environmental awareness index of non-lobbying, financially constrained and unconstrained firms. The sample period is from 1987 to 2016. The sample only includes firms that do not lobby and are financially constrained (i.e. top 1/3 of firms ranked by financial constraint index) or unconstrained (i.e. bottom 1/3 of firms ranked by financial constraint index). The independent variable, *Regulated_Plant_Ratio*, is the number of regulated plants located in nonattainment areas divided by the total number of plants. Robust t-statistics are clustered at the firm level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% significance.

	(1)	(2)	(3)	(4)
	Environmental Awareness			
	Constrained		**Unconstrained**	
Regulated_Plant_Ratio	0.0130***	0.0128***	0.0208***	0.0208***
	(2.8797)	(2.8564)	(2.6919)	(2.6614)
Cash_Flow		-0.0036		-0.0000
		(-0.3138)		(-0.0026)
Leverage		-0.0025		-0.0004
		(-0.2498)		(-0.0350)
OCF		0.0009		0.0081
		(0.0501)		(0.4593)
Sales_Growth		-0.0026		0.0009
		(-0.7099)		(0.3883)
Total_Assets		0.0000		0.0000
		(0.1266)		(0.0105)
Intercept	0.0638***	0.0658***	0.0478***	0.0478***
	(9.4855)	(7.1974)	(21.2257)	(6.1936)
Year Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm
Observations	2317	2302	1716	1708
R-squared	0.94	0.94	0.94	0.94

Table 7: The effects of mandatory pollution abatement regulation on pollution abatement investment and environmental awareness index in three years

This table presents the OLS regression estimates of the pollution reduction index, clean energy investment index and environmental awareness index in three years of non-lobbying, financially constrained and unconstrained firms. The sample period is from 1987 to 2016. The sample only includes firms that do not lobby and are financially constrained (i.e. top 1/3 of firms ranked by financial constraint index) or unconstrained (i.e. bottom 1/3 of firms ranked by financial constraint index). The independent variable, *Regulated_Plant_Ratio*, is the number of regulated plants located in nonattainment areas divided by the total number of plants. Robust t-statistics are clustered at the firm level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% significance.

	(1)	(2)	(3)	(4)	(5)	(6)
		Constrained			**Unconstrained**	
	Pollution Reduction in 3 Years	**Clean Energy Investment in 3 Years**	**Environmental Awareness in 3 Years**	**Pollution Reduction in 3 Years**	**Clean Energy Investment in 3 Years**	**Environmental Awareness in 3 Years**
Regulated_Plant_Ratio	-0.2057**	-0.2999***	-0.0159***	0.1088***	0.2039***	0.0265***
	(-2.5133)	(-2.7132)	(-2.7045)	(2.6438)	(2.8487)	(2.8321)
Cash_Flow	-0.0742	0.0624	-0.0056	0.1904*	0.4674**	-0.0103
	(-1.0800)	(0.6125)	(-0.5105)	(1.7691)	(2.1848)	(-0.7411)
Leverage	0.0123	-0.0715	-0.0128	-0.0928	-0.0101	-0.0073
	(0.1596)	(-0.6583)	(-1.3194)	(-1.0163)	(-0.0695)	(-0.5239)
OCF	0.1206	-0.0619	-0.0037	-0.2440**	-0.0690	0.0018
	(1.2231)	(-0.3712)	(-0.2006)	(-1.9876)	(-0.4170)	(0.0812)
Sales_Growth	-0.0022	-0.0133	-0.0033	0.0125	-0.0058	0.0002
	(-0.2033)	(-0.5318)	(-1.0726)	(0.6561)	(-0.1020)	(0.0861)
Total_Assets	-0.0000	0.0000	0.0000	-0.0000	0.0000	-0.0000
	(-0.0098)	(0.6272)	(0.2761)	(-0.2961)	(0.3666)	(-0.2638)
Intercept	-0.0224	0.0743	0.0433***	0.0525	-0.1103	0.0683***
	(-0.4477)	(0.8616)	(4.6261)	(0.9122)	(-1.1858)	(7.4745)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm
Observations	1218	1200	1492	1164	1147	1431
R-squared	0.68	0.69	0.96	0.60	0.69	0.93

Table 8: The effects of mandatory pollution abatement regulation on profit margin and ROA in three years

This table presents the OLS regression estimates of the profit margin and ROA in three years of non-lobbying, financially constrained and unconstrained firms. The sample period is from 1987 to 2016 The sample only includes firms that do not lobby and are financially constrained (i.e. top 1/3 of firms ranked by financial constraint index) or unconstrained (i.e. bottom 1/3 of firms ranked by financial constraint index). The independent variable, *Regulated_Plant_Ratio*, is the number of regulated plants located in nonattainment areas divided by the total number of plants. Robust t-statistics are clustered at the firm level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% significance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Constrained				**Unconstrained**			
	Profit Margin in 3 Years		**ROA in 3 Years**		**Profit Margin in 3 Years**		**ROA in 3 Years**	
Regulated_Plant_Ratio	-0.0790*	-0.0537*	-0.0347***	-0.0235**	0.0280***	0.0267***	0.0286***	0.0275***
	(-1.8155)	(-1.6775)	(-2.8965)	(-2.0332)	(2.6883)	(2.6101)	(2.8668)	(2.5940)
Cash_Flow		0.0049		0.0189		-0.0226		0.0113
		(0.1143)		(0.4328)		(-0.4846)		(0.2552)
Leverage		0.0372		0.0774***		-0.0246		0.0031
		(1.3983)		(2.7893)		(-0.5267)		(0.0699)
OCF		0.0007		0.0406		0.0345		0.0351
		(0.0150)		(0.7548)		(0.7332)		(0.5978)
Sales_Growth		-0.0145		-0.0215*		0.0233**		0.0092
		(-0.9113)		(-1.6656)		(2.4201)		(0.6508)
Total_Assets		0.0000		-0.0000		-0.0000**		-0.0000
		(0.3121)		(-1.2683)		(-2.3148)		(-1.1972)
Intercept	0.2232***	0.1976***	0.0048	-0.0412**	0.1957***	0.2095***	0.0055	0.0011
	(15.1139)	(8.5408)	(0.3721)	(-1.9668)	(48.2425)	(7.6928)	(0.9901)	(0.0436)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Observations	1732	1727	1476	1469	1559	1555	1398	1393
R-squared	0.57	1.00	0.60	0.62	0.99	0.99	0.74	0.75

Table 9: The effects of mandatory pollution abatement regulation on Tobin's Q and cumulative abnormal return

This table presents the OLS regression estimates of the Tobin's Q, 1-factor CAR of window (-2, +2), 3-factor CAR of window (-2, +2) and 4-factor CAR of window (-2, +2) of non-lobbying, financially constrained and unconstrained firms. The sample period is from 1987 to 2016. The sample only includes firms that do not lobby and are financially constrained (i.e. top 1/3 of firms ranked by financial constraint index) or unconstrained (i.e. bottom 1/3 of firms ranked by financial constraint index). The independent variable, *Regulated_Plant_Ratio*, is the number of regulated plants located in nonattainment areas divided by the total number of plants. Robust t-statistics are clustered at the firm level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% significance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Constrained				**Unconstrained**			
	Tobin's Q	**1-factor CAR(-2, 2)**	**3-factor CAR(-2,2)**	**4-factor CAR(-2, 2)**	**Tobin's Q**	**1-factor CAR(-2, 2)**	**3-factor CAR(-2,2)**	**4-factor CAR(-2, 2)**
Regulated_Plant_Ratio	-1.0694***	-0.0293***	-0.0235***	-0.0305***	-0.5849***	-0.0205***	-0.0208***	-0.0198***
	(-2.6088)	(-3.4921)	(-3.2915)	(-3.1356)	(-3.2445)	(-2.9204)	(-3.0752)	(-2.8743)
Cash_Flow	-6.3184***	0.0303	0.0252	0.0223	1.6187***	0.0136	-0.0121	-0.0219
	(-5.9967)	(1.1087)	(1.0672)	(0.9191)	(3.0406)	(0.4252)	(-0.3905)	(-0.6635)
Leverage	-6.3535***	0.0185	0.0138	0.0111	-3.8077***	0.0257	0.0131	0.0121
	(-6.0406)	(0.6850)	(0.5915)	(0.4599)	(-7.4066)	(1.5954)	(0.9296)	(0.8608)
OCF	7.5954***	-0.0039	-0.0129	-0.0112	4.2557***	0.0311	0.0396	0.0234
	(5.4447)	(-0.0970)	(-0.3150)	(-0.2718)	(5.4375)	(0.9466)	(1.1145)	(0.6393)
Sales_Growth	0.7615**	-0.0023	-0.0070	-0.0085	0.0175	0.0015	-0.0015	-0.0050
	(2.0067)	(-0.3113)	(-1.1394)	(-1.2586)	(0.0816)	(0.1614)	(-0.1630)	(-0.5171)
Total_Assets	-0.0000***	0.0000***	0.0000*	0.0000*	-0.0000**	-0.0000	-0.0000	-0.0000
	(-2.6080)	(2.7157)	(1.8554)	(1.6533)	(-2.0742)	(-0.7775)	(-1.6129)	(-1.0046)
Intercept	5.8389***	-0.0090	-0.0001	0.0052	3.9051***	-0.0338**	-0.0198	-0.0096
	(9.0744)	(-0.5649)	(-0.0060)	(0.3580)	(9.5907)	(-2.2217)	(-1.3944)	(-0.6869)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Observations	2261	2231	2231	2231	1715	1689	1689	1689
R-squared	0.94	0.41	0.32	0.39	0.95	0.34	0.35	0.34

Table 10: The effects of regulation on all non-lobbying firms

This table presents the results of OLS regressions showing how the effects of the percentage of newly regulated plants in nonattainment areas and financial constraint on firm investment and performance measures. The sample period is from 1987 to 2016. The main independent variable of interest is the interaction between *Regulated_Plant_Ratio* and an indicator variable *Dummy(Constrained)* that equals one if the firm-year observation's financial constraint index falls in the top 1/3, and zero otherwise. The two standalone variables are also included. Robust t-statistics are clustered at the firm level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% statistical significance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	R&D	**Capex**	**Profit Margin**	**ROA**	**Pollution Reduction in 3 Years**	**Clean Energy Investment in 3 Years**	**Environmental Awareness in 3 Years**	**Profit Margin in 3 Years**	**ROA in 3 Years**	**Tobin's Q**	**1-factor CAR(-2, 2)**
Model-Predicted Sign	**-**	**-**	**+**	**+**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Regulated_Plant_Ratio*Dummy(Constrained)	-0.0027***	-0.0041***	0.0126**	0.0071*	-0.0483***	-0.0747***	-0.0081***	-0.0085	-0.0125***	-0.1426	-0.0049
	(-3.3973)	(-2.6715)	(2.0390)	(1.6656)	(-3.1122)	(-3.6167)	(-3.1986)	(-1.5280)	(-2.6596)	(-0.9855)	(-1.3438)
Dummy(Constrained)	0.0006*	0.0006	-0.0076**	-0.0053***	0.0237***	0.0189*	0.0021*	0.0009	0.0070***	-0.0855	0.0042**
	(1.6603)	(0.7851)	(-2.0790)	(-2.7809)	(2.5965)	(1.8655)	(1.7059)	(0.3671)	(3.0980)	(-1.5353)	(2.5723)
Regulated_Plant_Ratio	0.0006	0.0020	-0.0110	-0.0019	-0.0582	-0.0482	0.0054	-0.0101	0.0061	-0.2641	-0.0152***
	(0.3880)	(0.7943)	(-0.6066)	(-0.2692)	(-1.5612)	(-0.7563)	(1.0960)	(-0.6270)	(0.8125)	(-1.1886)	(-3.6834)
Cash_Flow	-0.0021	-0.0037	0.0300	0.1444***	0.0218	0.0653	-0.0071	0.0063	0.0438***	-3.6402***	0.0126
	(-1.1564)	(-0.7704)	(0.4416)	(5.0650)	(0.5323)	(1.0184)	(-1.1447)	(0.4561)	(3.1443)	(-7.5127)	(1.2886)
Leverage	-0.0020	-0.0064	0.0199	0.1020***	0.0033	0.0528	-0.0047	0.0066	0.0377***	-4.0045***	0.0013
	(-1.0932)	(-1.3689)	(0.3202)	(5.4709)	(0.0699)	(0.7730)	(-0.7486)	(0.4843)	(2.6960)	(-9.5115)	(0.1318)
OCF	0.0045	0.0499***	0.2310***	0.3857***	-0.0888	0.0417	0.0070	-0.0057	0.0507**	7.4785***	0.0247
	(1.1804)	(5.8151)	(4.5248)	(11.5980)	(-1.4581)	(0.5357)	(0.7462)	(-0.1411)	(2.1971)	(9.3469)	(1.3598)
Sales_Growth	0.0000	-0.0005***	-0.0001	0.0007	-0.0025	0.0114	-0.0025	-0.0091	-0.0054	0.0126	-0.0004***
	(0.8333)	(-7.7143)	(-0.2210)	(1.3166)	(-0.2305)	(0.3805)	(-1.1925)	(-0.9416)	(-0.7905)	(1.4048)	(-3.7321)
Total_Assets	-0.0000***	-0.0000	0.0000	-0.0000**	-0.0000	0.0000	0.0000	-0.0000	-0.0000**	-0.0000***	0.0000*
	(-3.1131)	(-0.7906)	(0.0554)	(-2.5271)	(-0.2489)	(0.1208)	(0.1046)	(-0.8834)	(-2.5214)	(-4.3564)	(1.8638)
Intercept	0.0014	0.0427***	0.1824***	-0.0422***	-0.0508	-0.1043**	0.0478***	0.1967***	-0.0211**	4.1534***	-0.0088
	(0.9773)	(12.6582)	(4.0172)	(-3.7889)	(-1.3147)	(-2.2529)	(10.3878)	(18.8636)	(-2.1321)	(14.4499)	(-1.3419)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Observations	5894	6064	6036	6064	3616	3546	4337	4903	4256	6012	5891
R-squared	0.95	0.87	0.94	0.68	0.48	0.61	0.93	0.99	0.62	0.91	0.26

Table 11: The effects of regulation on lobbying and non-lobbying firms

Panel A: The effects of regulation on lobbying, non-lobbying and financially unconstrained firms

This table presents the results of OLS regressions showing how the effects of the percentage of newly regulated plants in nonattainment areas on investment and performance of all financially unconstrained firms. The sample period is from 1987 to 2016. The main independent variable of interest is the interaction between *Regulated_Plant_Ratio* 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 year fixed effects and firm fixed effects in all regressions. Robust t-statistics are clustered at the firm level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% statistical significance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	R&D	**Capex**	**Profit Margin**	**ROA**	**Pollution Reduction in 3 Years**	**Clean Energy Investment in 3 Years**	**Environmental Awareness in 3 Years**	**Profit Margin in 3 Years**	**ROA in 3 Years**	**Tobin's Q**	**1-factor CAR(-2, 2)**
Regulated_Plant_Ratio * Dummy (Lobbying)	-0.0156***	-0.0449***	-0.0220	-0.0021	-0.5724	-0.0246	0.0029	-0.0912	-0.0933	-0.4371	0.0404
	(-2.5921)	(-2.8462)	(-0.3403)	(-0.0630)	(-1.0064)	(-0.0361)	(0.0743)	(-0.8738)	(-0.8510)	(-0.3512)	(1.5024)
Regulated_Plant_Ratio	0.0068**	0.0327*	-0.0386	-0.0459***	0.1465	-0.4172	0.0395	0.0007	0.0585	-0.4614	-0.0377**
	(2.5225)	(1.7138)	(-1.3378)	(-3.1586)	(0.3659)	(-0.9041)	(0.9138)	(0.0136)	(1.0909)	(-0.4231)	(-2.2314)
Dummy (Lobbying)	0.0021	0.0007	-0.0112	0.0034	0.0615	0.0181	-0.0070**	-0.0113**	-0.0035	0.3112	-0.0004
	(1.1562)	(0.3880)	(-1.1445)	(0.9817)	(1.4044)	(0.5194)	(-2.0993)	(-2.1939)	(-0.5661)	(1.5004)	(-0.0876)
Cash_Flow	0.0022	-0.0079	0.0093	0.1389***	0.1357	0.3722**	-0.0079	-0.0235	0.0207	-6.1854***	0.0319*
	(0.5820)	(-0.5900)	(0.3130)	(5.6033)	(1.6063)	(2.3106)	(-0.6874)	(-0.6099)	(0.5890)	(-6.7161)	(1.8573)
Leverage	0.0019	-0.0097	0.0076	0.1211***	0.0257	0.0151	-0.0050	-0.0254	0.0128	-6.2579***	0.0264
	(0.5034)	(-0.7306)	(0.2565)	(4.7363)	(0.3254)	(0.1155)	(-0.4284)	(-0.6592)	(0.3645)	(-6.8158)	(1.5378)
OCF	0.0202***	0.0609***	0.2303***	0.3566***	-0.1402	-0.0311	-0.0009	0.0252	0.0113	9.2974***	0.0003
	(2.7634)	(3.0143)	(4.5890)	(8.8504)	(-1.0241)	(-0.1411)	(-0.0542)	(0.5722)	(0.2435)	(7.4351)	(0.0079)
Sales_Growth	0.0005	0.0057**	0.0002	0.0328***	0.0135	0.0533	-0.0029	0.0218***	0.0049	0.7506**	-0.0030
	(0.4346)	(2.1249)	(0.0077)	(3.3119)	(0.6352)	(1.0942)	(-1.2051)	(3.0217)	(0.4367)	(2.5273)	(-0.7112)
Total_Assets	-0.0000	0.0000	0.0000*	-0.0000	-0.0000	0.0000***	0.0000	0.0000	-0.0000**	-0.0000	-0.0000***
	(-0.9700)	(0.1291)	(1.6968)	(-0.9796)	(-0.9953)	(3.6721)	(0.0443)	(0.4974)	(-2.3765)	(-1.2923)	(-3.0441)
Intercept	0.0176***	0.0395***	0.2944***	-0.0556***	0.0794	0.1229	0.0750***	0.3287***	0.0475**	6.4637***	-0.0133
	(7.4069)	(4.6940)	(18.1641)	(-3.5922)	(1.5065)	(1.5231)	(9.7203)	(13.5691)	(2.2129)	(11.7207)	(-1.3753)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Observations	2011	2045	2033	2058	1452	1436	1734	1861	1694	2047	2022
R-squared	0.92	0.89	0.98	0.74	0.22	0.44	0.90	0.99	0.59	0.91	0.04

Panel B: The effects of regulation on lobbying, non-lobbying and financially constrained firms

This table presents the results of OLS regressions showing how the effects of the percentage of newly regulated plants in nonattainment areas on investment and performance of all financially constrained firms. The sample period is from 1987 to 2016. The main independent variable of interest is the interaction between *Regulated_Plant_Ratio* 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 year fixed effects and firm fixed effects in all regressions. Robust t-statistics are clustered at the firm level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% statistical significance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	R&D	**Capex**	**Profit Margin**	**ROA**	**Pollution Reduction in 3 Years**	**Clean Energy Investment in 3 Years**	**Environmental Awareness in 3 Years**	**Profit Margin in 3 Years**	**ROA in 3 Years**	**Tobin's Q**	**1-factor CAR(-2, 2)**
Regulated_Plant_Ratio * Dummy (Lobbying)	0.0040	0.0116*	-0.0055	0.0138	0.2862	0.2669	0.0108	0.0619	0.0229	0.8091**	0.0219
	(1.6068)	(1.8063)	(-0.0946)	(0.8772)	(1.5092)	(1.3033)	(1.0637)	(0.9738)	(0.6783)	(2.2306)	(1.2235)
Regulated_Plant_Ratio	-0.0050**	-0.0062*	-0.0539	-0.0259*	0.0165	0.1383	-0.0152	-0.1987***	-0.0691***	-1.1244***	-0.0321**
	(-1.9879)	(-1.6988)	(-0.9765)	(-1.7654)	(0.2072)	(1.2576)	(-1.3988)	(-3.1991)	(-3.0105)	(-4.1118)	(-2.0578)
Dummy (Lobbying)	0.0007	0.0052*	0.0112	-0.0025	-0.0062	0.0170	0.0036	0.0041	0.0057	0.0882	0.0054
	(1.2483)	(1.8515)	(1.3133)	(-0.7266)	(-0.4259)	(0.3980)	(0.9459)	(0.3639)	(0.9032)	(1.3936)	(1.2217)
Cash_Flow	-0.0078**	0.0095	0.3637***	0.6115***	-0.0920*	0.0924	-0.0040	-0.0066	0.0044	1.0347**	0.0155
	(-2.4662)	(1.5489)	(3.4142)	(15.2218)	(-1.6620)	(0.8465)	(-0.5223)	(-0.0757)	(0.1372)	(2.0000)	(0.5885)
Leverage	-0.0010	-0.0150**	0.0479	-0.0167	0.0386	0.0545	-0.0164**	0.0372	0.0689***	-3.7892***	0.0292**
	(-0.2909)	(-2.5075)	(1.5217)	(-1.4019)	(0.7103)	(0.5629)	(-2.3207)	(1.5916)	(2.9804)	(-7.3641)	(1.9752)
OCF	0.0003	0.0424***	0.2496***	0.1073***	0.1499*	0.0920	0.0014	0.0316	0.0806*	4.5505***	0.0634**
	(0.0437)	(3.5411)	(3.8180)	(3.7568)	(1.8777)	(0.6294)	(0.0927)	(0.8828)	(1.9435)	(6.1517)	(2.3156)
Sales_Growth	-0.0008	0.0026	0.0033	0.0059*	0.0049	0.0391	-0.0073***	-0.0128	-0.0060	0.2517**	0.0053
	(-1.2229)	(0.8899)	(0.2775)	(1.8340)	(0.5387)	(0.9330)	(-2.6382)	(-1.4925)	(-0.9312)	(2.1469)	(0.6668)
Total_Assets	-0.0000*	0.0000**	0.0000	-0.0000*	0.0000	0.0000	-0.0000	0.0000	-0.0000***	-0.0000***	-0.0000
	(-1.6716)	(2.3411)	(1.0010)	(-1.7714)	(1.4301)	(0.6457)	(-0.0022)	(0.1612)	(-3.6390)	(-2.6542)	(-0.3514)
Intercept	0.0133***	0.0469***	0.1733***	-0.0093	-0.0040	0.0714	0.0924***	0.2384***	-0.0156	4.3917***	-0.0215**
	(5.2623)	(12.0541)	(7.2744)	(-1.2134)	(-0.1089)	(1.1144)	(20.0035)	(12.2712)	(-1.1052)	(13.2431)	(-2.2723)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Observations	2914	3005	2993	3022	1686	1664	1981	2294	1954	2948	2910
R-squared	0.82	0.87	0.93	0.79	0.17	0.38	0.94	0.95	0.39	0.92	0.08

Panel C: The effects of regulation on all (lobbying, non-lobbying, financially constrained, unconstrained and middle 1/3) firms

This table presents the results of OLS regressions showing how the effects of the percentage of newly regulated plants in nonattainment areas on investment and performance of all firms. The sample period is from 1987 to 2016. The main independent variable of interest is the interaction between *Regulated_Plant_Ratio* 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 year fixed effects and firm fixed effects in all regressions. Robust t-statistics are clustered at the firm level and presented in parentheses. ***, ** and * denote 1%, 5% and 10% statistical significance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	R&D	**Capex**	**Profit Margin**	**ROA**	**Pollution Reduction in 3 Years**	**Clean Energy Investment in 3 Years**	**Environmental Awareness in 3 Years**	**Profit Margin in 3 Years**	**ROA in 3 Years**	**Tobin's Q**	**1-factor CAR(-2, 2)**
Regulated_Plant_Ratio * Dummy (Lobbying)	0.0019	-0.0071	0.0115	-0.0180	0.2790	0.2811	-0.0025	-0.0007	0.0263	0.0351	-0.0089
	(1.0941)	(-1.4372)	(0.1698)	(-1.4993)	(1.4569)	(1.4627)	(-0.3151)	(-0.0165)	(0.8830)	(0.1150)	(-0.7887)
Regulated_Plant_Ratio	-0.0031*	0.0070	-0.0632	-0.0026	-0.1046	-0.1499	-0.0043	-0.0712*	-0.0265	-0.2054	-0.0071
	(-1.8528)	(1.5828)	(-0.8477)	(-0.4037)	(-0.7244)	(-0.8705)	(-0.7757)	(-1.7415)	(-1.6180)	(-0.8173)	(-0.9684)
Dummy (Lobbying)	0.0006	0.0032**	0.0018	0.0007	0.0067	-0.0339	-0.0008	0.0009	-0.0016	0.0891	0.0040*
	(1.0001)	(2.2963)	(0.3240)	(0.2717)	(0.3548)	(-1.2928)	(-0.3805)	(0.1998)	(-0.5032)	(1.1618)	(1.9114)
Cash_Flow	-0.0014	-0.0034	0.0415	0.1541***	0.0364	0.1241*	-0.0083	0.0158	0.0532***	-3.6649***	0.0128
	(-0.7487)	(-0.7244)	(0.7553)	(5.0127)	(1.0137)	(1.6547)	(-1.6259)	(1.2619)	(4.5515)	(-7.2017)	(1.6319)
Leverage	-0.0013	-0.0066	0.0262	0.1029***	0.0173	0.1054	-0.0062	0.0154	0.0478***	-4.1267***	0.0040
	(-0.6840)	(-1.4485)	(0.5369)	(6.2031)	(0.4239)	(1.6132)	(-1.1784)	(1.2656)	(4.0717)	(-9.7173)	(0.5289)
OCF	0.0076***	0.0609***	0.2733***	0.3923***	-0.0818	-0.0181	0.0075	0.0212	0.0543***	7.6621***	0.0291*
	(2.6891)	(7.6513)	(6.2511)	(12.4816)	(-1.4076)	(-0.2142)	(0.9673)	(0.7144)	(2.9614)	(10.0145)	(1.9298)
Sales_Growth	-0.0000	-0.0005***	-0.0001	0.0009	-0.0012	0.0316	-0.0031*	-0.0088	-0.0020	0.0154	-0.0003***
	(-0.0244)	(-6.7610)	(-0.2183)	(1.3515)	(-0.1409)	(1.1738)	(-1.7627)	(-1.3326)	(-0.5525)	(1.3170)	(-2.8159)
Total_Assets	-0.0000*	0.0000	0.0000**	-0.0000*	-0.0000	0.0000	0.0000	0.0000	-0.0000***	-0.0000**	-0.0000
	(-1.6634)	(1.3337)	(2.1497)	(-1.9251)	(-0.0326)	(1.0583)	(0.2586)	(0.5418)	(-2.9868)	(-2.1289)	(-1.5344)
Intercept	0.0172***	0.0406***	0.2373***	-0.0628***	0.0575**	0.0821**	0.0830***	0.2767***	0.0132	5.0220***	-0.0048
	(13.0901)	(13.2021)	(7.1546)	(-6.2233)	(2.1854)	(2.0501)	(23.5246)	(29.7999)	(1.6297)	(18.0614)	(-1.0162)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Observations	7856	8049	8020	8063	5091	5016	5910	6632	5819	7984	7845
R-squared	0.84	0.85	0.92	0.54	0.14	0.37	0.90	0.96	0.45	0.88	0.05

Appendix Table A1: Variable Definition

Variable Name	Definition	Source
Regulated_Plant_Ratio	Firm-year level variable. The number of regulated plants divided by the total number of plants of a firm in a given year.	EPA, CFR, NETS
Regulated_Plant_Ratio_Weighted	Firm-year level variable. The employment-weighted number of regulated plants divided by the total number of plants of a firm in a given year.	EPA, CFR, NETS
Regulated_Plant_Ratio_TRI	Firm-year level variable. The number of regulated plants divided by the total number of TRI plants of a firm in a given year.	EPA, CFR
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
Cash_Flow	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
Capex	Firm-year level variable. Capital expenditure divided by total book assets(AT).	Compustat
Clean Energy Investment	MSCI ESG-constructed firm-year level index that indicates to what extent a firm has taken significant measures to reduce its impact on climate change and air pollution through use of renewable energy and clean fuels or through energy efficiency.	MSCI ESG
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(Constrained)	Firm-year level variable. A dummy variable that equals one if the firm-year observation's financial constraint index falls in the top 1/3, and equals zero if it falls in the bottom 1/3. Observations with financial constraint index in the middle 1/3 are excluded and values are put as missing. The financial constraint index is constructed following Bodnaruk, Loughran and McDonald (2015).	SEC Edgar filings, constructed following Bodnaruk, Loughran and McDonald (2015)

Dummy(lobbying)	Firm-year level variable. A dummy indicating with the firm lobbies 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
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
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
Leverage	Firm-year level variable. Total liabilities (LT) divided by total book assets (AT).	Compustat
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
OCF	Firm-year level variable. The operating cash flow (OANCF) divided by total book assets (AT).	Compustat
Pollution Reduction	MSCI ESG-constructed firm-year level index that indicates to what extent a firm has notably strong emissions reductions and toxic-use reduction programs.	MSCI ESG
Profit Margin	Firm-year level variable. (Revenue (REVT) - Cost of Goods Sold (COGS)) divided by REVT.	Compustat
R&D	Firm-year level variable. Research and development expense (XRD) divided by total book assets(AT).	Compustat
Recycling Investment	MSCI ESG-constructed firm-year level index that indicates to what extent a firm is a substantial user of recycled materials as raw materials in its manufacturing processes.	MSCI ESG
ROA	Firm-year level variable. Net income (NI) 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
Tobin's Q	Firm-year level variable. Market value of assets (MKVALT + LT) divided by book value of assets (BKVLPS + LT).	Compustat
Total_Assets	Firm-year level variable. The value of total assets reported on the balance sheet (AT).	Compustat

One additional file with three appendices

Online Appendix A

In this online appendix we present a more general model and provide detailed proof steps.

Online Appendix B

This online appendix provides additional robustness tests.

Table B1: Complement of Table 7 (without firm level control)

Table B2: Complement of Table 9 (without firm level control)

Table B3: Complement of Table 10 (without firm level control)

Table B4, B5: Results for Section 8b.

Online Appendix C

In this appendix we replace the independent variable *Regulated_Plant_Ratio* by *Regulated_Plant_Ratio_Weighted* and redo Tables 2 to Table 11 using this variable.