When the EPA is in play, risk-taking goes away: The effect of environmental regulations on CEO compensation*

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Abstract

We examine the impact of environmental regulations and firms' polluting behavior on CEO incentive compensation. Using the application of the National Ambient Air Quality Standards as an exogenous source of variation in regulatory stringency, we find that noncompliance prompts boards to reduce risk-taking incentives by decreasing the convexity of compensation payoffs. Higher regulation intensity and operating risk amplify the decrease in risk-taking incentives, while financially distressed firms exhibit a less pronounced reduction. Existing governance structures including CEO entrenchment, institutional investors, bargaining power, and overconfidence moderate the relationship between regulatory exposure and risk-taking incentives. Our findings highlight the active role of boards in adjusting incentive contracts to align the risk preferences between shareholders and managers in response to environmental regulations.

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1. Introduction

In recent years, there has been a growing impact of environmental regulations on polluting firms, prompting shareholders to address and navigate the associated risks that directly influence corporate governance (Krueger, Sautner, & Starks, 2020; Stroebel & Wurgler, 2021). Moreover, there is a long-standing debate regarding how a firm's corporate governance influences shareholders' ability to modify incentive compensation for executives under various circumstances (Chen, Jung, Peng, & Zhang, 2022; De Angelis, Grullon, & Michenaud, 2017; Gormley, Matsa, & Milbourn, 2013; Hayes, Lemmon, & Qiu, 2012). Given that environmental regulations can significantly alter a firm's operating conditions, it is important to examine how such regulations reshape the governance dynamics between shareholders and managers. This paper focuses specifically on the compensation of CEOs, which is one of the cornerstones of corporate governance that allows boards to align managers' interests with those of shareholders (Holmström, 1979), and investigates how exogenous changes in firms' regulatory exposure influence the risk-taking incentives provided to CEOs through their incentive compensation design.

We posit that polluting firms subject to stringent environmental regulations will need to allocate resources towards pollution abatement to internalize environmental costs (Xu & Kim, 2022). Additionally, compliance efforts may lead to penalties and legal actions in case of violations (Hsu, Li, & Tsou, 2022). As a result, environmental regulations reduce shareholders' expected cash flows from new investments, leading to a decrease in their willingness to pursue marginal projects that previously had positive net present value (NPV) but now carry the risk of noncompliance. To avoid undertaking excessive risks, we expect boards to adjust CEO compensation packages to reduce risk-taking incentives when facing regulatory exposure.

To test this hypothesis, we exploit a natural experiment based on a key regulatory component of the U.S. Clean Air Act (CAA), specifically the yearly designation of counties as attainment or nonattainment with respect to the National Ambient Air Quality Standards (NAAQS) for ground-level ozone.[1] The NAAQS threshold, set by the United States Environmental Protection Agency (EPA), establishes the maximum allowable concentrations of ozone pollution. Counties exceeding this threshold are designated as noncompliant (nonattainment), while those below are classified as compliant (attainment). Nonattainment designations represent legally binding regulations enforced by the federal government. They impose stringent requirements on all firms operating facilities that emit ozone pollutants in nonattainment

[1]Henceforth, we refer to ground-level ozone as simply ozone.

counties, including costly emission limits and pollution abatement measures (Becker, 2005; Becker & Henderson, 2000, 2001; Greenstone, 2002). In contrast, firms in attainment counties face less stringent regulations. We utilize nonattainment designations as an exogenous source of variation in local regulatory stringency, which represents a negative shock to the cash flows of firms exposed to these regulations.

This unique institutional setting allows us to precisely identify the firms that experience additional regulatory costs due to nonattainment designation. For instance, a firm that operates multiple ozone-emitting plants located exclusively in attainment counties is unaffected by the regulation. Similarly, a firm that operates several polluting plants in nonattainment counties, but none of them emit ozone, is also unaffected. To capture a firm's exposure to nonattainment designations, we first manually map plant-level chemical emissions into ozone and non-ozone pollutants to determine regulatory treatment at the plant-level based on the quantity of ozone emissions. We then combine the regulatory status of each plant with their geographic distribution across attainment and nonattainment counties to generate a firm-level measure of nonattainment exposure.

Our identification strategy employs a difference-in-differences (DiD) approach with continuous treatment to examine how CEOs' incentive compensation is affected by a firm's nonattainment exposure. We measure risk-taking incentives using the sensitivity of CEO wealth to stock return volatility (vega), which is a well-recognized measure of the convexity in compensation payoffs (Coles, Daniel, & Naveen, 2006; Low, 2009). Previous research has demonstrated that higher vega is associated with riskier investment and financing decisions (Chava & Purnanandam, 2010; Guay, 1999; Rajgopal & Shevlin, 2002). Our sample consists of 2,765 unique publicly listed firms in the US, comprising 31,202 firm-year observations from 1993 to 2019. We find a significant decrease in vega as firms' nonattainment exposure increases, suggesting that boards adjust managers' risk-taking incentives to align with shareholders' risk preferences.

Given that the board can observe a county's monitored ozone pollution levels, they may anticipate a county's nonattainment status and adjust compensation packages accordingly. This anticipation introduces the possibility that changes in vega are not solely driven by exogenous variation in nonattainment exposure. To address this concern, we employ a regression discontinuity design (RDD) to decompose nonattainment designations into an unexpected (exogenous) component and an anticipated (predictable) component. Our findings indicate that the decrease in vega is primarily driven by the exogenous component of nonattainment designations, rather than the potentially predictable component.

To further validate our results, we examine dynamic versions of the DiD model and find no significant changes in vega prior to firms' exposure to unexpected or anticipated nonattainment designations, which supports the parallel trends assumption underlying our DiD specification. Notably, we observe that CEOs' vega experiences a decline for firms exposed to unexpected nonattainment designations in the four years following the exposure, while it remains unchanged for those with anticipated nonattainment exposure. This suggests that unexpected events have a more pronounced impact on CEOs' risk-taking incentives compared to events that were anticipated by the board.

We proceed to investigate the underlying mechanism driving the decrease in vega. We begin by analyzing the impact of nonattainment exposure on the structure of new option grants to determine whether the changes in vega are initiated by the board or the managers themselves. Our findings reveal that nonattainment exposure leads to a reduction in vega through a decrease in managers' current year compensation from option grants, representing the portion of compensation directly controlled by the board. Additionally, we observe a significant decline in the number of options granted to the CEO relative to shares outstanding in response to nonattainment exposure. However, we do not find any evidence to suggest that managers adjust their existing portfolios, as there are no changes in the value or number of options exercised in response to nonattainment exposure. These findings imply that the board actively manages new option grants rather than managers altering their behavior regarding option exercise.

We also examine the impact of nonattainment exposure on the various components of CEO compensation structure. While our results indicate that the decrease in risk-taking incentives arises from the board's active management of CEOs' incentive compensation, an alternative possibility could be that risk-averse managers negotiate with the board to modify their compensation packages in response to the negative cash flow shock caused by nonattainment designations. This negotiation may involve shifting the compensation mix away from options, which can amplify exposure to the firm's risk, and towards more stable forms such as cash (Carpenter, 2000; Lambert, Larcker, & Verrecchia, 1991). Consistent with our findings on the decrease in new option grants, we find a significant reduction in the value of option awards relative to the total compensation of CEOs in response to nonattainment exposure. However, we do not find any significant changes in the sum of salary and bonus compensation, suggesting limited evidence of managers substituting options for cash.

To enhance the validity of our findings, we examine the impact of attainment redesignations, which occur when a county successfully achieves compliance with the NAAQS and transitions from nonattainment to attainment status. Since nonattainment exposure prompts the board to reduce risk-taking incentives, we anticipate that attainment redesignations, which indicate a relaxation in regulatory stringency, will have the opposite effect and increase risk-taking incentives. Using a similar DiD model with continuous treatment to measure a firm's attainment redesignation exposure, we find that the board increases the convexity of compensation payoffs in response to attainment redesignations, further highlighting their active role in aligning CEO incentives with the firm's risk-taking objectives.

In the next set of analyses, we explore cross-sectional tests to gain a deeper understanding of the heterogeneity in the negative treatment effect of nonattainment exposure on vega. Since not all firms face uniform regulatory conditions when exposed to nonattainment designations, we anticipate that the board will respond by reducing risk-taking incentives to a greater extent for firms subject to more intense regulation. Additionally, certain firms may have higher operating risk, making them more susceptible to the adverse cash flow shocks associated with nonattainment exposure, prompting the board to curtail risk-taking incentives even more for these firms. Using various proxies to measure differences in regulation intensity and operating risk, we find that nonattainment exposure results in a more pronounced decrease in risk-taking incentives for firms with higher regulation intensity or operating risk.

To further establish the channel of causation, we examine how financial constraints affect the relationship between nonattainment exposure and risk-taking incentives. In financially distressed firms, shareholders are aware that the firm's equity value will decrease due to the negative cash flow shock resulting from nonattainment exposure. As a result, they may be inclined to engage in riskier projects to gamble for favorable outcomes that could potentially raise the value of their shares. Therefore, we expect a firm's level of financial constraints to influence how the board adjusts the incentive compensation of managers in response to nonattainment exposure. Using proxies of financial constraints from the existing literature, we find that financially constrained firms experience a comparatively smaller decrease in risk-taking incentives when exposed to nonattainment designations relative to unconstrained firms. Furthermore, we observe that for the most financially distressed firms, exposure to nonattainment designations actually leads to an increase in risk-taking incentives. Overall, these findings support the notion that shareholders of financially distressed firms engage in "gambling for resurrection" by taking on additional risks in the hope of achieving positive outcomes (Admati, Demarzo, Hellwig, & Pfleiderer, 2018; White, 1989).

In our final analysis, we investigate how a firm's corporate governance environment interacts with nonattainment exposure to shape CEO incentive compensation dynamics. Our findings reveal that firms with greater CEO entrenchment, characterized by more anti-takeover provisions and higher CEO influence over the board, experience a smaller decline in risk-taking incentives when faced with nonattainment exposure. This suggests that CEO entrenchment impedes the board's ability to effectively align risk preferences between shareholders and managers. Additionally, we examine the role of institutional investors in monitoring corporate governance practices. Consistent with prior research highlighting the stronger governance mechanisms in firms with long-term investors (Derrien, Kecskés, & Thesmar, 2013; Harford, Kecskés, & Mansi, 2018), our analysis reveals that the presence of long-term investors enables the board to make more significant downward adjustments to vega in response to nonattainment exposure.

In terms of CEO bargaining power, our results demonstrate that firms with more powerful CEOs experience a weaker reduction in risk-taking incentives when exposed to nonattainment designations. This finding underscores the challenge faced by the board in modifying incentive compensation when CEOs have significant influence, which can create agency problems (Bebchuk, Cremers, & Peyer, 2011). Lastly, we examine the impact of CEO overconfidence and observe that in firms with overconfident CEOs, the board responds to nonattainment designations by further reducing risk-taking incentives. This observation is consistent with the board's attempt to mitigate the excessive risk-taking behavior commonly associated with overconfident CEOs, as they tend to overestimate investment returns (Malmendier, Tate, & Yan, 2011).

Our research contributes to the understanding of how environmental regulations impact on the corporate governance of firms through CEO incentive compensation. Deng and Gao (2013) and Banerjee, Humphery-Jenner, Nanda, and Zhang (2022) show that companies located in polluted areas tend to provide higher compensation to their CEOs. Levine, Lin, and Wang (2020) document that local pollution can lead to executive departures. Tian (2023) finds that, in response to environmental spills, neighboring firms adjust their executive compensation structures by shifting towards stock options and away from cash. We extend this literature by shifting the focus from pollution itself to pollution *regulation*. While previous research has explored the consequences of external pollution on executive compensation contracts, our analysis examines the interaction between pollution regulation and a firm's own polluting behavior, and how this interaction influences CEO incentive compensation. Moreover, we go beyond examining the level of compensation and delve into the risk-taking incentives provided to managers through the convexity of their compensation payoffs, which have significant implications for corporate investment policies.

Our research also contributes to the literature on how different firm conditions affect performance-based compensation. Gormley et al. (2013) document that firms decrease the convexity of new equity grants following a shock to liability risk. Hayes et al. (2012) find that firms reduce their usage of stock options in response to increased accounting costs. Chen et al. (2022) demonstrate that firms convexify compensation payoffs when CEOs face restricted outside job opportunities. De Angelis et al. (2017) find that the removal of short-selling constraints causes firms to increase the convexity of compensation payoffs. By leveraging the NAAQS as a natural experiment, our study offers a unique opportunity to explore the effects of pollution regulation on the design of managerial incentive contracts, which highlights the potentially unintended consequences of environmental regulation as changes in risk-taking incentives are likely to influence managers' decision-making beyond mere compliance with the regulation itself.

Lastly, our study contributes to the ongoing debate on how corporate governance influences the ability of firms operating in different environments to adjust executive compensation. Hoi, Wu, and Zhang (2019) find that social capital plays a role in mitigating agency problems by curbing managerial rent extraction in CEO compensation. Dai, Rau, Stouraitis, and Tan (2020) demonstrate that CEO power increases the CEO's capacity to earn compensation premiums in response to negative shocks related to nonmonetary factors impacting their quality of life. Humphery-Jenner, Lisic, Nanda, and Silveri (2016) show that firms offer incentive-heavy compensation contracts to overconfident CEOs to exploit their positively biased views of firm prospects. In our study, we utilize changes in the application of environmental regulations as a mechanism to identify shifts in conditions where theory provides a range of predictions regarding how they will alter the dynamics between shareholders and managers and reshape the governance structure.

2. Institutional background and identification strategy

In this section, we discuss the regulatory framework that forms the basis of our identification strategy. The CAA requires the EPA to set NAAQS for six pollutants: carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, particulate matter, and lead. We focus on ozone because counties most often fail to meet the NAAQS by exceeding ozone limits, rather than by violating the NAAQS for the other pollutants (Curtis, 2020). As a result, ozone offers a much larger treatment group of counties for our analyses.[2]

The centerpiece of the NAAQS regulation is that each year, the EPA designates each county either as being in attainment or out of attainment (nonattainment) with the NAAQS threshold. These designations are federally mandated and rely on daily and hourly readings from ozone monitoring stations across the United States. To assess compliance, the EPA calculates an annual county-level summary statistic using monitor readings across the county, known as a "design value" (DV). Counties with DVs above the threshold for a given standard are considered to be nonattainment with the standard, while counties with DVs below the threshold are in attainment. During our sample period from 1993 to 2019, the EPA successively implemented four different ozone standards, which are detailed in Internet Appendix Table IA.1.

When a county is designated nonattainment, the EPA requires the state to submit and adopt regulatory plans, known as a SIP (state implementation plan), which outlines how the state will bring nonattainment counties back into compliance with the NAAQS. While SIPs may vary from state to state, they must follow EPA's guidelines and be approved by the EPA. Failure to submit and execute an acceptable SIP can result in federal sanctions, including withholding federal grants, penalties, and construction bans on new polluting establishments. The SIP is federally-enforced and legally binding for *all* firms that operate polluting plants in the nonattainment county regardless of, for example, whether the firm has a record of good environmental performance prior to the designation (Greenstone, 2002).

Environmental regulations under the SIP in nonattainment counties are intended to be stringent and involve regulatory actions to curb emissions. Large pollution sources are required to satisfy the standard of "lowest achievable emission rate" (LAER), which involve the installation of the cleanest available technology, regardless of economic costs. In attainment counties, plants face significantly less stringent environmental standards relative to those in nonattainment counties. Polluting plants are subject to the installation of the "best available control technology" (BACT), whereby the EPA considers the technology's economic burden on the plant as the foremost priority in determining an acceptable emissions technology. Using plant-level survey data, Becker (2005) finds that BACT is significantly less costly to plants than LAER technology.

Beyond capital expenditures such as LAER and BACT, SIPs also require states to develop

[2]Another advantage with focusing only on ozone is that the NAAQS specifies only one primary standard for ozone, while there exists both a primary and secondary standard for other pollutants such as particulate matter. The existence of only one standard for ozone allows us to precisely identify treatment and control groups.

plant-specific regulations for every major pollution source in nonattainment counties. These plant-specific regulations usually come in the form of emission limits, such as requirements to use materials and alter operating and maintenance procedures in ways that reduce emissions (Becker & Henderson, 2000), and thus impose more costly regulatory burdens on plants operating in nonattainment counties. Becker and Henderson (2001) find that total operating costs are, on average, 17% higher in polluting plants from nonattainment areas relative to similar plants in attainment areas. Moreover, any additional emissions from one pollution source must be offset by paying another source in the same county to reduce its emissions (Nelson, Tietenberg, & Donihue, 1993). Shapiro and Walker (2020) show that expenditures on these emission offsets are one of the largest environmental expenditures for polluting plants in nonattainment areas. In addition to abatement compliance costs, plants also face more persistent inspections and oversight in nonattainment counties.

2.1. Nonattainment designations as an identification strategy

We exploit nonattainment designations as an exogenous shock to a firm's exposure to environmental regulations as a means of identification to investigate how a change in regulatory stringency affects CEOs' risk-taking incentives. Due to the way the NAAQS is implemented, there are three sources of variation in which plants are affected by nonattainment designations.

First, only counties with DVs that violate the NAAQS threshold are designated nonattainment. Thus, at any point in time, there is geographic cross-sectional variation in regulatory stringency across counties. Second, temporal variation in regulatory stringency exists from counties that go in (and out of) nonattainment based on annual changes in DVs.[3] Consequently, plants might be subject to nonattainment designations in one year but not in a different one. This longitudinal variation means that any time-invariant unobservables unique to firms may be controlled for by including a set of firm fixed effects. The inclusion of firm fixed effects ensures that estimates are derived only from those observations that experience a change in regulatory stringency, allowing for pre and post comparisons of the outcome variable. Internet Appendix Figure IA.1 illustrates these two sources of variation by showing each county's designation status in 2004.

Finally, within any nonattainment county, a polluting plant is regulated only if it emits ozone. This intracounty variation implies that regulatory stringency can differ across plants within nonattainment counties because not all plants emit ozone. Internet Appendix Figure IA.2

[3] Nonattainment designations are fairly persistent; the mean duration of nonattainment for the sample of counties that we study is around 16 years.

shows the fraction of plants that are labeled as ozone emitters across major industries in nonattainment counties. Even within two-digit industry NAICS codes, there is a considerable amount of variation in the fraction of plants that are classified as ozone polluters. Taken together, these sources of variation allow us to construct a time-varying continuous treatment variable that measures a firm's nonattainment exposure in any given year. We employ a DiD methodology in a panel regression setting to gauge the effect of the continuous treatment on CEO risk-taking incentive outcome variables. The construction of the treatment variable and the DiD regression estimator will be formally described in Sections 3.2 and 4, respectively.

Although nonattainment designations are typically treated as exogenous events because of their federally mandated nature (Greenstone, 2002; Walker, 2013), a potential concern is that local pollution levels may not be randomly assigned, implying that time series variation in nonattainment designations may be correlated with local economic activity. For example, counties that switch to nonattainment may also have more underlying economic activities. This potential endogeneity implies that some nonattainment designations may be anticipated in advance. Borochin, Celik, Tian, and Whited (2022) show that estimated market reactions in event studies may be biased downwards due to event anticipation. To address this issue, we exploit the regulatory design of DVs in a RDD to decompose nonattainment designations into an exogenous ("unexpected") and endogenous ("anticipated") component. We discuss this procedure in more detail in Section 4.1.

3. Data and variables

We examine the relation between nonattainment exposure and CEO incentive compensation over the sample period 1993 to 2019. We obtain compensation data from ExecuComp and merge these data with the Center for Research in Securities Prices (CRSP) and Compustat datasets to obtain financial and accounting variables. Following the literature (Coles et al., 2006), financial firms [standard industrial classification (SIC) codes between 6000 and 6999] and utility firms (SIC codes between 4900 and 4999) are excluded. We require all firms to have non-negative sales and total assets, and non-missing equity compensation data. We also exclude firm-years with stock prices less than \$5.

Firms' plant-level ozone pollution data comes from the EPA's TRI database. The TRI data file contains information on the disposal and release of over 650 toxic chemicals from more than 50,000 plants in the U.S. since 1987. Industrial facilities that fall within a specific industry (e.g., manufacturing, waste management, mining, etc), have ten or more full time employees, and handle amounts of toxic chemicals above specified thresholds must submit detailed annual reports on their releases of toxins to the TRI. The TRI provides self-reported toxic emissions at the plant-level along with identifying information about the facility such as the plant's name, county of location, industry, and parent company's name.[4] We use the emissions data in TRI to classify whether a facility is a polluter of ozone.[5] In any given year, a facility is labeled as an ozone-emitting plant if it emits chemicals that are classified as volatile organic compounds or nitrogen oxides, both precursors to ozone formation.[6] Although the TRI data provides information on chemical emissions through the ground, air and water, we only consider emissions through the air (measured in pounds) because the NAAQS only regulates air emissions.

Each county's designation status is collected by manually searching the Federal Register annually. Furthermore, we obtain monitor-level ozone concentrations from the Air Quality System (AQS) database maintained by the EPA. For each ozone monitor, the database includes ozone concentration readings and the county location of the monitor. We use these ozone concentrations to calculate DVs, which are the statistics that the EPA uses to determine whether a county is in compliance with the NAAQS. The rules that we use to calculate the DVs for different ozone standards as well as the relevant thresholds are given in Table IA.1 of the Internet Appendix.

After merging the aforementioned data, our final sample consists of 2,765 unique US publicly listed firms containing 31,202 firm-year observations. However, the sample sizes decrease when we require additional data for supplementary analyses.

3.1. Compensation variables

To measure the convexity of compensation payoffs, we follow the existing literature (Coles et al., 2006; Guay, 1999) and compute the sensitivity of CEO wealth to stock return volatility (vega) as follows. *Vega* measures the dollar change in the value of the CEO's portfolio of current option grants and accumulated option holdings for a 0.01 increase in the annualized standard deviation of a firm's stock returns (Core & Guay, 2002).[7] Since managers can adjust their accumulated holdings to interact with new compensation changes, we also compute the vega of managers' *current* year compensation of option grants (*Flow vega*). Both *Vega* and

[4]While the TRI data are self-reported, the EPA regularly conducts quality analyses to identify potential errors and purposefully misreporting emissions can lead to criminal or civil penalties (Xu & Kim, 2022).

[5]We use the mapping from TRI chemicals to CAA criteria pollutants from Greenstone (2003). However, additional chemicals have been introduced into the TRI since the creation of the mapping. Thus, we contacted the EPA and also hired a Ph.D. chemist in atmospheric science to classify the remaining chemicals.

[6]Ozone is not directly emitted by plants, but rather formed through chemical reactions in the atmosphere. Henceforth, we refer to emitters of ozone precursors as ozone emitters.

[7]Following Coles et al. (2006), we assume that vega of stock holdings is zero.

Flow vega are stated in thousands of dollars and are winsorized at the 99th percentile.

We construct variables to measure changes in the composition of a CEO's portfolio of option holdings. *Number of options granted* is the number of options granted to the CEO in the current year multiplied by one thousand (for ease of interpretation) divided by shares outstanding (Hayes et al., 2012). *Value of options exercised* is the dollar (in thousands) value of options exercised by the CEO in the current year (Gormley et al., 2013). *Number of options exercised* is the number of options exercised by the CEO in the current year multiplied by one thousand (for ease of interpretation) divided by shares outstanding (Chen et al., 2022).

We employ several variables to capture information about the structure of CEO compensation (Humphery-Jenner et al., 2016). *Total pay* is the logarithm of one plus the CEO's total compensation (in thousands), consisting of salary, bonuses, value of restricted stocks granted, value of options granted, long-term incentive awards, and other types of compensation. *Option intensity* is the proportion of total annual CEO compensation that comes from option grants. *Salary intensity*, *Bonus intensity*, and *Cash intensity* are the proportion of total annual CEO compensation that comes from salary, bonuses, and the sum of salary and bonuses, respectively.

3.2. Measure of nonattainment exposure

To capture the fact that a firm can operate many plants located across multiple counties, we construct a firm-level measure of nonattainment exposure based on the geographic distribution of a firm's plants across counties and the amount of ozone emissions at each plant. Formally, we define

$$NA\ exposure_{i,t} = \ln\left(1 + \sum_{j} ozone_{j,i,t-1} \cdot NA_{j,i,t}\right), \tag{1}$$

where j denotes plant, i denotes firm, and t denotes year. $ozone_{j,i,t-1}$ is the total amount of ozone air emissions for plant j of firm i in year $t-1$ and $NA_{j,i,t}$ is a dummy variable equal to one if plant j of firm i is located in a nonattainment county in year t, and zero otherwise. *NA exposure* can be interpreted as a measure of a firm's time-varying exposure to nonattainment designations. For example, a multi-plant firm that operates many heavy ozone-emitting plants in nonattainment counties will have a higher value of *NA exposure*, indicating that the firm is more exposed to nonattainment designations.

We highlight three noteworthy points for the above definition. First, we lag plant ozone emissions by one year because the specific timing of the release of the TRI data implies that emissions data for a given year only becomes available the following year (Hsu et al., 2022). Second, by weighting the nonattainment dummy by a plant's total amount of ozone emissions, this measure captures the fact that the intensity of regulation for a given plant in a nonattainment county is proportional to the intensity of its ozone emissions in that county. For example, a plant that does not emit any ozone in a nonattainment county is unaffected by the regulation. Third, we use the *amount* of ozone emissions as opposed to ozone emission intensity (i.e., ozone emissions per unit of production) since the EPA imposes emission limits in nonattainment counties based on the actual amount of ozone emissions.[8]

4. Research design

We examine the impact of nonattainment exposure on CEO incentive compensation using a DiD specification with continuous treatment (Acemoglu, Autor, & Lyle, 2004; Bertrand & Mullainathan, 2003). Specifically, we estimate the following firm-year panel regression:

$$Vega_{i,t} = \beta_0 + \beta_1 NA\ \ exposure_{i,t} + \beta_2 X_{i,t-1} + \tau_i + \rho_t + \varepsilon_{i,t} \tag{2}$$

where i denotes firm and t denotes year. The dependent variable, *Vega*, captures the risk-inducing incentives provided by CEOs' compensation. Treatment in this setting is measured by the continuous variable *NA exposure*. For example, in the years where a firm operates ozone-emitting plants in only attainment counties or only non-ozone-emitting plants in nonattainment counties, this variable takes on a value of 0. However, for the firm-years where the firm operates an ozone-emitting plant in a nonattainment county, this variable will change from 0 to a positive value that captures the intensity of treatment. Firms that do not own any polluting plants will by definition have a nonattainment exposure of 0; these observations serve as the never-treated units.

Our baseline specification uses standard two-way fixed effects based on firm and year. Firm fixed effects (τ_i) ensure that we estimate the impact of nonattainment exposure after controlling for any time-invariant firm-specific factors. Year fixed effects (ρ_t) control for any secular time trends. Since our sample period covers four different ozone standard cohorts, we also estimate a more stringent specification that allows firm and year fixed effects to vary by ozone standard cohort by using firm × cohort and year × cohort fixed effects. Gormley and Matsa (2014) show that this approach is more conservative than including two-way fixed effects, which helps to further strengthen identification. The standard errors are clustered at the firm level. The main coefficient of interest is β_1, which is the coefficient of the DiD estimate

[8] Our results are robust to various alternative definitions of *NA exposure*. See Section 5.8.3 for more details.

for the causal effect of nonattainment exposure on CEOs' risk-taking incentives through their compensation package.

We include a vector of variables, $X_{i,t-1}$, to control for factors that may affect risk-inducing incentives provided to CEOs following prior research (Core & Guay, 1999; Guay, 1999). At the CEO level, we control for age, tenure, and ownership. At the firm level, we control for size, book-to-market ratio, return on assets, leverage, cash, sales growth, stock return, and stock return volatility. Table A.1 in Appendix A describes the control variables in detail.

4.1. Decomposition of nonattainment exposure

Since a county's monitored ozone pollution levels are observable, the board may anticipate a county's nonattainment status and adjust compensation packages in advance. In the case of event anticipation, our continuous treatment variable, *NA exposure*, may not be a fully exogenous measure of a firm's nonattainment exposure (Borochin et al., 2022). To isolate the component of *NA exposure* that is potentially predictable, we decompose nonattainment designations into an anticipated component and an unexpected component based on county-level DVs. The intuition is that counties with a DV far above the NAAQS threshold will most likely remain in nonattainment, while those with a DV far below the threshold will most likely remain in attainment. The question then becomes how far above or below the NAAQS threshold can one reasonably predict a county's designation status.

The idea underlying our approach is that nonattainment designations are essentially a random outcome in an arbitrarily small interval around the NAAQS threshold; for example, whether a county is in compliance with a DV slightly below the NAAQS threshold or in violation with a DV slightly above the threshold is arguably random. To operationalize this, we use a RDD to exploit the sharp increase in nonattainment probability when a county's DV violates the threshold to estimate an optimal "bandwidth" that determines the region where ozone concentrations are as good as randomly assigned, and hence, unpredictable. For the sake of brevity, the full details of the RDD specification along with tests that support the identifying assumptions and the estimation results are presented in Section IA of the Internet Appendix.

We summarize the decomposition procedure in Figure 1, which plots a county's probability of nonattainment conditional on the distance of its DV from the threshold. As expected, the probability of nonattainment appears to be a continuous and smooth function of the centered DVs everywhere except at the NAAQS threshold, where there is a discontinuous jump upwards. The two dashed vertical lines on either side of the discontinuity represent the optimal bandwidth estimate. The region within the bounds of the optimal bandwidth is the unpredictable region; changes in the probability of nonattainment are attributable to random fluctuations in the underlying DVs and hence unpredictable. Thus, we define any county that belongs to the unpredictable region and is subsequently designated as nonattainment as an "unexpected" nonattainment. The region to the right of the optimal bandwidth is defined as the predicted nonattainment region. Any county that resides in this region and is subsequently designated as nonattainment is defined as an "anticipated" nonattainment.

The above decomposition allows us to measure a firm's exposure to unexpected and anticipated nonattainment designations, respectively, as follows:

$$Unexp.\ NA\ exposure_{i,t} = \ln\left(1 + \sum_j ozone_{j,i,t-1} \cdot Unexp.\ NA_{j,i,t}\right), \tag{3}$$

$$Antic.\ NA\ exposure_{i,t} = \ln\left(1 + \sum_j ozone_{j,i,t-1} \cdot Antic.\ NA_{j,i,t}\right), \tag{4}$$

where $Unexp.\ NA_{j,i,t}$ ($Antic.\ NA_{j,i,t}$) is a dummy variable equal to one if plant j of firm i is located in an unexpected (anticipated) nonattainment county in year t, and zero otherwise. All other variables are defined as in Equation (1). A higher value of *Unexp. NA exposure* (*Antic. NA exposure*) indicates that the firm has a greater exposure to unexpected (anticipated) nonattainment designations. We also estimate a similar DiD as Equation (2), except we decompose *NA exposure* into its unexpected and anticipated components as follows:

$$Vega_{i,t} = \beta_0 + \beta_1 Unexp.\ NA\ exposure_{i,t} + \beta_2 Antic.\ NA\ exposure_{i,t} + \beta_3 X_{i,t-1} + \tau_i + \rho_t + \varepsilon_{i,t}. \tag{5}$$

The main coefficient of interest is β_1, which is the coefficient of the DiD estimate of the causal effects driven by the exogenous component of nonattainment exposure.

5. Results

5.1. Descriptive statistics

Table 1 presents summary statistics for the key variables used in our analyses. The average vega, computed based on a CEO's total portfolio of option holdings, is \$126.69 thousand, while the average vega based on current year option holdings is smaller (\$22.30 thousand). On average, total compensation amounts to \$2.83 million, with option grants and cash awards representing 25.7% and 40.4% of total compensation, respectively. CEOs, on average, have an age of 55.63 years, a tenure of 4.86 years, and an ownership stake of 2.4%. These sample statistics align with prior studies (Hayes et al., 2012; Humphery-Jenner et al., 2016).

Among the 31,202 firm-year observations, approximately 28% belong to the treated group. Within this group, the average *NA exposure* is 8.556, with a standard deviation of 3.581, indicating substantial variation in firms' exposure to nonattainment designations, even among treated firms. Comparing the mean and median of *Unexp. NA exposure (Treated group)* and *Antic. NA exposure (Treated group)*, we find that the average treated firm has a higher exposure to unexpected nonattainment designations compared to anticipated nonattainment designations. This result suggests that the firms in our sample primarily experience exogenous, rather than predictable, nonattainment designations.

5.2. Effect of nonattainment exposure on CEO incentive compensation

Table 2 presents the results from estimating Equation (2). If the board seeks to curb risk-taking incentives to mitigate the negative cash flow shocks of nonattainment designations, then we should observe a decrease in vega as the firm's nonattainment exposure increases. Column (1) includes *NA exposure* as the only independent variable. The estimated coefficient on *NA exposure* is -3.609 and is significant at the 1% level, indicating a decrease in the convexity of compensation payoffs following an increase in firms' nonattainment exposure. The decline in vega remains robust even after controlling for CEO and firm characteristics (column (3)) and including firm-cohort and year-cohort fixed effects (column (5)).[9] In terms of economic magnitude, a one standard deviation increase in *NA exposure* decreases vega by roughly 8.81% to 14.71% relative to the sample mean.

To account for the potentially predictable component of nonattainment designations, we present the results obtained from estimating Equation (5) in columns (2), (4), and (6) of Table 2. Across all specifications, the coefficients on *Unexp. NA exposure* are negative and statistically significant, indicating a decrease in the convexity of compensation payoffs. However, the coefficients on *Antic. NA exposure* are statistically insignificant and smaller in magnitude. These results suggest that the observed decrease in the convexity of compensation payoffs is primarily driven by the exogenous component of nonattainment designations, rather than the component that is potentially predictable.

5.2.1. Dynamic effects

Our identification strategy is based on the parallel trends assumption, which posits that both treated and control firms should exhibit similar trends in vega prior to nonattainment

[9] The signs of the estimated coefficients on the control variables are largely consistent with the existing literature (Core & Guay, 1999; Guay, 1999; Hayes et al., 2012).

exposure. Ideally, we expect the effect of *NA exposure* to manifest only after the nonattainment designation and not before. To test for the absence of pre-trends, we estimate a dynamic version of Equation (5), focusing on the four years preceding and following nonattainment exposure. As our treatment variable is continuous, we follow the approach employed in previous studies (Fuest, Peichl, & Siegloch, 2018; Smith, Yagan, Zidar, & Zwick, 2019) to estimate the dynamic treatment effects based on the intensity of treatment as follows:

$$Vega_{i,t} = \sum_{\substack{\ell=-4 \\ \ell\neq-1}}^{\ell=+4} \gamma_\ell \textit{Unexp. NA intensity}^{\ell}_{i,t} + \sum_{\substack{\ell=-4 \\ \ell\neq-1}}^{\ell=+4} \lambda_\ell \textit{Antic. NA intensity}^{\ell}_{i,t} + \beta X_{i,t-1} + \tau_i + \rho_t + \varepsilon_{i,t} \tag{6}$$

where

$$\textit{Unexp. NA intensity}^{\ell}_{i,t} = \begin{cases} \sum_{s=-\infty}^{\ell} \Delta \textit{Unexp. NA exposure}_{i,t-s}, & \text{if } \ell = -4 \\ \Delta \textit{Unexp. NA exposure}_{i,t-\ell}, & \text{if } -4 < \ell < +4 \\ \sum_{s=\ell}^{\infty} \Delta \textit{Unexp. NA exposure}_{i,t-s}, & \text{if } \ell = +4 \end{cases} \tag{7}$$

and *Antic. NA intensity*$^{\ell}_{i,t}$ is defined similarly.[10] All other variables are defined as in Equation (5).

Equation (6) is a generalization of Equation (5) that allows for the effects of *Unexp. NA exposure* and *Antic. NA exposure* to evolve incrementally over time for the four years before and after the nonattainment designation. The dynamic effects, denoted as γ_ℓ and λ_ℓ, provide event-study style regression estimates that capture the varying trend of vega for firms exposed to unexpected and anticipated nonattainment designations, respectively. These effects reflect the changes in vega over time, both before and after the nonattainment designation. We define the year prior to the nonattainment designation as the reference period, denoted by year $\ell = -1$. This choice allows us to express all dynamic effects relative to this reference year. To identify the dynamic effects during the event window, we bin the endpoints ($\ell = -4, +4$) according to Equation (7).

Figure 2 shows the dynamic effects from estimating Equation (6). There is no indication of any significant changes in vega prior to firms' exposure to either unexpected or anticipated nonattainment designations. This finding supports our assumption that there are no differential responses before nonattainment designations. In the periods following the nonattainment

[10] Here, $\Delta Y_{i,t} = Y_{i,t} - Y_{i,t-1}$.

designation, CEOs' vega shows a decrease for firms exposed to unexpected nonattainment designations. This decrease begins in the year of the designation and continues to remain lower thereafter. In contrast, CEOs' vega for firms with anticipated nonattainment exposure remains unchanged throughout the post-treatment periods. Additionally, the 95% confidence intervals of γ_ℓ and λ_ℓ do not overlap, except for $\ell = +3$. Overall, the results indicate that firms' exposure to unexpected nonattainment designations leads to a decrease in the convexity of compensation payoffs.

5.3. Mechanism

In this section, we investigate the source of the decrease in the convexity of compensation payoffs in response to nonattainment exposure by studying the structure of new option grants and CEOs' compensation structure.

5.3.1. Effect of nonattainment exposure on the structure of new option grants

There are two primary ways in which a CEO's vega can change: changes initiated by the board and changes initiated by the manager. First, the board has the ability to alter new option grants given to managers. While both current option grants and the CEO's accumulated option holdings provide risk-taking incentives, the current grants specifically represent the portion of compensation that falls directly under the board's control. Second, vega can change for reasons that are beyond the board's influence. This occurs when managers make adjustments to their existing portfolios, exercising vested options to interact with the compensation incentives provided by the board. To better understand the mechanism through which nonattainment exposure changes vega, we explore whether the decrease in vega is driven by new option grants and/or option exercises during the year.

We replace the dependent variable in Equation (2) with *Flow vega* and present the results in column (1) of Table 3. The findings reveal that nonattainment exposure leads to a decrease in vega stemming from new option grants. Column (2) demonstrates that this decrease is driven by exposure to unexpected nonattainment designations rather than anticipated ones. Economically, a one standard deviation increase in *Unexp. NA exposure* reduces *Flow vega* by 6.27% relative to the sample mean, while a one standard deviation increase in *Antic. NA exposure* only reduces *Flow vega* by 1.17%. Notably, this difference in economic magnitude is statistically significant as we reject the null hypothesis of equality between the coefficients on *Unexp. NA exposure* and *Antic. NA exposure* (F-statistic = 4.50, p-value = 0.03).

Moving to columns (3) and (4) of Table 3, we focus on *Number of options granted*. Consistent with the results on *Flow vega*, we find evidence that the number of options granted to the CEO relative to shares outstanding decreases significantly in response to nonattainment exposure. Once again, we observe that the economic impact of *Unexp. NA exposure* on the *Number of options granted* is larger than that of *Antic. NA exposure*, as we reject the null hypothesis of equality between the coefficients on *Unexp. NA exposure* and *Antic. NA exposure* (F-statistic = 4.73, p-value = 0.03). In the remaining columns, we examine the effect of nonattainment exposure on *Value of options exercised* and *Number of options exercised.* We find no evidence that nonattainment exposure impacts option exercises by the CEO. Overall, the results are consistent with the board actively managing CEOs' risk-taking incentives in response to nonattainment exposure, while providing no support for the CEO changing option exercise behavior.

5.3.2. Effect of nonattainment exposure on CEO compensation structure

In light of the findings thus far, which indicate that the board plays a crucial role in determining the manager's compensation package to address risk-taking incentives, we acknowledge the possibility that managers themselves may engage in negotiations with the board to modify their compensation arrangement in response to the adverse cash flow shocks associated with nonattainment designations. Specifically, managers might opt to shift their compensation mix away from options and towards more stable forms such as cash. We explore this possibility in Table 4. Columns (1) and (2) show that nonattainment exposure has no impact on total CEO compensation. Subsequently, in the remaining columns, we further investigate the effect of nonattainment exposure on the individual components of CEO compensation.

The results in columns (3) and (4) of Table 4 confirm and support the earlier findings regarding the structure of new option grants. Specifically, we observe a significant reduction in the value of option awards relative to the total compensation of CEOs in response to (unexpected) nonattainment exposure. However, the evidence regarding managers' substitution away from options towards cash compensation is mixed. In particular, columns (5) and (6) indicate that nonattainment exposure does not have a significant impact on base salaries, while columns (7) and (8) show that bonuses increase in response to nonattainment exposure. When considering salaries and bonuses together (columns (9) and (10)), nonattainment exposure does not have a significant overall impact. In summary, our findings suggest that the board takes the lead in selecting compensation packages to manage the risk-taking incentives of CEOs, rather than managers modifying their compensation arrangements in response to nonattainment exposure.

5.4. *Redesignation to attainment*

Our analysis has so far focused on the implications of nonattainment designations for risk-taking incentives. However, once a county successfully achieves compliance with the NAAQS, it undergoes a redesignation back to attainment status, signifying a decrease in regulatory constraints. If nonattainment exposure prompts the board to reduce risk-taking incentives in response to negative cash flow shocks, then we expect attainment redesignations to have the opposite effect. Specifically, firms with greater exposure to attainment redesignations are expected to increase the convexity of compensation payoffs. To test this hypothesis, we create a comparable measure of attainment redesignation exposure as follows:

$$Redesig\ exposure_{i,t} = \ln\left(1 + \sum_{j} ozone_{j,i,t-1} \cdot Redesig_{j,i,t}\right), \tag{8}$$

where j denotes plant, i denotes firm, and t denotes year. $ozone_{j,i,t-1}$ is the total amount of ozone air emissions for plant j of firm i in year $t-1$ and $Redesig_{j,i,t}$ is a dummy variable equal to one if plant j of firm i is located in a county that has been redesignated to attainment in year t, and zero otherwise.

To investigate the impact of attainment redesignations on incentive compensation, we employ a similar DiD framework as presented in Equation (2), using *Redesig exposure* as the continuous treatment variable. The estimation equation is as follows:

$$Vega_{i,t} = \beta_0 + \beta_1 Redesig\ exposure_{i,t} + \beta_2 X_{i,t-1} + \tau_i + \rho_t + \varepsilon_{i,t}. \tag{9}$$

In this context, the treated units refer to firms that experience at least one redesignation event at an operating ozone-emitting plant during the sample period. To ensure a clean control sample, we exclude firms that operate exclusively in attainment counties or in nonattainment counties that have never undergone redesignation. As indicated in Table 1, out of the total 26,419 firm-year observations, approximately 7.77% of these observations belong to the treated group.

The estimation results are presented in Table 5. Across all specifications, we observe a positive and statistically significant coefficient on *Redesig exposure*, suggesting that the board offers higher risk-taking incentives to the CEO when the firm is exposed to attainment redesignations. In economic terms, a one standard deviation increase in *Redesig exposure* corresponds to an approximate increase in vega ranging from 4.72% to 9.81% relative to the sample mean. Additionally, the findings in Internet Appendix Table IA.9 further support these results, showing that exposure to attainment redesignations also leads to an increase in *Flow vega*, *Number of options granted*, and *Option intensity*. Overall, the analysis of attainment redesignations presents a contrasting pattern compared to the nonattainment analysis. It reveals the board's adaptive behavior in adjusting CEO compensation packages based on the regulatory context, with a reduction in risk-taking incentives during nonattainment periods and an increase in risk-taking incentives during attainment redesignations.

5.5. Cross-sectional analyses

In this section, we examine cross-sectional predictions examining whether variation in regulation intensity and firms' operating risk alters the effect of nonattainment exposure on CEO incentive compensation. Not all firms are subject to the same level of regulatory scrutiny when exposed to nonattainment designations. Thus, we expect that the board will respond by reducing risk-taking incentives even more for firms subjected to stricter regulations. Additionally, we anticipate that firms with higher operating risk will be more significantly affected by the negative cash flow shocks associated with nonattainment exposure, leading the board to further curtail risk-taking incentives for these firms. Our empirical specification expands Equation (5) by introducing interaction terms between *Unexp. NA exposure* and *Antic. NA exposure* with a variable *Z*, which captures the cross-sectional variable of interest.

5.5.1. Regulation intensity

We utilize three proxies to capture variations in regulatory intensity when firms are exposed to nonattainment designations. First, we consider the proximity of an ozone-emitting plant to the nearest ozone air quality monitor. In nonattainment counties, firms operating ozone-emitting plants located closer to monitors face more intense regulations compared to those located farther away, as regulatory efforts are concentrated in the vicinity of the monitors (Auffhammer, Bento, & Lowe, 2009; Bento, Freedman, & Lang, 2015; Gibson, 2019). Given the higher regulatory costs incurred by such firms, we anticipate that their boards would significantly reduce risk-taking incentives in response to nonattainment exposure. Following the existing literature, we define a dummy variable, *Close monitor*, equal to one if a firm operates ozone-emitting plants within one mile of an ozone air quality monitor in a nonattainment county, and zero otherwise. In column (1) of Table 6, we observe results consistent with our expectations, as the negative effect of unexpected nonattainment exposure on vega is more pronounced for firms with ozone-emitting plants located closer to air monitors.

Second, we differentiate between young and old plants as another proxy for regulatory intensity. Becker and Henderson (2000) observe that newer plants bear the brunt of nonattainment regulations due to expensive LAER requirements, while older plants are grandfathered and escape regulation until they expand operations.[11] Specifically, Becker and Henderson (2001) estimate that compliance costs are higher for young ozone-emitting plants between zero and five years of age in nonattainment counties compared to similar plants in attainment counties. Following their definition, we define *Young plant* as a dummy variable equal to one if a firm operates ozone-emitting plants that are between zero and five years of age in nonattainment counties, and zero otherwise.[12] Column (2) of Table 6 reveals a significant negative coefficient for the interaction term *Unexp. NA exposure* × *Young plant*. This result indicates that firms operating young ozone-emitting plants exhibit a greater reduction in vega when faced with unexpected nonattainment exposure.

Lastly, we assess the degree to which a plant's economic activity relies on ozone emissions by employing the ozone production ratio obtained from the TRI. The ozone production ratio measures the change in output associated with the release of ozone chemicals in a given year (Akey & Appel, 2021), allowing us to gauge the significance of ozone emissions in a plant's production process.[13] We expect that plants operating in nonattainment counties will face stricter regulation if ozone emissions are integral to their economic output. To capture this relationship, we introduce the variable *Production ratio*, which is a dummy variable equal to one if the average ozone production ratio across all plants in nonattainment counties for a firm exceeds the sample median, and zero otherwise. In column (3) of Table 6, we observe that firms operating plants with a higher dependence on ozone emissions for production experience a significant reduction in vega in response to unexpected nonattainment exposure, indicating that the board adjusts risk-taking incentives more prominently for these firms.

[11] While younger plants may benefit from certain cost savings in terms of NPV due to a slower equipment renewal rate compared to older plants, they also face immediate costs associated with nonattainment designations. Older plants may already have implemented LAER measures, thus avoiding additional capital expenditures. In contrast, younger plants may need to invest in implementing these control measures. Similarly, older plants may have established maintenance procedures to reduce emissions, while younger plants may not have implemented such procedures yet. These factors contribute to the higher immediate compliance costs faced by younger plants when subjected to nonattainment regulations.

[12] The first year a plant appears in the TRI database is not necessarily its first year of operation, since a plant only reports to TRI if it meets the reporting requirements. Thus, to compute the age of a given plant, we use the first year of operation of a given facility in the National Establishment Time-Series (NETS) database.

[13] For example, if a chemical is used in the manufacturing of refrigerators, the production ratio for year t is given by $\frac{\text{\#Refrigerators produced}_t}{\text{\#Refrigerators produced}_{t-1}}$. If the chemical is used as part of an activity and not directly in the production of goods, then the production ratio represents a change in the activity. For instance, if a chemical is used to clean molds, then the production ratio for year t is given by $\frac{\text{\#Molds cleaned}_t}{\text{\#Molds cleaned}_{t-1}}$.

5.5.2. Operating risk

We use four proxies to capture variations in firms' operating risk when they are exposed to nonattainment designations. The first proxy is the plant's minimum paydex score in a given year, obtained from NETS, which represents the facility's trade credit performance on a scale of 0 to 100. Higher paydex scores indicate greater ability to meet contractual repayment obligations. We expect that firms operating plants with lower paydex scores, indicating potential difficulties in meeting repayments, are more likely to be adversely affected by the negative cash flow shocks associated with nonattainment exposure. This suggests that reducing risk-taking incentives becomes even more crucial for these firms. We define *Low paydex* as a dummy variable equal to one if the average paydex score across all ozone-emitting plants in nonattainment counties for a firm is less than the sample median, and zero otherwise. Consistent with our expectations, the results in column (4) of Table 6 demonstrate that firms operating ozone-emitting plants with lower creditworthiness experience a pronounced reduction in vega in response to unexpected nonattainment exposure.

Next, we examine a measure of a firm's reputational risk exposure to media news of their CSR-related incidents. Specifically, we use the Reputational Risk Index (RRI) obtained from RepRisk, which is a data provider that screens over 80,000 media sources for CSR incidents. The RRI is a score ranging from 0 to 100, with higher values indicating a higher rate of CSR incidents. To capture the long-term CSR incident history of a firm, we focus on the "Peak RRI" score, which represents the maximum value of the RRI over a two-year period. Prior studies by Glossner (2021) and Yang (2021) demonstrate that a firm's past history of news-based CSR incidents is the best predictor of future incidents. Consequently, firms with a high RRI score, when exposed to the negative cash flow shocks resulting from nonattainment exposure, could potentially face an increase in their operating risk due to a higher occurrence of incidents. We define *High RRI* as a dummy variable equal to one if a firm's peak RRI is above 50, and zero otherwise.[14] Examining column (5) of Table 6, we observe that firms with a higher reputational risk exposure experience a more substantial reduction in vega in response to unexpected nonattainment exposure.

Finally, we consider two measures that capture a firm's history of regulatory noncompliance based on regulatory violations. The first measure is the facility's high priority violation (HPV) status, obtained from the EPA's ICIS-Air database. When a facility is classified as HPV, it

[14]The cutoff of 50 is chosen based on RepRisk's classification, where firms with an RRI above 50 are considered to have high risk exposure.

signifies serious or repeated violations that result in intense oversight by the EPA.[15] This heightened scrutiny can lead to higher fines and additional reporting requirements, thereby increasing the operating costs of the facility (Blundell, Gowrisankaran, & Langer, 2020). The second measure is the facility's enforcement cases, obtained from the EPA's FE&C database. Enforcement cases encompass both judicial and administrative actions initiated by the EPA against facilities that have violated environmental statutes. Such cases can be financially burdensome for firms due to potential legal penalties (Shive & Forster, 2020; Xu & Kim, 2022). Firms operating ozone-emitting plants in nonattainment counties that have either HPV status or enforcement cases face increased operating risk due to their history of regulatory noncompliance. Consequently, it is more likely for boards to reduce risk-taking incentives for such firms. We define *HPV* and *Enforcement* as dummy variables equal to one if a firm has experienced HPV status or an enforcement case, respectively, within the past three years among their ozone-emitting plants in nonattainment counties, and zero otherwise. Columns (6) and (7) of Table 6 indicate that firms with a history of regulatory noncompliance experience a greater decrease in vega when unexpected nonattainment designations occur.

5.6. Financial constraints

In this section, we investigate the impact of financial constraints on the relationship between nonattainment exposure and risk-taking incentives. We hypothesize that the board, acting in the best interests of shareholders, should adjust the incentive compensation of managers in response to nonattainment exposure based on the level of the firm's financial constraints. When firms face the negative cash flow shock resulting from nonattainment exposure, insider shareholders of financially distressed firms are aware that the firm's equity value will decrease as the constraints unveil. As shareholders are protected by limited liability, they may be incentivized to pursue riskier projects, as successful outcomes could lead to a recovery and an increase in the value of their shares (Jensen & Meckling, 1976). Therefore, if the board sets managers' incentive compensation to maximize shareholder value, risk-taking incentives may not be reduced as significantly for financially distressed firms or, in extreme cases, the board might even increase risk-taking incentives.

To assess whether shareholders in financially distressed firms engage in "gamble for resurrection" behavior in response to nonattainment exposure, we employ five measures of financial constraints. We utilize three widely used accounting-based measures: the Kaplan-

[15]HPVs cover a broad range of issues related to regulatory noncompliance, including excess emissions, failure to install required plant modifications, and violations of operating parameters, among others.

Zingales index (Kaplan & Zingales, 1997; Lamont, Polk, & Saá-Requejo, 2001), the Hadlock-Pierce index (Hadlock & Pierce, 2010), and the Whited-Wu index (Whited & Wu, 2006). However, since these accounting-based measures are often correlated with production levels, which influence emission volumes, we also incorporate a text-based measure of financial constraints developed by Hoberg and Maksimovic (2015). This index utilizes qualitative information extracted from corporate disclosure documents to capture financial constraints. Following Xu and Kim (2022), our analysis uses the debt-market text measure, which describes a firm's intention to issue debt to solve its liquidity problems. Finally, we employ the Campbell-Hilscher-Szilagyi index (Campbell, Hilscher, & Szilagyi, 2008), which is positively correlated with a firm's forecasted probability of failure and is calculated based on a 12-month-ahead financial failure model.

In Table 7, we include interactions between *Unexp. NA exposure* and *Antic. NA exposure* with the financial constraints measures (*FC index*). To facilitate interpretation, the financial constraints measures are normalized to start from zero, which allows us to interpret the coefficients on *Unexp. NA exposure* and *Antic. NA exposure* as the effects of unexpected and anticipated nonattainment exposure, respectively, on vega for firms with no financial constraints. Across all specifications, we observe a significant negative coefficient on *Unexp. NA exposure*, indicating that firms without financial constraints reduce risk-taking incentives in response to nonattainment exposure. However, the coefficient on the interaction term *Unexp. NA exposure* × *FC index* is positive and statistically significant. This implies that financially constrained firms exhibit a relatively smaller reduction in risk-taking incentives in response to unexpected nonattainment events compared to their unconstrained counterparts.

To gain a deeper understanding of how risk-taking incentives vary in response to nonattainment exposure based on financial constraints, we plot the marginal effects of *Unexp. NA exposure* on vega conditional on the level of financial constraints in Figure 3. The solid line represents the point estimates, while the dashed lines indicate the corresponding 95% confidence intervals. We divide the sample into quartiles based on each financial constraint index, denoted as Q1, Q2, and Q3. Across all panels, we find that the marginal effect of unexpected nonattainment exposure on risk-taking incentives increases with a firm's level of financial constraints. However, among firms in the top quartile, we observe some evidence of a reversal in the sign of the marginal effect from negative to positive. This suggests that the most financially distressed firms, when exposed to nonattainment events, actually increase risk-taking incentives, likely because they perceive they have very little to lose and are thus willing to take higher risks in hopes of a successful turnaround or "gamble for resurrection".

5.7. Governance structure

To provide insight into the more nuanced dynamics between nonattainment exposure and CEO incentive compensation, we investigate the influence of a firm's corporate governance on this relationship. First, we explore the impact of CEO entrenchment. Firms with entrenched CEOs are more likely to experience a misalignment of risk preferences between managers and shareholders due to agency problems (Core, Holthausen, & Larcker, 1999). As adjustments to decrease vega can be influenced by negotiations between the CEO and the board, firms with more entrenched CEOs may hinder the board's ability to effectively reduce risk-taking incentives in response to nonattainment exposure. We employ three measures to gauge CEO entrenchment. First, we utilize the *E-index* (Bebchuk, Cohen, & Ferrell, 2009), an index comprising six key anti-takeover provisions that indicates the degree of entrenchment, with higher values suggesting greater entrenchment. Second, following the approach of Adams, Almeida, and Ferreira (2005), we use a dummy variable equal to one if a firm's CEO also serves as the chairperson of the board in a given year, and zero otherwise (*CEO duality*). Lastly, we adopt the measure proposed by Coles, Daniel, and Naveen (2014), which is defined as the number of CEO appointed directors divided by the total number of board members for a firm in a given year (*Co-option*). Both *CEO duality* and *Co-option* capture the CEO's personal influence over the board. In columns (1) to (3) of Table 8, we include interactions between *Unexp. NA exposure* and *Antic. NA exposure* with the aforementioned measures of CEO entrenchment. Consistent with our expectations, the results indicate that firms with higher CEO entrenchment exhibit a smaller decrease in risk-taking incentives in response to nonattainment exposure. This finding suggests that when the board's monitoring effectiveness is compromised by entrenched managers, the ability to adjust vega is more limited.

Next, we examine the monitoring role of institutional investors. We differentiate between long-term and short-term institutional investors because not all institutional investors are equally effective as monitors. Long-term institutional investors typically play a significant role in corporate governance and monitoring due to their substantial ownership stakes and longer investment horizons (Derrien et al., 2013; Harford et al., 2018). We anticipate that firms with a higher proportion of long-term investors will have stronger corporate governance mechanisms in place, enabling the board to make more substantial downward adjustments to vega in response to nonattainment exposure. To classify institutional investors, we adopt the framework proposed by Bushee and Noe (2000), which considers portfolio turnover rates and portfolio diversification, resulting in three categories: dedicated investors, transient investors, and quasi indexers. To assess the influence of long-term and short-term investors, we measure the fraction of a firm's shares held by dedicated (*IO DED*) and transient (*IO TRA*) institutional investors, respectively. The findings presented in columns (4) and (5) of Table 8 reveal that the coefficient on the interaction term *Unexp. NA exposure* × *IO DED* is negative, indicating that the presence of long-term investors corresponds to a more pronounced decrease in vega. Conversely, the coefficient on the interaction term *Unexp. NA exposure* × *IO TRA* is positive, suggesting that firms with a higher proportion of short-term investors experience a less significant reduction in vega.

We proceed to examine the influence of CEOs' bargaining power on the board's adjustments to risk-taking incentives. Previous studies have highlighted that CEOs with greater bargaining power often have more influence over corporate policies, including the design of compensation packages, due to agency problems (Bebchuk et al., 2011). If CEOs with higher bargaining power make it more difficult for the board to modify incentive compensation, we would expect to observe a less pronounced decrease in risk-taking incentives in response to nonattainment exposure for such firms. To capture CEOs' bargaining power, we employ two commonly used measures following Bebchuk et al. (2011): the ratio of total CEO compensation to the highest compensation earned by any other executive in the firm (*Pay slice 1*), and the CEO's total compensation scaled by the sum of the total compensation of the top-three highest remunerated non-CEO executives (*Pay slice 3*). Consistent with our expectations, the results presented in columns (6) and (7) of Table 8 indicate that an increase in CEO bargaining power is associated with a significantly less pronounced decrease in vega in response to nonattainment exposure.

Finally, we explore how the board adjusts risk-taking incentives when dealing with overconfident CEOs. Overconfident CEOs tend to overestimate investment returns and underestimate risks (Malmendier & Tate, 2005, 2008). In the presence of overconfident CEOs, firms may opt to further constrain risk-taking incentives to mitigate the negative impact of nonattainment exposure on cash flows and to curb excessive risk-taking behavior. To measure CEO overconfidence, we employ two commonly used measures based on existing literature: a continuous measure called *Confidence*, which captures the extent to which the CEO's vested stock options are in-the-money (Banerjee, Humphery-Jenner, & Nanda, 2015), and a binary measure called *Holder67*, which equals one if the CEO fails to exercise options with five years remaining duration despite a 67% or higher increase in stock price since the grant date, and zero otherwise

(Malmendier et al., 2011). Consistent with our expectations, columns (8) and (9) of Table 8 demonstrate that the board indeed adjusts risk-taking incentives downward even more when faced with overconfident CEOs.

5.8. Robustness of main analysis

5.8.1. Propensity score matching

One possible concern is that firm-year observations with non-zero nonattainment exposure ("treated') may not be directly comparable to those with no exposure ("control") because they differ on some dimensions. We use propensity score matching to account for systematic differences between treated and control observations. The propensity score, $\widehat{p}$, is generated by estimating a logistic regression model, where the dependent variable is a dummy variable equal to one if the firm-year observation belongs to the treated group, and zero otherwise. The independent variables include all variables specified in the baseline model described in Equation (2). Using the propensity scores, each treated observation is matched with a control observation using one-to-one nearest neighbor matching with replacement (Roberts & Whited, 2013). This matching procedure ensures that treated and control observations have similar propensity scores, accounting for systematic differences between the two groups. To assess the effectiveness of the matching procedure, Internet Appendix Table IA.4 shows that there are no observable differences between treated and control observations after the matching.

Using the matched sample, we re-estimate Equations (2) and (5), and the results are reported in columns (1) and (2) of Table 9 respectively. In these columns, we examine the effect of nonattainment exposure on vega by comparing firm-year observations with non-zero nonattainment exposure to observations with comparable propensity scores but without actual exposure. The results demonstrate that our main findings remain consistent in the matched sample, indicating that an increase in firms' nonattainment exposure leads to a decrease in the convexity of compensation payoffs.

Instead of discarding non-matched observations, an alternative approach is to incorporate all observations using a weighted least squares procedure. This method assigns weights that are inversely proportional to the probability of an observation being a treated or control unit. Specifically, we follow the procedure in Caliendo and Kopeinig (2008), whereby firm-year observations in the treated group receive a weight of $1/\widehat{p}$, while those in the control group receive a weight of $1/(1-\widehat{p})$. Intuitively, propensity score weighting assigns a lower weight to treated observations, which are "very different" (in terms of CEO and firm characteristics) from control observations and similarly, gives a lower weight to control observations, which are "very different" from treated bank observations. The results are presented in columns (3) and (4) of Table 9. As before, the analysis demonstrates that nonattainment exposure has a negative impact on vega. Overall, the results in this section suggest that the relationship between nonattainment exposure and vega is unlikely to be driven by selection bias.

5.8.2. Heterogeneous treatment effects

In order to address the potential bias arising from treatment effect heterogeneity and negative weights in two-way fixed effects regressions, we follow the approach proposed by de Chaisemartin and D'Haultfoeuille (2020, 2022). First, we estimate the weights attached to the two-way fixed effects regressions in our analysis and find that only a small percentage (2.8%) of the weights are negative, with the sum of these weights being -0.0009. This indicates that negative weights are not a significant concern in our study.

To address treatment effect heterogeneity, we employ the DiD estimator developed by de Chaisemartin and D'Haultfoeuille (2020, 2022). Since their estimator is most suitable for binary treatments, we dichotomize our continuous treatment variable.[16] Specifically, we define the variable *NA exposed* as a dummy variable equal to one for firm-year observations with non-zero nonattainment exposure, and zero otherwise. Similarly, we define the variables *Unexp. NA exposed* and *Antic. NA exposed* as dummy variables equal to one for firm-year observations with non-zero exposure to unexpected and anticipated nonattainment designations, respectively, and zero otherwise.[17] The results, presented in Table 10, show that our inferences continue to hold even after controlling for treatment effect heterogeneity.[18] Furthermore, none of the individual placebo estimators exhibit statistical significance, and we fail to reject the null hypothesis that all placebo estimators are equal to zero. Hence, it appears that there are no observable pre-trends in the four years leading up to the nonattainment exposure.

5.8.3. Alternative measures of nonattainment exposure

We employ various alternative definitions of our nonattainment exposure measure to address specific considerations. First, we consider the possibility of multi-plant firms reallocating

[16] Although the estimator developed by de Chaisemartin and D'Haultfoeuille (2020, 2022) can handle treatment effect heterogeneity for continuous treatments, it is not well-suited when the continuous treatment variable, such as *NA exposure*, can take on a large number of values.

[17] Note that we can only include the unexpected or anticipated nonattainment treatment one at a time due to the setup of the de Chaisemartin and D'Haultfoeuille (2020, 2022) estimator.

[18] The economic magnitude of the estimated effects are larger in this analysis compared to the baseline model, as we are now examining a discrete change in nonattainment exposure rather than a change in the intensity of the continuous treatment variable.

production (and hence, emissions) from nonattainment counties to attainment counties. To address this concern, we calculate an alternative measure by dividing ozone emissions by the total number of ozone-emitting plants owned by the firm when defining *NA exposure*. This adjustment recognizes that a multi-plant firm with the same ozone emissions in nonattainment counties as a single-plant firm would have lower nonattainment exposure due to its ability to redistribute emissions.[19] Another concern in our main analysis is that *NA exposure* may not reflect the relative importance of a firm's different polluting plants. For example, it may be more costly if polluting plants that generate the majority of sales for a given firm are located in nonattainment counties. We conduct robustness checks by constructing measures of nonattainment exposure based on plant-level sales and employee data from NETS. In these alternative measures, we weight each plant's ozone emissions by their corresponding sales share or employee share.

Considering the varying toxicity levels of different chemicals, we incorporate the inherent heterogeneity by multiplying the mass of each chemical by its toxicity, derived from the EPA's Risk-Screening Environmental Indicator model. Given our focus on air emissions, we follow the approach of Gamper-Rabindran (2006) and utilize the inhalation toxicity weight. Consequently, we redefine *NA exposure* by incorporating toxicity-weighted ozone emissions. To address concerns regarding reporting errors in the TRI data, we narrow our focus to core ozone chemicals. Core chemical groups consist of chemicals that remained consistent in the TRI list throughout our sample period, ensuring uniform reporting requirements across all reporting years. Moreover, routine inspections and audits are more likely to ensure accurate reporting for the core chemical groups. Thus, we redefine *NA exposure* by considering only ozone emissions from core chemicals. Lastly, some ozone chemicals can only be emitted if the plant possesses operating permits issued by the EPA. To account for this, we redefine *NA exposure* by considering ozone emissions specified in operating permits. Our main results remain robust when employing all of these alternative measures of nonattainment exposure, as demonstrated in Internet Appendix Table IA.5.

5.8.4. Placebo tests

Since nonattainment designations regulate the onsite ozone emissions of facilities, firms that produce offsite ozone emissions or non-ozone chemicals such as particulate matter should

[19] In practice, given that firms need time to make the necessary investments to shift production, it may be difficult for firms to strategically time their investments to expand into attainment counties. Additionally, the benefits from the less stringent regulations in attainment counties may be offset by the costs of sacrificing local supply chains and local customers in nonattainment counties, which may make reallocation less appealing.

not be affected by nonattainment regulation. Consequently, we can define placebo treatment variables by substituting ozone emissions with offsite ozone emissions or particulate matter emissions in the definition of *NA exposure*. If the board reduces risk-taking incentives in response to actual regulatory exposure, the use of placebo treatment variables should have no impact on vega. Our expectations are supported by the findings in Internet Appendix Table IA.6, which indicate no effect of placebo treatment variables on vega.

5.8.5. Alternative measures of CEO incentive compensation

To account for potential skewness in vega, we use the natural log transformation of one plus vega as the dependent variable. Results presented in columns (1) and (2) of Internet Appendix Table IA.7 show that our main results remain intact. We also consider the use of fixed-effects Poisson models, as suggested by recent literature (Cohn, Liu, & Wardlaw, 2022), which can mitigate biases associated with regressions of the log of one plus the outcome. Estimating a Poisson version with vega as the dependent variable, we find that our results are qualitatively robust, as shown in columns (3) and (4). Lastly, following De Angelis et al. (2017), we utilize the ratio of vega to delta as the dependent variable.[20] This measure captures the trade-off between risk and return that managers face when considering project decisions. Specifically, high vega compensation may encourage a manager to accept a risky negative NPV project, while high delta compensation could counterbalance this effect by motivating the manager to reject such a project. The scaling of vega by delta captures this offsetting relationship. Our results, presented in columns (5) and (6), confirm the robustness of our findings when using this scaling.

5.8.6. Treatment sample only

To ensure that our main results are not driven by changes in CEOs' incentive compensation for firms in the control sample, we conduct the analysis using treated firm-year observations only. In this setting, firm-year observations that experience a change in the intensity of nonattainment exposure later in the sample period are considered as "controls" for those that experience a change earlier in the sample period. Results presented in Internet Appendix Table IA.8 show that nonattainment exposure leads to a decrease in vega even among treated observations. This finding indicates that the baseline effect we document is not reliant on the control group and that the treatment effect arises from the exposed firms.

[20]Delta measures the dollar (in thousands) change in the value of the CEO's portfolio of current option and stock grants and accumulated option and stock holdings for a 1% change in the stock price.

6. Conclusion

Our study examines the impact of environmental regulations and their interaction with firms' polluting behavior on the risk-taking incentives provided to CEOs through their incentive compensation. Using a DiD approach, we exploit nonattainment designations under the NAAQS as an exogenous source of regulatory stringency that negatively affects firms' cash flows. We find that firms exposed to nonattainment designations experience a decrease in the convexity of their compensation payoff. Our evidence is consistent with the board actively adjusting the structure of CEOs' compensation to reduce risk-taking incentives given the decline in shareholders' desired investment when facing regulatory exposure.

Further analysis reveals that the changes in compensation structure are initiated by the board through adjustments in new option grants, rather than managers altering their option exercise behavior or substituting options for cash. Additionally, we strengthen our findings by examining the effects of attainment redesignations, which represent a relaxation in regulatory stringency. In these cases, we observe an opposite behavior from boards as they increase the convexity of compensation payoffs, suggesting a reversal in risk-taking incentives. Our cross-sectional analyses utilizing nonattainment designations reveal that boards reduce risk-taking incentives to an even greater extent for firms facing more intense regulations or exhibiting higher operating risk. Financial constraints also play a crucial role in moderating the relationship between nonattainment exposure and risk-taking incentives. Particularly, financially distressed firms tend to encourage more risk-taking in an attempt to pursue potentially positive outcomes. Finally, we investigate the impact of various aspects of a firm's existing corporate governance structure on CEO incentive compensation dynamics. Factors such as CEO entrenchment, institutional investors, CEOs' bargaining power, and CEOs' overconfidence all interact with nonattainment exposure, shaping the overall risk-taking incentives for CEOs.

Our findings provide strong evidence that environmental regulations have a significant impact on the design of CEOs' incentive compensation. By adjusting the compensation structure, boards aim to align the risk-taking behavior of CEOs with the changing preferences of shareholders in the face of regulatory challenges. This highlights the importance of considering the interplay between environmental regulations, firm behavior, and CEO incentives in corporate governance practices.

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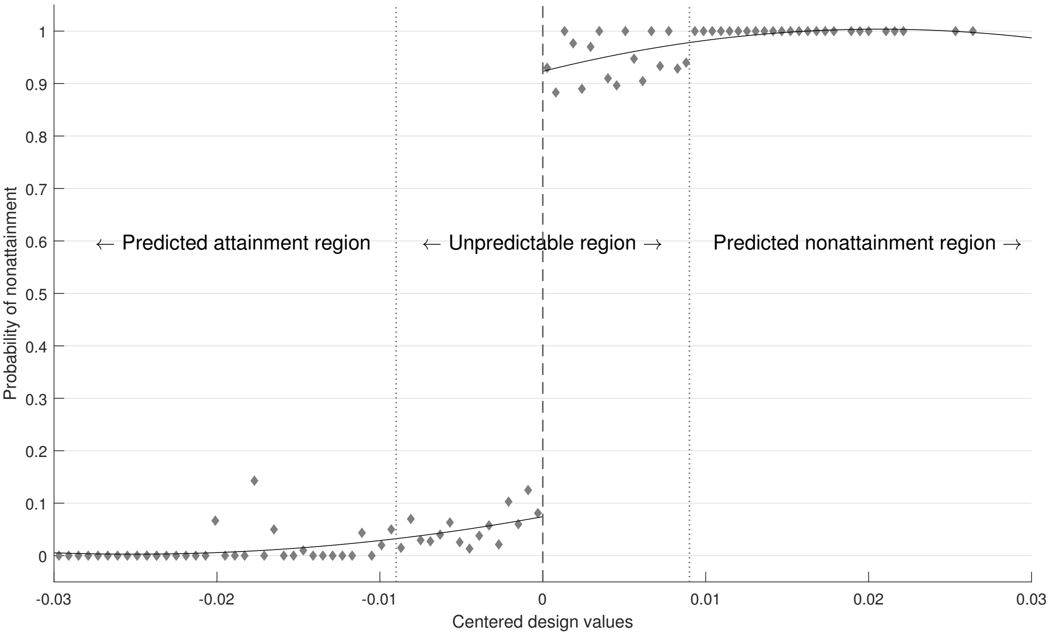
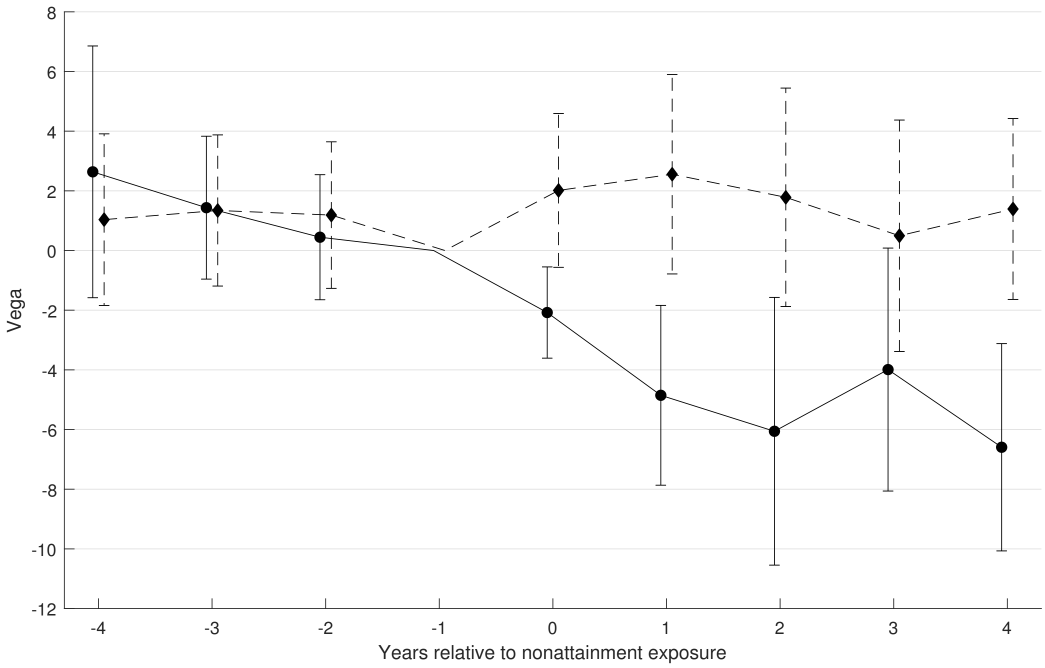
Figure 1
Probability of nonattainment around ozone NAAQS thresholds.



This figure presents the regression discontinuity relating centered DVs to the probability of nonattainment. The regression discontinuity is estimated from a local linear regression specification using the mean squared error optimal bandwidth with rectangular kernels following Calonico, Cattaneo, and Titiunik (2014). Further details are provided in Section IA of the Internet Appendix. The vertical axis shows the probability of nonattainment. The horizontal axis shows the centered DVs around zero by subtracting the NAAQS threshold from the DVs. The dashed vertical line at zero represents the NAAQS threshold for ozone nonattainment status. Observations on the right (left) of the line indicate that the county is in violation of (compliance with) the NAAQS threshold. Each dot in the figure represents the average of $NA_{c,t+1}$, defined as a dummy variable equal to one if county c is designated nonattainment in year $t + 1$, using integrated mean squared error optimal bins following Calonico et al. (2014). The solid lines on either side of the NAAQS threshold is based on two separate regressions of $NA_{c,t+1}$ on local quartic polynomials in centered DVs. The unpredictable region refers to the narrow region surrounding the NAAQS threshold, which is bounded by the mean squared error optimal bandwidth. The predicted nonattainment region refers to the region to the right of the optimal bandwidth. The predicted attainment region refers to the region to the left of the optimal bandwidth.

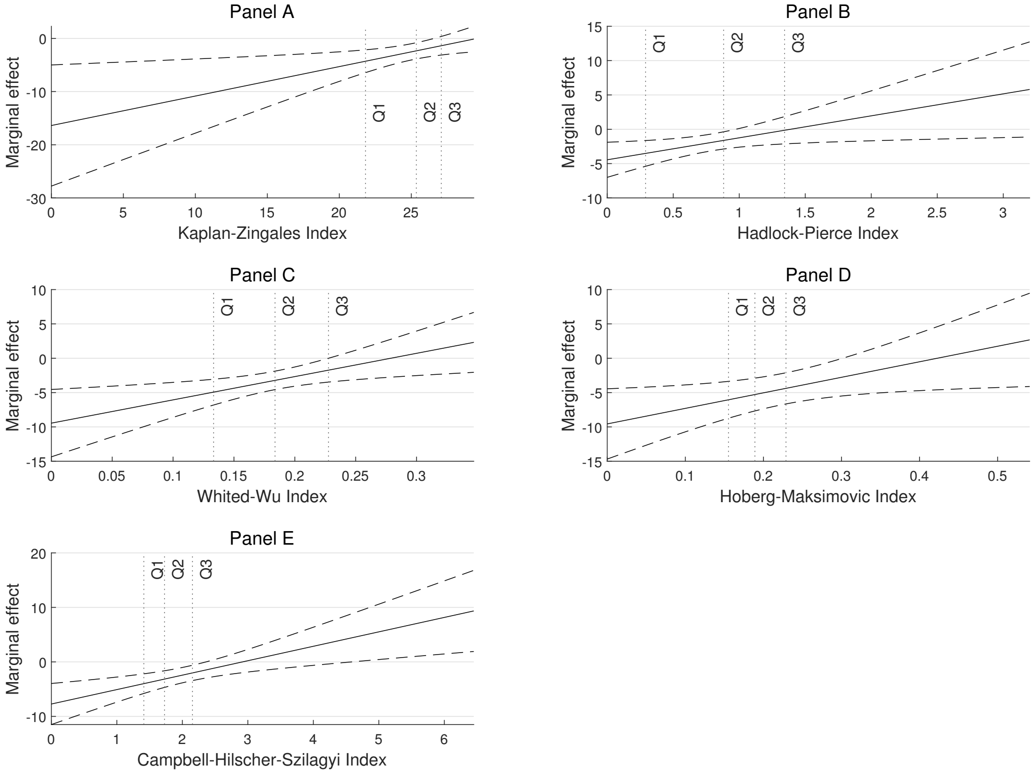
Figure 2
Dynamic effects of nonattainment exposure on CEO incentive compensation.



This figure plots the event study estimates and corresponding 95% confidence intervals according to the specification in Equation (6). The sample period is fiscal year 1993 to 2019. We focus on a window of four years before to four years after the nonattainment exposure. Event year $t = -1$ is the omitted category, implying that all coefficient estimates are relative to this year. The dependent variable, *Vega*, measures the dollar (in thousands) change in the value of the CEO's portfolio of current option grants and accumulated option holdings for a 0.01 increase in the annualized standard deviation of a firm's stock returns. The solid and dashed lines represent the dynamic effects of unexpected and anticipated nonattainment exposure on *Vega*, respectively.

Figure 3

Marginal effects of nonattainment exposure on CEO incentive compensation conditional on financial constraints.



This figure plots the marginal effects of unexpected nonattainment exposure on CEO portfolio vega conditional on financial constraints. Panels A, B, C, D, and E plot the estimates of the marginal effects and corresponding 95% confidence intervals for the Kaplan-Zingales, Hadlock-Pierce, Whited-Wu, Hoberg-Maksimovic, and Campbell-Hilscher-Szilagyi indices, respectively, based on the regression results in Table 7. Note that each index is normalized so that it begins from zero. The dashed vertical lines split the sample into quartiles based on the financial constraints index.

Table 1
Summary statistics.

Variables	N	Mean	Median	Std. dev.	P25	P75
CEO compensation						
Vega	31,202	126.688	42.018	296.057	10.577	125.194
Flow vega	31,195	22.303	5.447	36.843	0.000	26.414
Number of options granted	30,331	1.648	0.664	2.670	0.000	2.140
Value of options exercised	30,329	1498.270	0.000	4059.690	0.000	797.424
Number of options exercised	30,329	0.864	0.000	2.012	0.000	0.657
Total pay	31,202	7.948	7.983	1.104	7.195	8.711
Option intensity	30,975	0.257	0.190	0.275	0.000	0.446
Cash intensity	30,975	0.512	0.467	0.274	0.298	0.711
CEO characteristics						
CEO age	30,985	55.625	56.000	7.446	51.000	60.000
CEO tenure	29,143	1.769	1.792	0.877	1.099	2.398
CEO ownership	30,427	0.024	0.004	0.056	0.001	0.015
Firm characteristics						
NA exposure	31,202	1.065	0.000	3.094	0.000	0.000
Unexp. NA exposure	31,202	0.835	0.000	2.743	0.000	0.000
Antic. NA exposure	31,202	0.512	0.000	2.196	0.000	0.000
NA exposure (Treated group)	8,770	8.556	9.388	3.581	6.472	11.081
Unexp. NA exposure (Treated group)	8,770	6.709	8.074	4.586	1.792	10.345
Antic. NA exposure (Treated group)	8,770	4.116	0.000	4.891	0.000	9.228
Redesig exposure	26,419	0.658	0.000	2.464	0.000	0.000
Redesig exposure (Treated group)	2,054	8.461	9.251	3.472	6.486	10.902
Firm size	31,202	7.278	7.133	1.591	6.132	8.285
Book-to-market	31,202	0.606	0.595	0.257	0.414	0.783
ROA	31,154	0.144	0.140	0.101	0.097	0.191
Leverage	31,195	0.211	0.201	0.171	0.051	0.327
Cash	31,197	0.153	0.086	0.171	0.027	0.221
Sales growth	31,179	0.168	0.086	2.085	0.008	0.199
Stock return	31,120	0.212	0.118	0.695	-0.115	0.380
Stock volatility	31,111	0.111	0.097	0.062	0.070	0.135

This table reports summary statistics over the sample period from fiscal year 1993 to 2019. Std. dev. displays the standard deviation, P25 the first and P75 the third quartile of the respective variable. Variable definitions are presented in Table A.1 in Appendix A.

Table 2
The effect of nonattainment exposure on CEO incentive compensation.

Dep. variable: *Vega*	(1)	(2)	(3)	(4)	(5)	(6)
NA exposure	-3.609***		-6.024***		-4.316***	
	(-3.70)		(-3.83)		(-3.36)	
Unexp. NA exposure		-3.495**		-5.319***		-3.876***
		(-2.50)		(-3.60)		(-3.05)
Antic. NA exposure		-2.253		-3.140		-1.662
		(-1.31)		(-1.33)		(-0.93)
CEO age			-0.867	-0.861	-1.254***	-1.246***
			(-1.13)	(-1.12)	(-2.71)	(-2.69)
CEO tenure			29.879***	29.952***	33.856***	33.907***
			(6.55)	(6.56)	(12.49)	(12.51)
CEO ownership			-36.933	-37.995	93.759	93.498
			(-0.31)	(-0.32)	(1.18)	(1.18)
Firm size			78.529***	78.409***	65.114***	64.956***
			(7.11)	(7.09)	(12.28)	(12.21)
Book-to-market			-91.181***	-90.914***	-103.920***	-103.576***
			(-5.60)	(-5.58)	(-10.59)	(-10.57)
ROA			20.358	20.131	23.280	23.073
			(0.58)	(0.58)	(1.26)	(1.25)
Leverage			-56.638*	-56.425*	-80.062***	-80.090***
			(-1.87)	(-1.86)	(-5.66)	(-5.64)
Cash			-1.843	-1.695	6.108	5.925
			(-0.05)	(-0.04)	(0.35)	(0.34)
Sales growth			-0.138	-0.138	-0.100	-0.098
			(-1.08)	(-1.08)	(-0.85)	(-0.84)
Stock return			-9.211***	-9.187***	-10.029***	-10.026***
			(-3.39)	(-3.38)	(-4.39)	(-4.39)
Stock volatility			-63.668	-64.812	-19.060	-19.166
			(-1.61)	(-1.64)	(-0.76)	(-0.76)
Firm F.E.	Yes	Yes	Yes	Yes	No	No
Year F.E.	Yes	Yes	Yes	Yes	No	No
Firm × Cohort F.E.	No	No	No	No	Yes	Yes
Year × Cohort F.E.	No	No	No	No	Yes	Yes
Observations	31,089	31,089	28,054	28,054	26,888	26,888
Adj R^2	0.47	0.47	0.50	0.50	0.65	0.65

This table reports coefficients from fixed effects panel regressions of CEO portfolio vega on nonattainment exposure. The sample period is fiscal year 1993 to 2019. The dependent variable, *Vega*, measures the dollar (in thousands) change in the value of the CEO's portfolio of current option grants and accumulated option holdings for a 0.01 increase in the annualized standard deviation of a firm's stock returns. *NA exposure* measures a firm's time-varying exposure to nonattainment designations based on the geographic distribution of its plants across nonattainment counties and the amount of ozone emissions at each plant. *Unexp. NA exposure* and *Antic. NA exposure* decompose a firm's exposure to nonattainment designations into an unexpected and anticipated component, respectively. The detailed definitions for *NA exposure*, *Unexp. NA exposure*, and *Antic. NA exposure* are given in Equations (1), (3), and (4), respectively. For all specifications, standard errors are robust to heteroskedasticity and clustered at the firm-level; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Table 3
The effect of nonattainment exposure on flow vega, options granted, and options exercised.

Dep. variable:	*Flow vega*		*Number of options granted*		*Value of options exercised*		*Number of options exercised*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NA exposure	-0.431***		-0.033***		12.647		0.005	
	(-3.21)		(-3.57)		(0.66)		(0.73)	
Unexp. NA exposure		-0.510***		-0.034***		3.280		0.005
		(-3.32)		(-3.85)		(0.16)		(0.66)
Antic. NA exposure		-0.119		-0.005		-3.252		-0.005
		(-0.84)		(-0.42)		(-0.11)		(-0.84)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	28,049	28,049	27,768	27,768	27,764	27,764	27,779	27,779
Adj R^2	0.46	0.46	0.28	0.28	0.23	0.23	0.19	0.19

This table reports results from firm and year fixed effects panel regressions describing changes in a CEO's portfolio of option holdings driven by nonattainment exposure. The sample period is fiscal year 1993 to 2019. The dependent variables are the dollar (in thousands) change in the value of the CEO's current option grants for a 0.01 increase in the annualized standard deviation of a firm's stock returns (*Flow vega*), the number of options granted to the CEO in the current year multiplied by one thousand divided by shares outstanding (*Number of options granted*), the dollar (in thousands) value of options exercised by the CEO in the current year (*Value of options exercised*), and the number of options exercised by the CEO in the current year multiplied by one thousand divided by shares outstanding (*Number of options exercised*). *NA exposure* measures a firm's time-varying exposure to nonattainment designations based on the geographic distribution of its plants across nonattainment counties and the amount of ozone emissions at each plant. *Unexp. NA exposure* and *Antic. NA exposure* decompose a firm's exposure to nonattainment designations into an unexpected and anticipated component, respectively. The detailed definitions for *NA exposure*, *Unexp. NA exposure*, and *Antic. NA exposure* are given in Equations (1), (3), and (4), respectively. Control variables include *CEO age*, *CEO tenure*, *CEO ownership*, *Firm size*, *Book-to-market*, *ROA*, *Leverage*, *Cash*, *Sales growth*, *Stock return*, and *Stock volatility.* For all specifications, standard errors are robust to heteroskedasticity and clustered at the firm-level; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Table 4
The effect of nonattainment exposure on CEO compensation structure.

Dep. variable:	*Total pay*		*Option intensity*		*Salary intensity*		*Bonus intensity*		*Cash intensity*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
NA exposure	0.001		-0.003**		-0.001		0.001**		0.000	
	(0.31)		(-2.31)		(-1.13)		(2.06)		(0.36)	
Unexp. NA exposure		0.001		-0.002**		-0.001		0.002***		0.001
		(0.25)		(-1.97)		(-1.37)		(3.16)		(0.73)
Antic. NA exposure		0.000		0.000		0.000		-0.000		0.000
		(0.14)		(0.08)		(0.36)		(-0.27)		(0.08)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	28,054	28,054	27,841	27,841	28,054	28,054	28,054	28,054	28,054	28,054
Adj R^2	0.68	0.68	0.41	0.41	0.48	0.48	0.46	0.46	0.50	0.50

This table reports coefficients from firm and year fixed effects panel regressions of the structure of CEO compensation on nonattainment exposure. The sample period is fiscal year 1993 to 2019. The dependent variables are the logarithm of one plus the CEO's total compensation (in thousands) (*Total pay*), the proportion of total annual CEO compensation that comes from option grants (*Option intensity*), and the proportion of total annual CEO compensation that comes from salary (*Salary intensity*), bonuses (*Bonus intensity*), and the sum of salary and bonuses (*Cash intensity*). *NA exposure* measures a firm's time-varying exposure to nonattainment designations based on the geographic distribution of its plants across nonattainment counties and the amount of ozone emissions at each plant. *Unexp. NA exposure* and *Antic. NA exposure* decompose a firm's exposure to nonattainment designations into an unexpected and anticipated component, respectively. The detailed definitions for *NA exposure*, *Unexp. NA exposure*, and *Antic. NA exposure* are given in Equations (1), (3), and (4), respectively. Control variables include *CEO age*, *CEO tenure*, *CEO ownership*, *Firm size*, *Book-to-market*, *ROA*, *Leverage*, *Cash*, *Sales growth*, *Stock return*, and *Stock volatility.* For all specifications, standard errors are robust to heteroskedasticity and clustered at the firm-level; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Table 5
The effect of attainment redesignation exposure on CEO incentive compensation.

Dep. variable: *Vega*	(1)	(2)	(3)	(4)
Redesig exposure	4.927***	5.045***	2.428***	2.837***
	(4.42)	(4.35)	(3.26)	(3.52)
Controls	No	Yes	No	Yes
Firm F.E.	Yes	Yes	No	No
Year F.E.	Yes	Yes	No	No
Firm × Cohort F.E.	No	No	Yes	Yes
Year × Cohort F.E.	No	No	Yes	Yes
Observations	26,061	23,617	25,020	22,589
Adj R^2	0.53	0.56	0.69	0.71

This table reports coefficients from fixed effects panel regressions of CEO portfolio vega on attainment redesignation exposure. The sample period is fiscal year 1993 to 2019. Treated units are those firms that experience at least one redesignation event at an operating plant during the sample period. We do not include firms that operate only in attainment counties or only in nonattainment counties that have never been redesignated. The dependent variable, *Vega*, measures the dollar (in thousands) change in the value of the CEO's portfolio of current option grants and accumulated option holdings for a 0.01 increase in the annualized standard deviation of a firm's stock returns. *Redesig exposure* measures a firm's time-varying exposure to attainment redesignations based on the geographic distribution of its plants across counties that have been redesignated and the amount of ozone emissions at each plant. The detailed definition for *Redesig exposure* is given in Equation (8). Control variables include *CEO age*, *CEO tenure*, *CEO ownership*, *Firm size*, *Book-to-market*, *ROA*, *Leverage*, *Cash*, *Sales growth*, *Stock return*, and *Stock volatility.* For all specifications, standard errors are robust to heteroskedasticity and clustered at the firm-level; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Table 6
Impact of regulation intensity and firms' operating risk on the relation between nonattainment exposure and CEO incentive compensation.

	Regulation intensity			Operating risk			
Dep. variable: *Vega*	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Z =	*Close monitor*	*Young plant*	*Production ratio*	*Low paydex*	*High RRI*	*HPV*	*Enforcement*
Unexp. NA exposure	-3.587***	-3.589***	-3.091***	-2.694***	-2.290**	-2.776**	-4.524***
	(-5.34)	(-4.82)	(-3.81)	(-3.02)	(-2.09)	(-2.08)	(-4.95)
Antic. NA exposure	-1.247	-1.123	0.671	-2.226	-0.371	-1.490	-2.514
	(-1.35)	(-1.12)	(0.64)	(-1.10)	(-0.14)	(-0.70)	(-1.27)
Z	46.151***	-2.309	8.396**	31.946**	-24.511	6.885	6.342
	(3.05)	(-0.32)	(2.11)	(2.07)	(-1.22)	(0.32)	(0.39)
Unexp. NA exposure × *Z*	-6.657***	-3.992***	-4.492***	-3.582**	-8.515**	-5.204**	-4.655**
	(-3.34)	(-2.61)	(-3.84)	(-1.98)	(-2.02)	(-2.48)	(-2.21)
Antic. NA exposure × *Z*	0.436	1.384	-0.859	-0.312	5.500	-0.653	3.699
	(0.22)	(1.17)	(-0.91)	(-0.16)	(0.86)	(-0.29)	(1.47)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	28,054	28,054	28,054	27,385	13,115	28,054	28,054
Adj R^2	0.57	0.57	0.57	0.49	0.68	0.65	0.50

This table contains models that analyze the impact of regulation intensity and firms' operating risk on the relation between nonattainment exposure and CEO portfolio vega. The sample period is fiscal year 1993 to 2019, except for column (6) where the sample period is fiscal year 2007 to 2019. The dependent variable, *Vega*, measures the dollar (in thousands) change in the value of the CEO's portfolio of current option grants and accumulated option holdings for a 0.01 increase in the annualized standard deviation of a firm's stock returns. The measures of regulation intensity are a dummy variable equal to one if a firm operates ozone-emitting plants located within one mile of an ozone air quality monitor in a nonattainment county, and zero otherwise (*Close monitor*), a dummy variable equal to one if a firm operates ozone-emitting plants that are between zero and five years of age in nonattainment counties, and zero otherwise (*Young plant*), and a dummy variable equal to one if the average ozone production ratio across all plants in nonattainment counties for a firm is greater than the sample median, and zero otherwise (*Production ratio*). The measures of operating risk are a dummy variable equal to one if the average paydex score across all ozone-emitting plants in nonattainment counties for a firm is less than the sample median, and zero otherwise (*Low paydex*), a dummy variable equal to one if a firm's peak RRI is above 50, and zero otherwise (*High RRI*), a dummy variable equal to one if a firm experiences a high priority violation in the past three years among ozone-emitting plants in nonattainment counties, and zero otherwise (*HPV*), and a dummy variable equal to one if a firm experiences a judicial or administrative enforcement case in the past three years among ozone-emitting plants in nonattainment counties, and zero otherwise (*Enforcement*). *NA exposure* measures a firm's time-varying exposure to nonattainment designations based on the geographic distribution of its plants across nonattainment counties and the amount of ozone emissions at each plant. *Unexp. NA exposure* and *Antic. NA exposure* decompose a firm's exposure to nonattainment designations into an unexpected and anticipated component, respectively. The detailed definitions for *NA exposure*, *Unexp. NA exposure*, and *Antic. NA exposure* are given in Equations (1), (3), and (4), respectively. Control variables include *CEO age*, *CEO tenure*, *CEO ownership*, *Firm size*, *Book-to-market*, *ROA*, *Leverage*, *Cash*, *Sales growth*, *Stock return*, and *Stock volatility.* For all specifications, standard errors are robust to heteroskedasticity and clustered at the firm-level; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Table 7
Impact of financial constraints on the relation between nonattainment exposure and CEO incentive compensation.

Dep. variable: *Vega*	(1)	(2)	(3)	(4)	(5)
FC index =	*KZ index*	*HP index*	*WW index*	*HM index*	*CHS index*
Unexp. NA exposure	-16.382***	-4.444***	-9.451***	-9.562***	-7.736***
	(-2.82)	(-3.41)	(-3.78)	(-3.66)	(-4.02)
Antic. NA exposure	1.350	-0.471	-3.041	-1.779	-3.255
	(0.34)	(-0.40)	(-1.03)	(-0.65)	(-1.40)
FC index	-0.079	-5.827	-23.210	-49.081***	2.386
	(-0.30)	(-0.86)	(-0.65)	(-2.56)	(1.47)
Unexp. NA exposure × *FC index*	0.554**	3.201**	33.897***	22.624**	2.649***
	(2.42)	(2.22)	(2.60)	(2.18)	(3.10)
Antic. NA exposure × *FC index*	-0.138	-0.879	0.302	2.762	0.866
	(-0.88)	(-0.64)	(0.02)	(0.24)	(0.80)
Controls	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes
Observations	23,364	26,612	26,106	16,208	23,121
Adj R^2	0.58	0.72	0.58	0.66	0.57

This table contains models that analyze the impact of firms' financial constraints on the relation between nonattainment exposure and CEO portfolio vega. The sample period is fiscal year 1993 to 2019, except for column (4) where the sample period is fiscal year 1997 to 2015. The dependent variable, *Vega*, measures the dollar (in thousands) change in the value of the CEO's portfolio of current option grants and accumulated option holdings for a 0.01 increase in the annualized standard deviation of a firm's stock returns. The measures of financial constraints are the Kaplan-Zingales (*KZ index*), Hadlock-Pierce (*HP index*), Whited-Wu (*WW index*), Hoberg-Maksimovic (*HM index*), and Campbell-Hilscher-Szilagyi (*CHS index*) indices. We normalize each index so that it begins from zero. *NA exposure* measures a firm's time-varying exposure to nonattainment designations based on the geographic distribution of its plants across nonattainment counties and the amount of ozone emissions at each plant. *Unexp. NA exposure* and *Antic. NA exposure* decompose a firm's exposure to nonattainment designations into an unexpected and anticipated component, respectively. The detailed definitions for *NA exposure*, *Unexp. NA exposure*, and *Antic. NA exposure* are given in Equations (1), (3), and (4), respectively. Control variables include *CEO age*, *CEO tenure*, *CEO ownership*, *Firm size*, *Book-to-market*, *ROA*, *Leverage*, *Cash*, *Sales growth*, *Stock return*, and *Stock volatility.* For all specifications, standard errors are robust to heteroskedasticity and clustered at the firm-level; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Table 8

Impact of corporate governance, bargaining power, and CEO type on the relation between nonattainment exposure and CEO incentive compensation.

	Corporate governance					Bargaining power		CEO type	
Dep. variable: *Vega*	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Z =	*E-index*	*CEO duality*	*Co-option*	*IO DED*	*IO TRA*	*Pay slice 1*	*Pay slice 3*	*Confidence*	*Holder67*
Unexp. NA exposure	-8.699***	-5.928***	-5.949***	-2.347***	-3.377**	-8.129***	-8.838***	-5.373***	-2.795**
	(-4.40)	(-5.19)	(-3.90)	(-2.73)	(-2.52)	(-6.15)	(-6.17)	(-4.29)	(-2.43)
Antic. NA exposure	-2.182	0.202	-2.950	-1.366	-6.080***	-2.431	-2.890	-1.591	-1.654
	(-0.79)	(0.14)	(-1.41)	(-1.34)	(-3.57)	(-0.97)	(-1.08)	(-0.88)	(-1.29)
Z	0.150	-6.762**	-23.643***	45.416***	-87.204***	5.557***	11.152***	-142.168***	-10.078**
	(0.07)	(-2.53)	(-3.30)	(3.49)	(-6.45)	(3.65)	(3.76)	(-10.94)	(-2.16)
Unexp. NA exposure × *Z*	1.255**	4.153***	7.457**	-15.537***	22.595***	1.567***	4.038***	-11.199***	-3.556**
	(2.54)	(3.66)	(1.97)	(-2.90)	(3.20)	(3.34)	(3.57)	(-2.90)	(-2.48)
Antic. NA exposure × *Z*	-0.214	-2.030	0.506	-0.368	7.399	-0.357	-0.227	-2.775	0.541
	(-0.26)	(-1.25)	(0.22)	(-0.08)	(1.40)	(-0.45)	(-0.11)	(-0.79)	(0.36)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	22,640	22,158	17,139	27,758	27,758	27,758	27,797	23,863	27,797
Adj R^2	0.50	0.73	0.56	0.56	0.57	0.50	0.50	0.53	0.50

This table contains models that analyze the impact of firms' corporate governance, CEO bargaining power, and CEO type on the relation between nonattainment exposure and CEO portfolio vega. The sample period is fiscal year 1993 to 2019. The dependent variable, *Vega*, measures the dollar (in thousands) change in the value of the CEO's portfolio of current option grants and accumulated option holdings for a 0.01 increase in the annualized standard deviation of a firm's stock returns. The measures of corporate governance are the total number of anti-takeover provisions a firm has in a given year, including staggered boards, limits to shareholder bylaw amendments, poison pills, golden parachutes, and supermajority requirements for mergers and charter amendments (*E-index*) (Bebchuk et al., 2009), a dummy variable equal to one if a firm's CEO also serves as the chairperson of the board in a given year, and zero otherwise (*CEO duality*) (Adams et al., 2005), the number of CEO appointed directors divided by the total number of board members for a firm in a given year (*Co-option*) (Coles et al., 2014), and the fraction of a firm's shares held by dedicated (*IO DED*) and transient (*IO TRA*) institutional investors following Bushee and Noe's (2000) classification. The measures of CEO bargaining power are the ratio of total CEO compensation to the highest compensation earned by any other executive in the firm (*Pay slice 1*) (Bebchuk et al., 2011) and the CEO's total compensation scaled by the sum of the total compensation of the top-three highest remunerated non-CEO executives (*Pay slice 3*) (Bebchuk et al., 2011). The measures of CEO type are a measure of how in-the-money the CEO's vested stock options are (*Confidence*) (Banerjee et al., 2015) and a measure of CEO overconfidence (*Holder67*) (Humphery-Jenner et al., 2016). *NA exposure* measures a firm's time-varying exposure to nonattainment designations based on the geographic distribution of its plants across nonattainment counties and the amount of ozone emissions at each plant. *Unexp. NA exposure* and *Antic. NA exposure* decompose a firm's exposure to nonattainment designations into an unexpected and anticipated component, respectively. The detailed definitions for *NA exposure*, *Unexp. NA exposure*, and *Antic. NA exposure* are given in Equations (1), (3), and (4), respectively. Control variables include *CEO age*, *CEO tenure*, *CEO ownership*, *Firm size*, *Book-to-market*, *ROA*, *Leverage*, *Cash*, *Sales growth*, *Stock return*, and *Stock volatility.* For all specifications, standard errors are robust to heteroskedasticity and clustered at the firm-level; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Table 9
Propensity score matching and weighting models.

	Matched sample		Weighted least squares	
Dep. variable: *Vega*	(1)	(2)	(3)	(4)
NA exposure	-4.461***		-5.089***	
	(-4.06)		(-5.54)	
Unexp. NA exposure		-4.121***		-4.607***
		(-2.70)		(-3.55)
Antic. NA exposure		-1.954		-2.667
		(-0.83)		(-1.29)
Controls	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
Observations	15,386	15,386	28,054	28,054
Adj R^2	0.55	0.55	0.51	0.52

This table reports coefficients from firm and year fixed effects panel regressions of CEO portfolio vega on nonattainment exposure using propensity score matching and weighting techniques. The sample period is fiscal year 1993 to 2019. In columns (1) and (2), we match firm-year observations with non-zero nonattainment exposure ("treated") to those with no exposure ("control") using one-to-one nearest neighbor propensity score matching with replacement (Roberts & Whited, 2013). In columns (3) and (4), we use weighted least squares regression with propensity score-derived weights, as in Caliendo and Kopeinig (2008). To generate the propensity score, $\widehat{p}$, we estimate a logistic regression where the dependent variable is one if the firm-year belongs to the treated group, and zero otherwise, and the independent variables are the control variables in Table 2. Firm-year observations in the treated group receive a weight of $1/\widehat{p}$, while those in the control group receive a weight of $1/(1-\widehat{p})$. The dependent variable, *Vega*, measures the dollar (in thousands) change in the value of the CEO's portfolio of current option grants and accumulated option holdings for a 0.01 increase in the annualized standard deviation of a firm's stock returns. *NA exposure* measures a firm's time-varying exposure to nonattainment designations based on the geographic distribution of its plants across nonattainment counties and the amount of ozone emissions at each plant. *Unexp. NA exposure* and *Antic. NA exposure* decompose a firm's exposure to nonattainment designations into an unexpected and anticipated component, respectively. The detailed definitions for *NA exposure*, *Unexp. NA exposure*, and *Antic. NA exposure* are given in Equations (1), (3), and (4), respectively. Control variables include *CEO age*, *CEO tenure*, *CEO ownership*, *Firm size*, *Book-to-market*, *ROA*, *Leverage*, *Cash*, *Sales growth*, *Stock return*, and *Stock volatility*. For all specifications, standard errors are robust to heteroskedasticity and clustered at the firm-level; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Table 10
Alternative difference-in-differences estimator with heterogeneous treatment effects.

Dep. variable: *Vega*	(1)	(2)	(3)
NA exposed	-18.104**		
	(-2.02)		
Unexp. NA exposed		-23.860***	
		(-2.62)	
Antic. NA exposed			3.258
			(0.305)
Placebo(-2)	-3.758	-0.324	-0.419
	(-0.27)	(-0.02)	(-0.03)
Placebo(-3)	-1.826	8.145	20.22
	(-0.18)	(0.81)	(1.61)
Placebo(-4)	-1.562	-5.521	17.73
	(-0.19)	(-0.59)	(1.30)
Controls	Yes	Yes	Yes
Observations	23,215	23,215	20,881
p-value: All placebos are zero	0.331	0.605	0.184

This table reports the results using the difference-in-differences estimator developed by de Chaisemartin and D'Haultfoeuille (2020, 2022), which addresses the issues of treatment effect heterogeneity and negative weights that may bias the standard two-way fixed effects estimator. The sample period is fiscal year 1993 to 2019. The dependent variable, *Vega*, measures the dollar (in thousands) change in the value of the CEO's portfolio of current option grants and accumulated option holdings for a 0.01 increase in the annualized standard deviation of a firm's stock returns. *NA exposed* is a dummy variable equal to one for firm-year observations with non-zero nonattainment exposure, and zero otherwise. *Unexp. NA exposed* and *Antic. NA exposed* are dummy variables equal to one for firm-year observations with non-zero exposure to unexpected and anticipated nonattainment designations, respectively, and zero otherwise. *Placebo(-2)*, *Placebo(-3)*, and *Placebo(-4)* are the placebo estimators of de Chaisemartin and D'Haultfoeuille (2020, 2022) that test for the parallel trends assumption in the two, three, and four years, respectively, before exposure to nonattainment designations. We also provide the p-value of the joint test that all placebo estimators are equal to zero. Control variables include *CEO age*, *CEO tenure*, *Firm size*, *Book-to-market*, *ROA*, *Leverage*, *Sales growth*, and *Stock return*. For all specifications, standard errors are clustered at the firm-level; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Appendix A: Variable definitions

Table A.1
Variable definitions.

Variable	Definitions	Data source
Vega	The dollar (in thousands) change in the value of the CEO's portfolio of current option grants and accumulated option holdings for a 0.01 increase in the annualized standard deviation of a firm's stock returns (Core & Guay, 2002).	ExecuComp
Flow vega	The dollar (in thousands) change in the value of the CEO's current option grants for a 0.01 increase in the annualized standard deviation of a firm's stock returns.	ExecuComp
Number of options granted	The number of options granted to the CEO in the current year multiplied by one thousand divided by shares outstanding.	ExecuComp
Value of options exercised	The dollar (in thousands) value of options exercised by the CEO in the current year.	ExecuComp
Number of options exercised	The number of options exercised by the CEO in the current year multiplied by one thousand divided by shares outstanding.	ExecuComp
Total pay	The logarithm of one plus the CEO's total compensation (in thousands), consisting of salary, bonuses, value of restricted stocks granted, value of options granted, long-term incentive awards, and other types of compensation.	ExecuComp
Option intensity	The proportion of total annual CEO compensation that comes from option grants.	ExecuComp
Salary intensity	The proportion of total annual CEO compensation that comes from salary.	ExecuComp
Bonus intensity	The proportion of total annual CEO compensation that comes from bonuses.	ExecuComp
Cash intensity	The proportion of total annual CEO compensation that comes from salary and bonuses.	ExecuComp
NA exposure	For a given firm i, we measure its exposure to nonattainment designations in year t, denoted $NA\ exposure_{i,t}$, as $$\ln\left(1+\sum_j ozone_{j,i,t-1}\cdot NA_{j,i,t}\right),$$ where $ozone_{j,i,t-1}$ is the total amount of ozone air emissions for plant j of firm i in year $t-1$ and $NA_{j,i,t}$ is a dummy variable equal to one if plant j of firm i is located in a nonattainment county in year t, and zero otherwise.	TRI; Federal Register
Unexp. NA exposure	The same expression as *NA exposure* except $NA_{j,i,t}$ is replaced with *Unexp.* $NA_{j,i,t}$, which is a dummy variable equal to one if plant j of firm i is located in an *unexpected* nonattainment county in year t, and zero otherwise.	TRI; Federal Register; AQS
Antic. NA exposure	The same expression as *NA exposure* except $NA_{j,i,t}$ is replaced with *Antic.* $NA_{j,i,t}$, which is a dummy variable equal to one if plant j of firm i is located in an *anticipated* nonattainment county in year t, and zero otherwise.	TRI; Federal Register; AQS
Redesig exposure	For a given firm i, we measure its exposure to attainment redesignations in year t, denoted $Redesig\ exposure_{i,t}$, as $$\ln\left(1+\sum_j ozone_{j,i,t-1}\cdot Redesig_{j,i,t}\right),$$ where $ozone_{j,i,t-1}$ is the total amount of ozone air emissions for plant j of firm i in year $t-1$ and $Redesig_{j,i,t}$ is a dummy variable equal to one if plant j of firm i is located in a county that has been redesignated to attainment in year t.	TRI; Federal Register
CEO age	The CEO's age (in years).	ExecuComp
CEO tenure	The logarithm of one plus the number of years the CEO has been in office.	ExecuComp
CEO ownership	The CEO's ownership in the firm. This is derived by dividing the CEO's stock ownership by shares outstanding.	ExecuComp

Table A.1 continued

Variable	Definitions	Data source
Firm size	The logarithm of one plus the book value of assets (at).	Compustat
Book-to-market	Book-to-market ratio ($at/(at - ceq + prcc\_f \times csho)$).	Compustat
ROA	Net income divided by total assets (ni/at).	Compustat
Leverage	Total liabilities divided by total assets ($(dltt + dlc)/at$).	Compustat
Cash	Cash divided by total assets (che/at).	Compustat
Sales growth	The logarithm of current year sales divided by previous year sales ($\log(sale_t/sale_{t-1})$).	Compustat
Stock return	The annual stock return of the firm.	CRSP
Stock volatility	The standard deviation of stock returns over the past 12 months.	CRSP
Close monitor	A dummy variable equal to one if a firm operates ozone-emitting plants located within one mile of an ozone air quality monitor in a nonattainment county, and zero otherwise.	TRI; AQS
Young plant	A dummy variable equal to one if a firm operates ozone-emitting plants that are between zero and five years of age in nonattainment counties, and zero otherwise.	NETS; TRI
Production ratio	A dummy variable equal to one if the average ozone production ratio across all plants in nonattainment counties for a firm is greater than the sample median, and zero otherwise.	TRI; Federal Register
Low paydex	A dummy variable equal to one if the average paydex score across all ozone-emitting plants in nonattainment counties for a firm is less than the sample median, and zero otherwise.	NETS; TRI; Federal Register
High RRI	A dummy variable equal to one if a firm's peak RRI is above 50, and zero otherwise.	RepRisk
HPV	A dummy variable equal to one if a firm experiences a high priority violation in the past three years among ozone-emitting plants in nonattainment counties, and zero otherwise.	ICIS-Air; TRI; Federal Register
Enforcement	A dummy variable equal to one if a firm experiences a judicial or administrative enforcement case in the past three years among ozone-emitting plants in nonattainment counties, and zero otherwise.	FE&C; TRI; Federal Register
KZ index	Kaplan-Zingales index (Kaplan & Zingales, 1997; Lamont et al., 2001) normalized to begin from zero.	Compustat
HP index	Hadlock-Pierce index (Hadlock & Pierce, 2010) normalized to begin from zero.	Compustat
WW index	Whited-Wu index (Whited & Wu, 2006) normalized to begin from zero.	Compustat
HM index	Hoberg-Maksimovic index (Hoberg & Maksimovic, 2015) normalized to begin from zero.	Hoberg-Maksimovic Financial Constraints Repository
CHS index	Campbell-Hilscher-Szilagyi index (Campbell et al., 2008) normalized to begin from zero.	Compustat
E-index	The total number of anti-takeover provisions a firm has in a given year, including staggered boards, limits to shareholder bylaw amendments, poison pills, golden parachutes, and supermajority requirements for mergers and charter amendments.	Bebchuk et al.'s (2009) website
CEO duality	A dummy variable equal to one if a firm's CEO also serves as the chairperson of the board in a given year, and zero otherwise (Adams et al., 2005).	ExecuComp
Co-option	The number of CEO appointed directors divided by the total number of board members for a firm in a given year (Coles et al., 2014).	RiskMetrics
IO DED	The fraction of a firm's shares held by dedicated institutional investors following Bushee and Noe's (2000) classification.	Bushee and Noe's (2000) website; Thomson Reuters s34
IO TRA	The fraction of a firm's shares held by transient institutional investors following Bushee and Noe's (2000) classification.	Bushee and Noe's (2000) website; Thomson Reuters s34
Pay slice 1	The ratio of total CEO compensation to the highest compensation earned by any other executive in the firm (Bebchuk et al., 2011).	ExecuComp
Pay slice 3	The CEO's total compensation scaled by the sum of the total compensation of the top-three highest remunerated non-CEO executives (Bebchuk et al., 2011).	ExecuComp
Confidence	A measure of how in-the-money the CEO's vested stock options are following Banerjee et al. (2015).	ExecuComp
Holder67	A dummy variable equal one if the CEO fails to exercise options with five years remaining duration despite a 67% or higher increase in stock price since the grant date, and zero otherwise (Malmendier et al., 2011).	ExecuComp

Internet Appendix For Online Publication Only

IA. Regression discontinuity design

Formally, we perform the RDD by using a nonparametric, local linear estimation. Small neighborhoods on the left- and right-hand sides of the NAAQS threshold are used to estimate discontinuities in nonattainment probability. We follow Calonico et al. (2014) to derive the asymptotically optimal bandwidth under a squared-error loss. The choices of the neighborhood (bandwidth) are data-driven (determined by the data structure) and different across samples and variables. By choosing the optimal bandwidth to the left and right of the threshold, we only include observations in the estimation if the absolute difference between the DV for that observation and the threshold is less than the bandwidth. The local linear regression model can therefore be specified as

$$NA_{c,t+1} = \alpha + \beta Noncompliance_{c,t} + \phi f(R_{c,t}) + \varepsilon_{c,t+1} \quad \text{(IA.1)}$$

for county c and year t. $NA_{c,t+1}$ is a dummy variable equal to one if county c is designated nonattainment in year $t+1$, and zero otherwise. $Noncompliance_{c,t}$ is a dummy variable equal to one if county c's DV is in violation of the NAAQS threshold in year t, and zero otherwise. $R_{c,t}$ is the centered DV (i.e., the running variable in RDD parlance), defined as the difference between the DV of county c in year t and the NAAQS threshold. Negative (positive) values indicate that the county is in compliance with (violation of) the NAAQS threshold. We use local linear functions in the running variable with rectangular kernels as represented by $f(R_{c,t})$. Since treatment assignment is at the county-level, standard errors are clustered by county and bias-corrected as discussed in Calonico et al. (2014).

The identifying assumption of the RDD is that, around the NAAQS threshold, a county's designation status is as good as randomly assigned. In the following sections, we perform two standard tests for the RDD validity that counties cannot precisely manipulate the running variable so that their DVs are right below the NAAQS threshold (Lee & Lemieux, 2010). If this assumption is satisfied, then the variation in a county's designation status around the NAAQS threshold should be as good as that from a randomized experiment.

IA.1. Continuity in the distribution of design values

Since being classified as nonattainment imposes costly regulatory actions to curb emissions, counties have a strong incentive to keep pollution levels below the threshold. Thus, one potential concern is that counties just above the threshold might try to manipulate their monitored ozone concentrations in order to be right below the threshold to avoid noncompliance. The first test that we conduct evaluates whether the distribution of DVs is continuous around the NAAQS threshold. Any discontinuity would suggest a nonrandom assignment of attainment versus nonattainment status around the threshold.

In practice, however, it is unlikely that counties could strategically manipulate their DVs. Since all counties are evaluated on the same standards, the EPA's federal enforcement power limits the states' ability to overlook non-compliers. Additionally, studies show that nonattainment designations often depend on weather patterns (Cleveland & Graedel, 1979; Cleveland, Kleiner, McRae, & Warner, 1976). Combined with the fact that ozone emissions are a result of complex chemical reactions in the atmosphere between pollutants such as volatile organic compounds and nitrogen oxides, it is extremely difficult for counties to manipulate their ozone concentration levels precisely around the NAAQS threshold. Lastly, ozone emissions that contribute to a county's DV not only originate from stationary sources such as the facilities examined in this paper, but also from mobile pollution sources (such as those from vehicles). Thus, even if there were a coordinated effort to manipulate ozone emissions by a group of facilities, it would still be unlikely to influence the DV of the entire county given other non-stationary emission sources.

Internet Appendix Figure IA.3 plots the local density of centered DVs, estimated separately on either side of the NAAQS threshold with the corresponding 95% confidence interval bounds, calculated using the plug-in estimator proposed by Cattaneo, Jansson, and Ma (2020). Observations on the left (right) of the vertical dashed line indicate that the county is in compliance with (violation of) the NAAQS threshold. If counties were manipulating their DVs to strategically avoid nonattainment designations, one would expect to see a bunching of counties just below the NAAQS thresholds. As shown in the figure, there is no evidence for a discontinuous jump around the threshold. Using the density break test following Cattaneo et al. (2020),[21] we fail to reject the null hypothesis that counties are unable to manipulate their pollution levels in order to be right below the NAAQS threshold (p-value = 0.943).

IA.2. Preexisting differences

The second testable implication of the randomness assumption is that the polluting facilities in counties whose DVs are immediately below or above the threshold should be very similar on the basis of ex ante characteristics. In other words, if a county's designation status is as good as randomized, it should be orthogonal to facility characteristics prior to the designation. In Internet Appendix Table IA.3, we examine whether there are any preexisting differences between plants operating in counties that violate and comply with the thresholds. The variables that we examine include a dummy variable equal to one if a plant emits ozone core chemicals as defined by TRI, and zero otherwise (*Core chemical*);[22] a dummy variable equal to one if a plant holds operating permits for ozone emissions, and zero otherwise (*Permit*); the logarithm of one plus the total amount (in pounds) of ozone source reduction activities that a plant engages in (*ln(Source reduction)*); the plant's ozone production ratio (*Production ratio*); the logarithm of one plus the number of employees at the plant (*ln(Employees)*); the logarithm of one plus the dollar amount of sales at the plant (*ln(Sales)*); the plant's minimum paydex score in a given year (*Paydex*); a dummy variable equal to one if a plant experiences a high priority violation in the past three years, and zero otherwise (*HPV*); and a dummy variable equal to one if a firm experiences an enforcement case in the past three years, and zero otherwise (*Enforcement*).

In column (1) of Internet Appendix Table IA.3, we examine these characteristics in the year preceding the designation ($t-1$). In column (2), we examine the change in these characteristics between years $t-2$ and $t-1$. Both columns report the differences using a narrow window around the NAAQS threshold by computing the mean squared error optimal bandwidth following Calonico et al. (2014). As can be seen in both columns, there are no systematic or statistically significant differences in facility characteristics in the optimal neighborhood around the threshold, which lends support to our identification strategy.

IA.3. Estimation results

We present the estimation results of Equation (IA.1) in Table IA.2 of the Internet Appendix. The coefficient estimate of β captures the discontinuity at the NAAQS threshold and is equal to the difference in the probability of nonattainment between counties that marginally violate the NAAQS threshold and those that marginally comply with the threshold. In column (1), we estimate the baseline specification without any covariate adjustments. Noncompliance based on DVs leads to an increase in the probability of nonattainment by roughly 74%. In

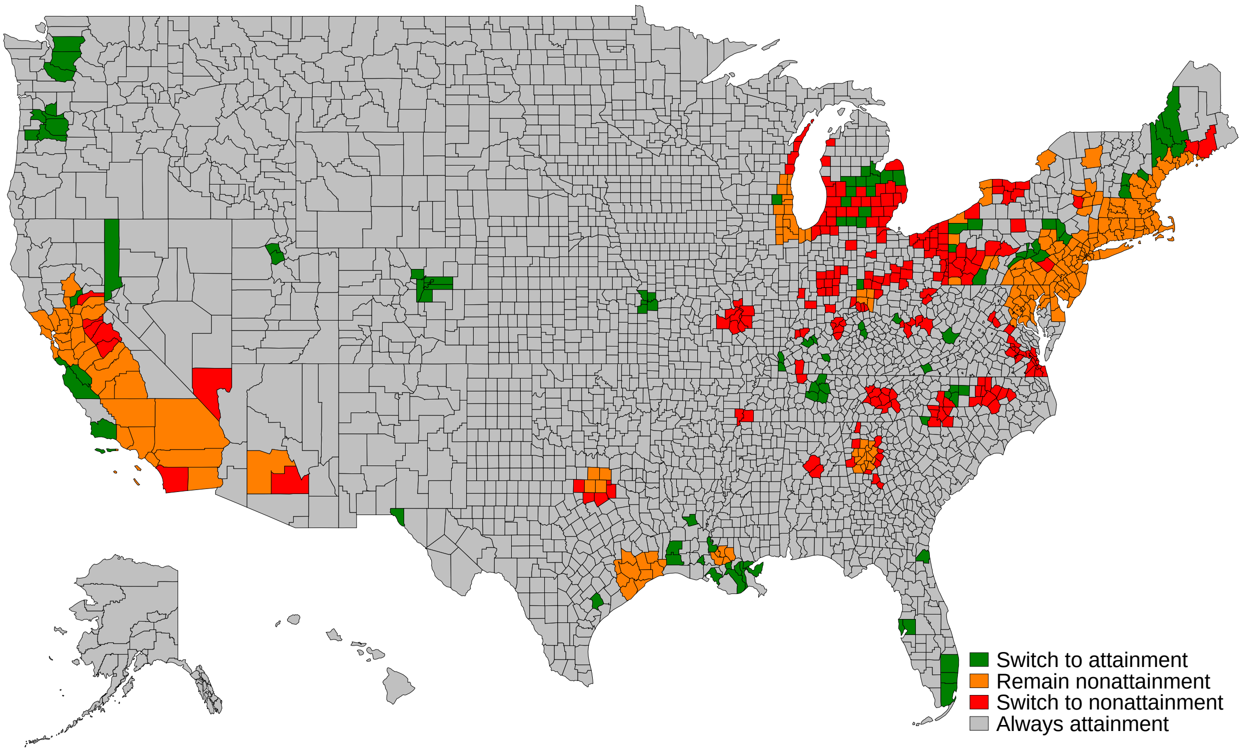
[21]The density break test builds upon the more standard density manipulation test by McCrary (2008).

[22]Core chemicals are those that have consistent reporting requirements in TRI.

column (2), following Curtis (2020), the point estimates on β and optimal bandwidth selection are covariate-adjusted by including additional county-level covariates such as the natural logarithm of one plus the employment levels in a given county, a given county's NOx emissions to employment ratio, the change in a given county's employment levels, and a dummy variable equal to one if the county is located in a MSA. We obtain qualitatively similar results.

Internet Appendix Table IA.2 also provides the estimates of the optimal bandwidth. The bandwidth estimate of 0.009 in both columns implies that counties with DVs that are within 0.009 ppm of the NAAQS threshold have ozone concentration levels that are as good as randomized. Counties with DVs that exceed the threshold by more than 0.009 ppm are considered to be far "enough" *above* the threshold that they will most likely be designated nonattainment in the following year. Similarly, counties with DVs that are below the threshold by more than 0.009 ppm are considered to be far "enough" *below* the threshold that they will most likely remain in attainment in the following year.

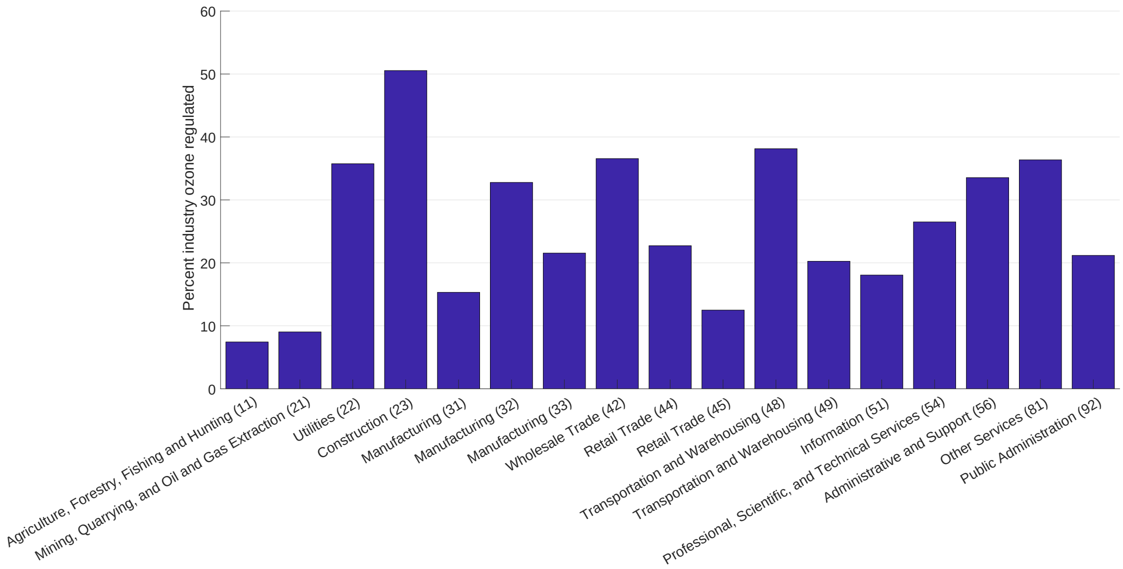
Figure IA.1
Nonattainment designations in 2004.



This figure compares the nonattainment/attainment status for each county for the 1997 ozone standard on the effective date, June 15, 2004 with that of the previous 1979 ozone standard.

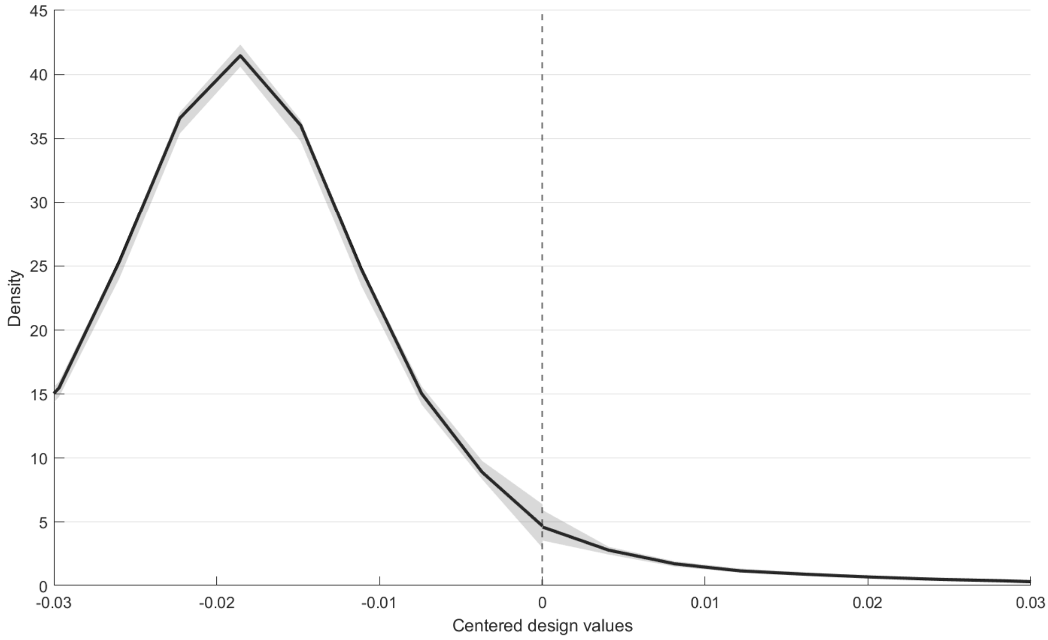
Figure IA.2

Fraction of ozone plants by industry in nonattainment counties.



This figure shows the fraction of ozone-emitting plants by major industry (categorized using two-digit industry NAICS codes) in nonattainment counties.

Figure IA.3
Density break test around NAAQS thresholds.



This figure presents the density of observations by the distance to the ozone NAAQS threshold. The horizontal axis shows the centered DVs around zero by subtracting the NAAQS threshold from the DVs. The dashed vertical line at zero represents the NAAQS threshold for ozone nonattainment status. Observations on the right (left) of the line indicate that the county is in violation of (compliance with) the NAAQS threshold. The solid black lines represent the local density on either side of the NAAQS threshold and the shaded gray area corresponds to the 95% confidence interval bounds, calculated using the plug-in estimator proposed by Cattaneo et al. (2020). We fail to reject the null hypothesis that there is no break in density around the threshold, with a p-value of 0.943.

Table IA.1
Ozone NAAQS.

Standard	Effective date	Averaging time	Threshold (ppm)	Form
1-Hour Ozone (1979)	January 6, 1992	1 hour	0.12	Attainment is defined when the expected number of days per calendar year, with maximum hourly average concentration greater than 0.12 ppm, is equal to or less than 1
8-Hour Ozone (1997)	June 15, 2004	8 hours	0.08	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
8-Hour Ozone (2008)	July 20, 2012	8 hours	0.075	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
8-Hour Ozone (2015)	August 3, 2018	8 hours	0.070	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years

This table provides basic descriptions of the ozone NAAQS used in our study. Standard refers to the name of the ozone NAAQS. Effective date is the date on which the standard is effectively implemented as stated in the Federal Register. Averaging time is the sampling frequency of the ozone concentration used to calculate DVs. Threshold refers to the DV value which if exceeded, then the county is considered to be in nonattainment. This value is measured in parts per million (ppm). Form is the rule used to compute the DVs for the relevant ozone standard. Our sample period is from 1993–2019. From 1993 to 2003, we use the 1-Hour Ozone (1979) standard. From 2004 to 2011, we use the 8-Hour Ozone (1997) standard. From 2012 to 2017, we use the 8-Hour Ozone (2008) standard. From 2018 onwards, we use the 8-Hour Ozone (2015) standard. This table is adapted from `https://www.epa.gov/ground-level-ozone-pollution/timeline-ozone-national-ambient-air-quality-standards-naaqs`.

Table IA.2
Noncompliant design values and probability of nonattainment.

Dep. variable: $NA_{c,t+1}$	(1)	(2)
$Noncompliance_{c,t}$	0.743***	0.721***
	(32.23)	(31.75)
Kernel	Rectangular	Rectangular
Bandwidth type	Optimal	Optimal
Bandwidth estimate	0.009	0.009
Covariates	No	Yes
Observations	7,409	6,723

This table presents the probability of nonattainment designation when a given county's DV is in violation of the NAAQS threshold. We estimate the local linear regression specification given in Equation (IA.1) using the mean squared error optimal bandwidth with rectangular kernels following Calonico et al. (2014). $NA_{c,t+1}$ is a dummy variable equal to one if county c is designated nonattainment in year $t+1$, and zero otherwise. $Noncompliance_{c,t}$ is a dummy variable equal to one if county c's DV is in violation of the NAAQS threshold in year t, and zero otherwise. County-level covariates include the natural logarithm of one plus the employment levels in a given county, a given county's NO_x emissions to employment ratio, the change in a given county's employment levels, and a dummy variable equal to one if the county is located in a MSA. For all specifications, standard errors are clustered by county and bias-corrected following Calonico et al. (2014); t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

Table IA.3
Preexisting differences in facility characteristics.

	Year ($t-1$)	Δ from year ($t-2$) to ($t-1$)
	(1)	(2)
Core chemical	-0.022	-0.005
	(0.023)	(0.007)
Permit	-0.004	-0.003
	(0.034)	(0.004)
ln(Source reduction)	-0.100	0.014
	(0.317)	(0.065)
Production ratio	0.001	-0.005
	(0.023)	(0.013)
ln(Employees)	-0.045	-0.014
	(0.067)	(0.030)
ln(Sales)	0.010	-0.091
	(0.070)	(0.105)
Paydex	0.031	-0.273
	(0.355)	(0.204)
HPV	0.004	-0.002
	(0.010)	(0.004)
Enforcement	-0.002	-0.004
	(0.006)	(0.004)
Sample:	Optimal	Optimal

This table examines the differences in observable facility characteristics between those that operate in counties that are in violation of the NAAQS thresholds and those operating in counties that are in compliance. In column (1), these characteristics are measured in the year preceding the designation ($t-1$). Column (2) considers the change in these characteristics between years $t-2$ and $t-1$. We focus on a narrow window around the NAAQS threshold by computing the mean squared error optimal bandwidth following Calonico et al. (2014). For all specifications, standard errors are clustered by county, bias-corrected following Calonico et al. (2014), and reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

Table IA.4

Differences between firm characteristics using propensity score matching.

	Treatment ($N = 7,873$)	Control ($N = 7,873$)	Difference	
Variables	Mean	Mean	Estimate	p-value
CEO age	56.971	57.065	-0.094	0.664
CEO tenure	1.681	1.690	-0.009	0.722
CEO ownership	0.013	0.013	0.000	0.832
Firm size	7.999	8.010	-0.011	0.890
Book-to-market	0.668	0.676	-0.008	0.386
ROA	0.140	0.136	0.003	0.251
Leverage	0.264	0.265	-0.001	0.840
Cash	0.095	0.091	0.004	0.388
Sales growth	0.085	0.091	-0.006	0.225
Stock return	0.150	0.147	0.003	0.688
Stock volatility	0.097	0.097	0.000	0.957

This table presents the mean firm characteristics across two subsamples based on propensity score matching. We match firm-year observations with non-zero nonattainment exposure ("treated") to those with no exposure ("control") using one-to-one nearest neighbor propensity score matching with replacement (Roberts & Whited, 2013). We test for differences in the means between the two subsamples and provide the p-values. Standard errors are clustered at the firm-level. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Table IA.5
Alternative measures of nonattainment exposure.

Dep. variable: *Vega*	(1)	(2)	(3)	(4)	(5)	(6)
Unexp. NA exposure (#plants)	-6.906***					
	(-3.73)					
Antic. NA exposure (#plants)	-3.288					
	(-1.05)					
Unexp. NA exposure (sales)		-7.361***				
		(-4.03)				
Antic. NA exposure (sales)		-3.794				
		(-1.45)				
Unexp. NA exposure (employees)			-7.305***			
			(-4.00)			
Antic. NA exposure (employees)			-3.832			
			(-1.47)			
Unexp. NA exposure (toxicity-weighted)				-1.836***		
				(-2.63)		
Antic. NA exposure (toxicity-weighted)				-0.656		
				(-1.42)		
Unexp. NA exposure (core chemical)					-5.205***	
					(-3.54)	
Antic. NA exposure (core chemical)					-2.913	
					(-1.22)	
Unexp. NA exposure (permit)						-6.664***
						(-3.66)
Antic. NA exposure (permit)						-2.308
						(-0.63)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	28,054	27,554	27,554	28,054	28,054	28,054
Adj R^2	0.50	0.50	0.50	0.50	0.50	0.50

This table reports coefficients from firm and year fixed effects panel regressions of CEO portfolio vega on alternative measures of nonattainment exposure. The sample period is fiscal year 1993 to 2019. The dependent variable, *Vega*, measures the dollar (in thousands) change in the value of the CEO's portfolio of current option grants and accumulated option holdings for a 0.01 increase in the annualized standard deviation of a firm's stock returns. *Unexp. NA exposure (#plants)* and *Antic. NA exposure (#plants)* are measures of unexpected and anticipated nonattainment exposure where each plant's ozone emissions are divided by the total number of ozone-emitting plants owned by the firm, respectively. *Unexp. NA exposure (sales)* and *Antic. NA exposure (sales)* are measures of unexpected and anticipated nonattainment exposure where each plant's ozone emissions are sales share-weighted, respectively. *Unexp. NA exposure (employees)* and *Antic. NA exposure (employees)* are measures of unexpected and anticipated nonattainment exposure where each plant's ozone emissions are employee share-weighted, respectively. *Unexp. NA exposure (toxicity-weighted)* and *Antic. NA exposure (toxicity-weighted)* are measures of unexpected and anticipated nonattainment exposure using toxicity-weighted ozone emissions, respectively. *Unexp. NA exposure (core chemical)* and *Antic. NA exposure (core chemical)* are measures of unexpected and anticipated nonattainment exposure using core chemical ozone emissions, respectively. *Unexp. NA exposure (permit)* and *Antic. NA exposure (permit)* are measures of unexpected and anticipated nonattainment exposure using ozone emissions specified in operating permits, respectively. Control variables include *CEO age*, *CEO tenure*, *CEO ownership*, *Firm size*, *Book-to-market*, *ROA*, *Leverage*, *Cash*, *Sales growth*, *Stock return*, and *Stock volatility.* For all specifications, standard errors are robust to heteroskedasticity and clustered at the firm-level; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Table IA.6
Placebo nonattainment exposure.

Dep. variable: *Vega*	(1)	(2)	(3)	(4)
NA exposure (offsite)	-1.936			
	(-1.20)			
Unexp. NA exposure (offsite)		-1.338		
		(-0.82)		
Antic. NA exposure (offsite)		-3.643		
		(-1.12)		
NA exposure (PM)			-2.430	
			(-0.68)	
Unexp. NA exposure (PM)				-2.829
				(-1.04)
Antic. NA exposure (PM)				-2.774
				(-0.50)
Controls	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
Observations	28,054	28,054	28,054	28,054
Adj R^2	0.50	0.50	0.50	0.50

This table reports coefficients from firm and year fixed effects panel regressions of CEO portfolio vega on placebo measures of nonattainment exposure. The sample period is fiscal year 1993 to 2019. The dependent variable, *Vega*, measures the dollar (in thousands) change in the value of the CEO's portfolio of current option grants and accumulated option holdings for a 0.01 increase in the annualized standard deviation of a firm's stock returns. *NA exposure (offsite)* measures a firm's exposure to nonattainment designations based on offsite ozone emissions. *Unexp. NA exposure (offsite)* and *Antic. NA exposure (offsite)* are measures of unexpected and anticipated nonattainment exposure based on offsite ozone emissions. *NA exposure (PM)* measures a firm's exposure to nonattainment designations based on onsite particulate matter emissions. *Unexp. NA exposure (PM)* and *Antic. NA exposure (PM)* are measures of unexpected and anticipated nonattainment exposure based on onsite particulate matter emissions. Control variables include *CEO age*, *CEO tenure*, *CEO ownership*, *Firm size*, *Book-to-market*, *ROA*, *Leverage*, *Cash*, *Sales growth*, *Stock return*, and *Stock volatility.* For all specifications, standard errors are robust to heteroskedasticity and clustered at the firm-level; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Table IA.7
Alternative measures of CEO incentive compensation.

Dep. variable:	$ln(1+Vega)$		$Poisson\ Vega$		$Vega/Delta$	
	(1)	(2)	(3)	(4)	(5)	(6)
NA exposure	-0.016***		-0.025***		-0.004***	
	(-2.85)		(-3.44)		(-3.58)	
Unexp. NA exposure		-0.016***		-0.026***		-0.004***
		(-2.96)		(-3.94)		(-3.51)
Antic. NA exposure		-0.003		-0.000		-0.001
		(-0.53)		(-0.00)		(-1.06)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	28,054	28,054	27,498	27,498	27,960	27,960
Adj R^2	0.61	0.61	0.76	0.76	0.50	0.50

This table reports coefficients from firm and year fixed effects panel regressions of alternative measures of CEO incentive compensation on nonattainment exposure. The sample period is fiscal year 1993 to 2019. *Vega* measures the dollar (in thousands) change in the value of the CEO's portfolio of current option grants and accumulated option holdings for a 0.01 increase in the annualized standard deviation of a firm's stock returns. *Delta* measures the dollar (in thousands) change in the value of the CEO's portfolio of current option and stock grants and accumulated option and stock holdings for a 1% change in the stock price. Columns (1), (2), (5), and (6) use ordinary least squares regression while columns (3) and (4) use Poisson regression. *NA exposure* measures a firm's time-varying exposure to nonattainment designations based on the geographic distribution of its plants across nonattainment counties and the amount of ozone emissions at each plant. *Unexp. NA exposure* and *Antic. NA exposure* decompose a firm's exposure to nonattainment designations into an unexpected and anticipated component, respectively. The detailed definitions for *NA exposure*, *Unexp. NA exposure*, and *Antic. NA exposure* are given in Equations (1), (3), and (4), respectively. Control variables include *CEO age*, *CEO tenure*, *CEO ownership*, *Firm size*, *Book-to-market*, *ROA*, *Leverage*, *Cash*, *Sales growth*, *Stock return*, and *Stock volatility*. For all specifications, standard errors are robust to heteroskedasticity and clustered at the firm-level; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Table IA.8

The effect of nonattainment exposure on CEO incentive compensation using only the treatment sample.

Dep. variable: *Vega*	(1)	(2)	(3)	(4)
NA exposure	-2.851***		-2.594**	
	(-2.64)		(-1.99)	
Unexp. NA exposure		-3.122**		-2.799**
		(-1.97)		(-2.01)
Antic. NA exposure		-0.041		-0.034
		(-0.02)		(-0.02)
Controls	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	No	No
Year F.E.	Yes	Yes	No	No
Firm × Cohort F.E.	No	No	Yes	Yes
Year × Cohort F.E.	No	No	Yes	Yes
Observations	7,826	7,826	7,434	7,434
Adj R^2	0.51	0.51	0.57	0.57

This table reports coefficients from fixed effects panel regressions of CEO portfolio vega on nonattainment exposure using only the treatment sample. The sample period is fiscal year 1993 to 2019. The dependent variable, *Vega*, measures the dollar (in thousands) change in the value of the CEO's portfolio of current option grants and accumulated option holdings for a 0.01 increase in the annualized standard deviation of a firm's stock returns. *NA exposure* measures a firm's time-varying exposure to nonattainment designations based on the geographic distribution of its plants across nonattainment counties and the amount of ozone emissions at each plant. *Unexp. NA exposure* and *Antic. NA exposure* decompose a firm's exposure to nonattainment designations into an unexpected and anticipated component, respectively. The detailed definitions for *NA exposure*, *Unexp. NA exposure*, and *Antic. NA exposure* are given in Equations (1), (3), and (4), respectively. Control variables include *CEO age*, *CEO tenure*, *CEO ownership*, *Firm size*, *Book-to-market*, *ROA*, *Leverage*, *Cash*, *Sales growth*, *Stock return*, and *Stock volatility.* For all specifications, standard errors are robust to heteroskedasticity and clustered at the firm-level; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Table IA.9
The effect of attainment redesignation exposure on options granted and compensation structure.

Dep. variable:	*Flow vega*	*Number of options granted*	*Option intensity*	*Cash intensity*
	(1)	(2)	(3)	(4)
Redesig exposure	0.751***	0.013*	0.004***	-0.001
	(3.67)	(1.75)	(2.82)	(-1.40)
Controls	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
Observations	23,836	23,841	23,668	23,841
Adj R^2	0.45	0.23	0.41	0.49

This table reports coefficients from firm and year fixed effects panel regressions of the number of options granted and CEOs' compensation structure on attainment redesignation exposure. The sample period is fiscal year 1993 to 2019. Treated units are those firms that experience at least one redesignation event at an operating plant during the sample period. We do not include firms that operate only in attainment counties or only in nonattainment counties that have never been redesignated. The dependent variables are the dollar (in thousands) change in the value of the CEO's current option grants for a 0.01 increase in the annualized standard deviation of a firm's stock returns (*Flow vega*), the number of options granted to the CEO in the current year multiplied by one thousand divided by shares outstanding (*Number of options granted*), the proportion of total annual CEO compensation that comes from option grants (*Option intensity*), and the proportion of total annual CEO compensation that comes from the sum of salary and bonuses (*Cash intensity*). *Redesig exposure* measures a firm's time-varying exposure to attainment redesignations based on the geographic distribution of its plants across counties that have been redesignated and the amount of ozone emissions at each plant. The detailed definitions for *Redesig exposure* is given in Equation (8). Control variables include *CEO age*, *CEO tenure*, *CEO ownership*, *Firm size*, *Book-to-market*, *ROA*, *Leverage*, *Cash*, *Sales growth*, *Stock return*, and *Stock volatility.* For all specifications, standard errors are robust to heteroskedasticity and clustered at the firm-level; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.