Environmental regulation, pollution, and shareholder wealth*

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Abstract

This paper examines how stock markets react to changes in environmental regulation and firm pollution. Our empirical setting exploits county-level ozone nonattainment designations induced by discrete policy changes in air quality standards as part of the Clean Air Act. Nonattainment designations impose strict environmental regulations on polluting firms and thus serve as an exogenous source of variation in local regulatory stringency. On the extensive margin of pollution, investors react positively to ozone-emitting firms impacted by nonattainment designations. However, in the cross-section, heavy ozone-polluting multi-plant firms experience less favorable stock price reactions. In contrast, during attainment redesignations, the overall stock market reaction is negative on the extensive margin of pollution, but investors revise upwards the valuation of heavy ozone-polluting multi-plant firms. Our results suggest that the stock market internalizes the perceived benefits and costs of local environmental regulation. Further analysis of the underlying market forces reveals that while nonattainment designations benefit incumbent firms by decreasing competition and improving environmental performance, they also impose additional compliance costs.

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1. Introduction

There is a growing body of work on environmental regulations and financial markets. Research has shown that environmental regulations impact on the pricing of municipal bonds (Jha, Karolyi, & Muller, 2020), corporate bonds (Seltzer, Starks, & Zhu, 2021), and bank loans (Delis, de Greiff, Iosifidi, & Ongena, 2021; Kleimeier & Viehs, 2018). Institutional investors have also started to account for changes in environmental regulations in their portfolio holdings (Krueger, Sautner, & Starks, 2020; Xu, 2022). However, there is less work that explores the interplay between environmental regulations and firm pollution, and their impact on the financial stock market. We fill this gap by examining whether the stock market incorporates the consequences of local regulation on air pollution into the valuation of polluting firms.

This paper employs a key regulatory component of the Clean Air Act (CAA), whereby counties are designated as attainment or nonattainment with respect to the National Ambient Air Quality Standards (NAAQS) for ozone. Through the NAAQS, the federal United States Environmental Protection Agency (EPA) sets maximum allowable ambient concentrations of ozone pollution. Counties with ozone pollution levels above the NAAQS threshold are deemed to be in nonattainment, while those with pollution levels below the threshold are considered in attainment. The implication for firms is that those operating polluting plants in nonattainment counties face stringent regulations and mandatory pollution abatement requirements compared to those in attainment counties (Becker, 2005; Becker & Henderson, 2000, 2001; Greenstone, 2002). Since nonattainment regulations are binding and enforced on polluting plants, our empirical strategy exploits county-level ozone nonattainment designations as an exogenous source of variation in local regulatory stringency to study whether environmental regulation affects shareholder value by analyzing how investors react to nonattainment designations.

Our empirical design relies on nonattainment designations induced by discrete policy changes in the NAAQS threshold from 1992 to 2019. The policy changes that we employ are based on EPA's periodic revisions to reflect new scientific research on the health effects of ozone air pollution. Given an exogenous revision in the NAAQS threshold, many counties suddenly found themselves in nonattainment relative to the year prior. Under this regulatory setting, we examine the stock price reactions of firms that operate polluting plants in counties that are designated as nonattainment. Our identification strategy is similar in spirit to an ideal controlled experiment, in which one compares the abnormal stock returns between the most regulated and least regulated firms after randomly assigning environmental regulations to polluting plants to causally attribute the difference to regulation.

How might nonattainment designations impact on shareholder value? To answer this question, we explore three potential market forces—competitive advantages, environmental performance, and compliance costs—that have offsetting effects on the benefits and costs to incumbents and new entrants in areas affected by the regulation. On the one hand, nonattainment designations may benefit incumbent plants by raising barriers to entry, which reduces local competition. Incumbents may also benefit from obtaining "grandfather" status, which allows them to operate at a cost advantage since incumbents are shielded from the strictest regulations until they decide to expand operations. New entrants, however, face the brunt of the regulations as they must make substantial investments to comply with emission limits. Nonattainment designations may also improve a firm's overall environmental performance and to the extent that better environmental outcomes are positively valued by investors, nonattainment designations may lead to an upward revision in firm valuation. On the other hand, compliance with stringent nonattainment regulations can force firms to divert resources away from production to emissions reduction and pollution abatement. Given an increase in compliance costs, shareholders may revise their beliefs downwards.

We rely on short-run event study methodology to examine the resultant effects of these market forces on the market's reaction to nonattainment designations. Our event study is thus akin to studying changes in shareholder value at instances during which investors update their beliefs about the interaction between a firm's pollution and local environmental regulation. On the extensive margin of ozone pollution, we show that, on average, investors react positively to nonattainment designations. Firms that own polluting plants located in nonattainment counties ("nonattainment plants") experience a mean 11-day cumulative abnormal return (CAR) of 0.62%, corresponding to a gain of approximately $8 million. However, since nonattainment regulations only apply to ozone-emitting plants under ozone NAAQS, we use the Toxics Release Inventory (TRI) database to classify facilities into those that emit ozone ("ozone plants") and those that emit non-ozone pollutants ("non-ozone plants"). Our results show that the positive market reaction is completely driven by firms that own ozone nonattainment plants, implying that shareholders only react to nonattainment designations for firms that are impacted by the regulation.

Our analysis also allows for the fact that attentive investors may be able to anticipate a county's nonattainment status, since the monitored pollution levels used to determine nonattainment status are observable. Specifically, we decompose shareholders' reaction to nonattainment designations into an anticipated and unexpected component, depending on whether investors' predictions of nonattainment status are in line or opposite to realized nonattainment designations. Our findings show that while investors react positively to both anticipated and unexpected nonattainment designations, the economic magnitude is much stronger for the latter, consistent with the fact that investors are updating their beliefs based on the new information content contained in the unexpected component of nonattainment designations.

Although our event study results indicate that the benefits of nonattainment designations dominate the associated costs on the extensive margin of pollution, not all firms are regulated uniformly in nonattainment counties. In particular, multi-plant firms that are also heavy polluters of ozone are more intensely regulated and usually targeted first by regulators (Becker & Henderson, 2000). Thus, we next focus on the intensive margin of ozone emissions by using cross-sectional analysis to study the variation in CARs that is explained by the interaction between the proportion of plants located in nonattainment counties of a given firm and its total ozone emissions in nonattainment counties. Our results indicate that investors react less favorably when firms own a high proportion of nonattainment plants and are heavy polluters of ozone in nonattainment counties, consistent with the rationale that these multi-plant firms face greater compliance costs which proportionately offset the benefits associated with nonattainment status. Furthermore, the cross-sectional variation in nonattainment CARs appears to be entirely driven by unexpected nonattainment designations.

We also explore possible heterogeneity in the cross-sectional variation in nonattainment CARs by focusing on certain firm characteristics that we predict to lead to lower stock market valuations for heavy ozone-polluting firms exposed to nonattainment designations. In particular, we argue that nonattainment regulations are more costly for those heavy ozone-polluting firms that operate a high proportion of nonattainment plants that are young or located close to ozone monitors, a low proportion of nonattainment plants that own ozone operating permits, and those firms that have a high risk of distress or a low environmental score. Our results show that heavy ozone-polluting firms with the aforementioned characteristics experience lower CARs during nonattainment designations.

In the next set of analysis, we study the market's reaction to a related regulatory event known as redesignations to attainment. These events occur when a county has attained the NAAQS and represent an easing of regulation. As regulation becomes more lax, compliance costs are reduced, but the competitive advantages that used to benefit incumbents are also diminished. Consequently, we expect the market to react in the opposite direction compared to nonattainment designations. Indeed, we find that, on average, the market responds negatively to attainment redesignations on the extensive margin of ozone pollution. The negative market reaction is driven entirely by unexpected attainment redesignations, indicating that there is minimal new information content contained in anticipated attainment redesignations. Examining cross-sectional variation in attainment redesignation CARs, we show that investors react more favorably for firms that operate a greater proportion of plants in counties redesignated to attainment and are heavy ozone polluters in those areas, with the effect concentrated in unexpected attainment redesignations. Since attainment redesignations should mostly favor those heavy ozone-polluting multi-plant firms due to a reduction in compliance costs if they decide to expand operations, this reversal is consistent with positive market updating for those firms where investors initially reacted less favorably to during nonattainment designations.

So far, our results suggest that nonattainment designations and attainment redesignations both contain value-relevant information that has stock-price implications. Our next objective is to provide evidence of the mechanisms of the market forces that drive the market's reaction to nonattainment designations. First, we examine whether nonattainment designations create barriers to entry and reduce local competition for incumbents. Using a difference-in-differences specification, we show that nonattainment designations decrease county-level competition among polluting plants, with ozone-dependent firms experiencing the most benefits from the decrease in competitive pressure. Second, we explore whether nonattainment designations can create shareholder value for incumbent firms through improved environmental performance. Using plant-level panel regressions that exploit the rich source of cross-sectional and longitudinal variation in nonattainment designations, we document that ozone-dependent plants in nonattainment counties decrease the amount of ozone emissions that are harmful to human health, suffer fewer legal liabilities, and experience fewer high priority violations (HPV).

Third, we explore the potential compliance costs that facilities are subject to during nonattainment designations. Since there is no data directly on plant-level pollution abatement costs, we examine a facility's observable regulatory enforcement and pollution abatement efforts as proxies for potential compliance costs. Our analysis specifically distinguishes between young and old plants because newer plants often bear the majority of nonattainment regulations, while older plants are grandfathered and escape regulation until they expand operations (Becker & Henderson, 2001). We find that young ozone-dependent plants bear most of the regulatory enforcement and pollution abatement costs in nonattainment counties as these plants are subject to more inspections, evaluations, and participate more in source reduction activities. These findings are consistent with our predictions that older incumbent plants operate at a cost advantage relative to new entrants in nonattainment areas.

Our paper contributes to the literature linking environmental regulation to financial markets. Prior studies have used nonattainment designations to study the effect of environmental policy on health outcomes (Bishop, Ketcham, & Kuminoff, 2020), industrial activity (Becker & Henderson, 2000; Greenstone, 2002; List, McHone, & Millimet, 2004; List, Millimet, Fredriksson, & McHone, 2003), housing prices (Bento, Freedman, & Lang, 2015; Chay & Greenstone, 2005; Grainger, 2012), employment (Curtis, 2020; Kahn & Mansur, 2013), labor reallocation (Walker, 2011, 2013), productivity (Greenstone, List, & Syverson, 2012; Shapiro & Walker, 2018), earnings (Isen, Rossin-Slater, & Walker, 2017), and pollution substitution (Gibson, 2019; Greenstone, 2003). To our knowledge, we provide the first empirical analysis that uses nonattainment designations to examine the effects of environmental regulation on shareholder value. By studying changes in regulatory stringency due to nonattainment designations, we present evidence that the financial stock market internalizes the perceived benefits and costs of local environmental regulation, which is reflected in stock market valuations.

Our study also contributes to the literature on investor reactions to environmental regulation. Prior work has focused on examining stock market reactions to environmental initiatives (Fisher-Vanden & Thorburn, 2011; Jacobs, Singhal, & Subramanian, 2010), awards (Hendricks & Singhal, 1996), management (Flammer, 2013; Klassen & McLaughlin, 1996), violations (Karpoff, Lott, & Wehrly, 2005), and green bonds (Flammer, 2021). In contrast, we focus on the stock-price effects of environmental regulation rather than changes to environmental outcomes. Other studies that do examine environmental regulation have looked at stock market reactions through the lens of voluntary (Blacconiere & Patten, 1994; Matsumura, Prakash, & Vera-Muñoz, 2014; Shane & Spicer, 1983) and mandatory (Downar, Ernstberger, Reichelstein, Schwenen, & Zaklan, 2021; Grewal, Riedl, & Serafeim, 2018; Hamilton, 1995; Jouvenot & Krueger, 2021; Konar & Cohen, 1997; Krueger, 2015) disclosures, elections (Ramelli, Wagner, Zeckhauser, & Ziegler, 2021), and climate policy (Monasterolo & de Angelis, 2020). Our study differs in that we are able to exploit local variation in regulation that has real effects on firms' polluting behavior to study stock market reactions.

Finally, we contribute to the understanding of how environmental regulations impact on plant and firm level outcomes. Although there is an extensive body of work that examines the impact of environmental *risk* on institutional investors' portfolio decisions (Ceccarelli, Ramelli, & Wagner, 2021; Ilhan, Krueger, Sautner, & Starks, 2021), activism campaigns (Akey & Appel, 2020; Dimson, Karakaş, & Li, 2015; Naaraayanan, Sachdeva, & Sharma, 2021), and the pricing of stocks (Bolton & Kacperczyk, 2020, 2021; Görgen et al., 2020; Hsu, Li, & Tsou, 2022) and municipal bonds (Baker, Bergstresser, Serafeim, & Wurgler, 2018; Goldsmith-Pinkham, Gustafson, Lewis, & Schwert, 2021; Painter, 2020), there is comparatively less work that explores the effects of environmental regulations on plant and firm outcomes. Our analysis shows that nonattainment regulations can reduce local competition for polluting firms and improve plant-level environmental performance. These regulations also impose additional compliance costs, especially for younger plants.

2. Background on pollution and environmental regulations

In the United States, air pollution is regulated under the CAA, the largest environmental program in the country. The act was passed in 1963 and subsequently amended in 1970, 1977, and 1990. The EPA is authorized to implement and regulate separate federal air quality standards, formally known as the NAAQS, for six criteria air pollutants (carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, particulate matter, and lead). The NAAQS place pollutant-specific limits on the maximum allowable concentration of pollution in a given area to provide protection of human health. In this paper, we focus only on ozone since the largest benefits from the CAA are derived from ozone (Muller, Mendelsohn, & Nordhaus, 2011) and the majority of counties are in nonattainment under the ozone NAAQS as the standards for ozone have been the most difficult for counties to meet (Curtis, 2020).

Every county in the United States must be designated as being in attainment or out of attainment (nonattainment) with respect to the NAAQS. Counties whose ozone concentrations are above (below) the NAAQS threshold are designated as nonattainment (attainment). For counties that are designated nonattainment, the EPA requires each state to submit state implementation plans (SIP), which are comprehensive plans that outline how a state will bring their counties back into compliance (US EPA, 2013). While SIPs may vary from state to state, they must follow EPA's guidelines in curbing emissions and be approved by the EPA. Failure to submit and execute an acceptable SIP can potentially result in federal sanctions,[1] including the withholding of federal grant monies (e.g., highway construction funds), direct EPA enforcement and control (through federal implementation plans), penalty fees,[2] and

[1] A 1999 report by the Congressional Research Service states that 858 notices of impending sanctions were issued by the EPA between 1990 and 1999 (McCarthy, 1999).

[2] For example, several counties in New Jersey were subject to such fees in 2009 for failing to meet the

construction bans on new polluting establishments.

Environmental regulations in nonattainment counties are intended to be stringent. States are mandated to set emission limits, which place a yearly limit on the amount of ozone emissions on polluting sources in nonattainment counties.[3] Newly constructed large pollution sources or large sources undergoing major modifications located in nonattainment counties are subject to a standard of "lowest achievable emission rate" (LAER), requiring the installation of the cleanest available technology, regardless of costs. Moreover, any emissions from new or expanding sources must be offset from an existing source located in the same county before commencing operations. Existing pollution sources in nonattainment counties are required to meet "reasonably available control technology" (RACT) standards, which are emission limits based on technological and economic feasibility (US EPA, 2006).

For a county to be redesignated as attainment, states must develop proper SIPs demonstrating the regulatory actions that will be taken to meet and maintain the NAAQS. In attainment counties, polluting plants face a considerably more lax regulatory standard. New plants are subject to the installation of "best available control technology" (BACT), whereby the economic burden on the plant is considered in arriving at a final solution. Large-scale investments involve less expensive pollution abatement equipment and emission offsets are not necessary. Finally, since the NAAQS only apply to plants that emit a given criteria air pollutant, nonpolluters are free from regulation no matter the county's designation status.

Since SIPs require states to develop plant-specific regulations for every major source of air pollution, plants in nonattainment counties face greater regulatory scrutiny than plants in attainment counties. Besides the differences in capital expenditures (i.e., LAER/RACT versus BACT), these plant-specific regulations may also impose greater operating costs such as more expensive materials, additional capital depreciation, maintenance costs, and so forth. Compliance with nonattainment regulations may also necessitate redesigns in production processes, introducing additional costs if output must be suspended in the interim (Becker, 2005). There could also be direct regulatory costs because plant inspections and oversight are more frequent in nonattainment counties. Taken together, polluting plants in nonattainment counties face significantly more stringent environmental regulations than those in attainment counties.

NAAQS by 2007 (New Jersey Department of Environmental Protection, 2009).

[3]For more details, see `https://www.epa.gov/ground-level-ozone-pollution/required-sip-elements-nonattainment-classification`.

2.1. Nonattainment designations as a research design

The ideal analysis of the relation between stock price valuations and environmental regulations would involve a controlled experiment in which environmental regulations are randomly assigned to polluting plants. One can then compare the abnormal stock returns between the most regulated and least regulated firms to causally attribute the difference to regulation. Obviously, such an ideal experiment would be unreasonably difficult to implement in practice.

Our identification strategy uses nonattainment designations as exogenous shocks to local regulatory stringency that is very close in spirit to this ideal experiment. Specifically, we examine the stock price reactions of firms that operate polluting plants in counties that are designated as nonattainment. Existing studies show that nonattainment designations are effective at reducing pollution levels, and much of this reduction is a result of increased firm compliance, implying that nonattainment regulations are binding for polluting plants (Chay & Greenstone, 2003; Henderson, 1996).[4]

A potential concern is that air pollution is driven by industrial activity. Thus, counties that are designated nonattainment may correspond to those that have more underlying economic activities. To address this concern, our empirical design relies on nonattainment designations induced by discrete policy changes in the NAAQS threshold.[5] Given an exogenous revision in the NAAQS threshold, many counties suddenly found themselves in nonattainment relative to the year prior. Therefore, it is not changes in county-level conditions that trigger a switch to nonattainment, but rather the local pollution levels exceeding the revised NAAQS threshold. This regulatory design is shown in Figure 1. The figure shows the difference in the number of nonattainment counties between the current year and the previous year during the sample period 1992 to 2019. As can be seen, each peak coincides with the implementation of a revised NAAQS threshold, which leads to a large number of counties falling into nonattainment. Consistent with the findings of Curtis (2020), the revision that occurred on June 15, 2004 saw an additional 195 counties entering into nonattainment, which is the most out of all the revisions. In between these policy changes, there are generally more counties redesignated

[4]The fact that nonattainment designations are federally-enforced legally binding regulations is a major difference to other climate policies (e.g., Paris Agreement) and mandatory emission disclosure laws. For example, global climate policies are less binding and harder to enforce than local environmental regulations. Similarly, disclosure laws may not necessarily impose any costly emission restrictions that impact on polluting firms' emission behavior.

[5]We focus on four discrete changes in the NAAQS threshold. In chronological order, these include the 1-Hour Ozone (1979) standard effective on January 6, 1992, 8-Hour Ozone (1997) standard effective on June 15, 2004, 8-Hour Ozone (2008) standard effective on July 20, 2012, and 8-Hour Ozone (2015) standard effective on August 3, 2018. For more details, see Table IA.1 of the Internet Appendix.

to attainment rather than entering into nonattainment, suggesting that it is revisions to NAAQS thresholds that drive nonattainment designations and not changes in county-level conditions. Furthermore, nonattainment designations are fairly persistent; the mean duration of nonattainment for the sample of counties that we study is around 16 years.[6]

In our empirical setting, nonattainment designations are as good as randomly assigned across counties. The discrete policy changes in the NAAQS threshold that we employ are exogenously determined since the revised thresholds are based on new scientific research to reflect the ongoing health effects of air pollution (Gibson, 2019). Additionally, all counties are designated on the basis of the same NAAQS thresholds, so nonattainment designations are unlikely to be driven by county-specific characteristics other than local air quality conditions. Studies have shown that nonattainment designations often depend on transported air pollution, whereby weather patterns cause air pollutants to be transported due to downwinds (Cleveland & Graedel, 1979; Cleveland, Kleiner, McRae, & Warner, 1976). Lastly, nonattainment regulations are generally unaffected by other local county-level influences or state-level policies. This is because the EPA must approve each state's SIP and its federal enforcement authority limits the states' ability to overlook violators. Thus, other factors such as a county's political environment and firms' lobbying powers are unlikely to affect local nonattainment regulations.

3. Conceptual framework

What are the competing market forces that determine the market's reaction to environmental regulations? In the following, we discuss three potential forces that have offsetting effects on the benefits and costs to incumbents and new entrants in areas affected by a nonattainment regulatory shock. These forces can be classified into: i) competitive advantages; ii) environmental performance; and iii) compliance costs.

3.1. Underlying market forces of environmental regulations

An increase in the stringency of environmental regulations can offer competitive advantages to incumbent plants over new entrants in the form of barriers to entry and grandfather status. By imposing additional costs, local environmental regulation drives less efficient facilities from heavily regulated areas to low abatement cost regions, leading to an exit of polluting firms (Gray & Shadbegian, 1998; Kahn & Mansur, 2013). For example, earlier research documents a dramatic decrease in manufacturing plant births in nonattainment counties (Becker &

[6] There is substantial variation in the length of time that a county remains in nonattainment; some counties are redesignated to attainment after one or two years, while others (e.g., counties in Southern California) have been in nonattainment for over a decade. Additionally, it is very rare for a county to be designated as nonattainment for a second time once it has been redesignated to attainment.

Henderson, 2000; List et al., 2004, 2003). Thus, greater regulatory oversight makes market entry more costly, which decreases the overall competition among existing firms (Mohr & Saha, 2008).

Incumbent plants may also benefit from environmental regulations due to obtaining grandfather status. Recall that existing plants are grandfathered from the strictest regulations (until they update or expand their operations) and are only subject to less expensive RACT requirements, whereas new plants are subject to costly LAER requirements. Incumbent plants, therefore, operate at a cost advantage relative to new entrants. Similarly, as regulations tighten over time, former new plants (with former LAER equipment) are exempt from the tightening, reinforcing their grandfather status. For example, Becker and Henderson (2000) and Kahn (1997) find that existing plants in nonattainment areas have better survival rates and are less likely to close, respectively.

Environmental regulations may improve a firm's overall environmental performance. Plants that operate in counties with more stringent environmental regulations are subject to additional monitoring and inspections which may result in fewer violations and less fines through dynamic enforcement (Blundell, Gowrisankaran, & Langer, 2020). Furthermore, investments in pollution abatement technologies and compliance with stringent emission limits will lead to a reduction in overall emissions (Chay & Greenstone, 2003; Henderson, 1996). Taken together, a decrease in violations and emissions reduces the likelihood of a firm paying substantial legal penalties and suffering associated market value losses (Karpoff et al., 2005).

On the other hand, compliance with stringent environmental regulations can increase costs by forcing firms to devote some part of inputs to emissions reduction and pollution abatement. These additional costs could result in firms diverting resources away from production, which hampers productivity and may result in shareholders revising their beliefs downwards (Ambec, Cohen, Elgie, & Lanoie, 2013). Although some research documents a negative relation between environmental regulation and productivity (Gollop & Roberts, 1983; Gray & Shadbegian, 2003), others have found either small or insignificant effects (Barbera & McConnell, 1990; Becker, 2011).

3.2. Hypotheses development

The market's reaction to different environmental regulatory shocks (i.e., nonattainment designations and attainment redesignations) depends on the interactions between the market forces described above. In this section, we make empirical predictions on the direction of the market's reaction by determining which market forces we expect to dominate.

3.2.1. *Market reactions to nonattainment designations*

We posit that the benefits for incumbent plants derived from the competitive advantages and improved environmental performance associated with nonattainment designations outweigh the potential compliance costs. On the side of competitive advantages, prior studies on ozone nonattainment designations have shown that they lead to a permanent decrease in the number of ozone-emitting plants (Curtis, 2020; Henderson, 1996). At the same time, stringent regulations in nonattainment counties discourage new entrants, thereby shielding incumbents from additional competition (Gray, 1997; Perez-Saiz, 2015; Ryan, 2012).

Grandfather status during nonattainment designations also give incumbent plants a competitive advantage in the market for emission offsets. Local authorities generally grandfather the operating permits of existing plants, while polluting plants that wish to enter or expand in nonattainment counties must offset their emissions by paying an incumbent polluter in the same county to reduce their emissions (Nelson, Tietenberg, & Donihue, 1993). Shapiro and Walker (2020) show that expenditures on these emission offsets are one of the largest environmental expenditures for new or expanding polluting plants in nonattainment areas. Given these competitive advantages, the market is likely to react favorably towards incumbent firms during nonattainment designations.

Firms' environmental performance is expected to improve in nonattainment counties due to decreases in their ozone emissions. Superior environmental performance have been linked with higher market valuations (Clarkson, Li, Richardson, & Vasvari, 2011; Dowell, Hart, & Yeung, 2000; Fernando, Sharfman, & Uysal, 2017; Flammer, 2013; Konar & Cohen, 2001) and operating performance (Hart & Ahuja, 1996; Nehrt, 1996; Russo & Fouts, 1997). Furthermore, firms that reduce toxic emissions can mitigate losses that arise from environmental accidents, lawsuits, and penalties, which in turn can create value for shareholders by lowering expected costs of environmental risk (Heinkel, Kraus, & Zechner, 2001). Assuming that environmental performance is positively priced by capital market participants (Fernando et al., 2017; Ramchander, Schwebach, & Staking, 2012), nonattainment designations should result in positive market updating.

On the side of compliance costs, prior studies that specifically use ozone nonattainment designations show that capital investments in pollution abatement have only a temporary short-term negative impact on plant-level productivity with almost all of the effect occurring in the first year of nonattainment status (Greenstone et al., 2012) and may even be positive after a few years (Berman & Bui, 2001). In particular, Becker (2011) finds that, for the average manufacturing plant, there is no statistically significant effect on productivity of being in a county with higher environmental compliance costs. These findings are consistent with the idea that pollution abatement costs associated with nonattainment status are usually fixed in nature and therefore do not affect marginal production decisions. For example, LAER and RACT requirements often involve process modifications and add-on controls, which have a sizable fixed-cost component. For those variable costs that are tied to current production, e.g., change in the raw materials processed, incumbent plants are grandfathered from these costs because they can escape stringent regulations on pollution abatement until they undergo large expansions.

In summary, we predict that, on the extensive margin of ozone pollution, the benefits to incumbent firms dominate the potential costs during nonattainment designations, which leads to the following hypothesis:

Hypothesis 1(a): Shareholders react positively to nonattainment designations.

While we expect an overall positive reaction to nonattainment designations, not all firms are regulated uniformly during nonattainment designations. For example, a firm that operates many ozone plants, but are all located in attainment counties, is unaffected by the costs of nonattainment regulations. Likewise, a firm that operates many plants in nonattainment counties, but none of the plants emit ozone, is also unaffected. In practice, the extent of environmental regulation a firm is subject to depends on: i) the fraction of plants it operates across nonattainment and attainment counties (i.e., whether it is a multi-plant firm); and ii) the intensive margin of ozone emissions in nonattainment counties (i.e., whether it is a heavy polluter of ozone).

The existing literature shows that multi-plant firms in nonattainment areas are regulated the most intensely and generally targeted first by regulators (Becker & Henderson, 2000). These firms are shown to face higher production costs in nonattainment areas relative to their less-regulated counterparts in attainment areas (Becker & Henderson, 2001). Additionally, Becker (2005) shows that heavy ozone polluters in nonattainment counties have higher air pollution abatement expenditures and operating costs than otherwise similar heavy polluters in attainment counties. Taken together, multi-plant firms that are also heavy ozone polluters in nonattainment counties face the majority of the compliance costs associated with nonattainment designations, which proportionately offsets the benefits of competitive advantages and improved environmental performance associated with nonattainment designations. This reasoning leads to the following hypothesis:

Hypothesis 1(b): Firms that operate a higher proportion of plants in nonattainment counties and are heavy polluters of ozone in these areas experience lower CARs.

3.2.2. Market reactions to attainment redesignations

After being designated as nonattainment, a county is given a certain amount of time to reach attainment.[7] If the EPA determines that the NAAQS have been attained and that the improvement in air quality is due to permanent and enforceable reductions in ozone emissions, then the county will be redesignated to attainment. An easing of regulation will reduce compliance costs, but will also diminish the competitive advantages that incumbents used to enjoy. Consequently, on the extensive margin of ozone pollution, we expect the market to react in the opposite direction to nonattainment designations. We state the following hypothesis:

Hypothesis 2(a): Shareholders react negatively to attainment redesignations.

Attainment redesignations imply that heavy ozone-polluting multi-plant firms are subject to BACT requirements if they decide to expand operations. Becker (2005) finds that BACT is significantly less costly to plants than RACT/LAER technology. Thus, these firms face a reduction in potential compliance costs compared to when the county was still in nonattainment. Since attainment redesignations should primarily benefit heavy ozone-polluting multi-plant firms that were subject to the most stringent regulations prior to redesignation and experienced lower CARs during nonattainment designations, attainment redesignations should reverse such reactions and shareholders should proportionately revise their beliefs upwards for these firms. This rationale leads to the following hypothesis:

Hypothesis 2(b): Firms that operate a higher proportion of plants in counties redesignated to attainment and are heavy polluters of ozone in these areas experience higher CARs.

4. Data

4.1. Firms' ozone pollution

The core analyses in this study use pollution data 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

[7] The amount of time depends on the severity of the nonattainment, which is usually set out in the SIP. Counties with ozone concentrations that are far above the NAAQS threshold are given up to 20 years to attain the threshold. If counties are unable to meet the attainment deadline, they may apply for an extension, which if granted by the EPA, will allow for additional time to reach attainment.

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. 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). Additionally, studies have shown that the aggregate effects of reporting errors appear to be marginal (Bui & Mayer, 2003; US EPA, 1998). Nonetheless, to minimize reporting errors due to changes in reporting requirements in the early years of TRI data collection (De Marchi & Hamilton, 2006), we follow Gibson (2019) and exclude the period 1987 to 1991 from our analysis. Internet Appendix Table IA.2 lists the three-digit NAICS industries in TRI that are included in our sample. Similar to Akey and Appel (2021), the most common industries are chemical manufacturing (12.97% of sample), fabricated metal product manufacturing (12.64%), and transportation equipment manufacturing (8.22%).

Within any nonattainment county, a polluting plant is regulated only if it emits the specific criteria air pollutant for which the county is in violation. Since we only focus on ozone, we use the emissions data in TRI to classify whether a facility is a polluter of ozone.[8] In any given year, a facility is labeled as an ozone plant if it emits chemicals that are classified as volatile organic compounds or nitrogen oxides, both precursors to ozone formation.[9] Although the TRI data provides information on chemical emissions through the ground, air and water, we only consider emissions through the air because the NAAQS only regulates air emissions. Internet Appendix Figure IA.1 shows the fraction of plants that are labeled as ozone polluters 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. Since our paper examines shareholder wealth, we only use the facilities that are owned by public companies in TRI. To obtain parent companies' financial and stock price information, we manually match the TRI parent company names to those in Compustat and CRSP. The final sample consists of 1,587 unique firms, 12,488 unique facilities, or 139,508 facility-year observations from 1992 to 2019.

[8]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.

[9]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/polluters.

4.2. Environmental regulation events

For our event study, we focus on nonattainment designations and redesignations to attainment. We manually search the Federal Register and hand-collect the effective dates of every event. To ensure that there are no spillover effects between different events, we remove any event that occurs within two weeks of another event centered on the event date. Since a firm can own many plants located across multiple counties, we consider a firm to be impacted by nonattainment designations if it owns facilities that operate in the counties designated nonattainment.[10] We require facilities to have no changes in parent firm ownership from the prior year to the event year and have non-missing ozone emissions data in TRI in the prior year. Our final event study sample consists of 1,698 nonattainment designation event-years concerning 932 firms and 1,822 attainment redesignation event-years concerning 530 firms.

4.3. Monitor-level ozone concentration

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 "design values" (DV) which are statistics that the EPA uses to determine whether a county is in compliance with the NAAQS each year. Counties with DVs that are above the relevant threshold are likely to be designated nonattainment while those below the threshold are likely to remain in attainment.[11] 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. We use the DVs in our event study to decompose shareholder reactions to nonattainment designations into an anticipated component and an unexpected component. Although the DVs are publicly released by the EPA annually, they only represent snapshots in time and may not correspond to the information publicly available to shareholders at the time of nonattainment designations.[12] Thus, we tailor the calculation of the DVs using time periods that mimics, as close as possible, the information available to shareholders at the time of nonattainment designations.

[10] Attainment redesignation events are aggregated at the firm-level in a similar manner.

[11] Although DVs are one component that the EPA uses to determine nonattainment status, they are not the only contributing factor. The EPA uses a five-factor approach in evaluating a county's designation status and each county's circumstances are considered on a case-by-case basis. See `https://www.epa.gov/ozone-designations/ozone-designations-guidance-and-data#B` for more details.

[12] The EPA may also retroactively change the design values after the date of publication for a variety of reasons, including revisions due to data being influenced by exceptional events and monitoring issues.

4.4. Plant-level variables

We use a host of plant-level variables obtained from various database which are summarized as follows. We obtain information on the toxicity of emissions from EPA's Integrated Risk Information System (IRIS). The database provides information on potential human health effects from exposure to over 400 chemicals. We match the chemicals in IRIS to those in TRI to determine whether a chemical poses potential harm to humans as well as which critical bodily systems are affected. We use the EPA's Pollution Prevention (P2) database to create pollution abatement variables. The database provides information on a facility's source reduction activities that limit the amount of toxic chemicals released (e.g., recycling, recovery, and treatment). We also use the production ratio variable in the P2 database, which measures the change in output associated with the release of a chemical in a given year.[13] We use EPA's Integrated Compliance Information System for Air (ICIS-Air) database for information on plant-level ozone violations, operating permits, inspections, compliance evaluations, and stack test results. We obtain data on formal administrative and judicial cases from EPA's Integrated Compliance Information System for Federal Civil Enforcement Case Data (ICIS FE&C). In particular, we collect information on the number and amount of federal penalties, supplemental environmental project (SEP) costs, and compliance action costs. Finally, we collect data on a plant's number of employees, sales, and first year of operation from the National Establishment Time-Series (NETS).

4.5. Control variables

In our analyses, we use a variety of control variables related to a firm's polluting activities and financial characteristics. The control variables for polluting activities include a dummy variable equal to one if a given firm operates plants that emit ozone core chemicals as defined by TRI, and zero otherwise (*Core chemical*);[14] a dummy variable equal to one if a given firm operates plants that hold operating permits for ozone emissions, and zero otherwise (*Permit*); a dummy variable equal to one if a given firm operates plants that engage in ozone source reduction activities (*Source reduction*); and a given firm's average ozone production ratio across all plants (*Production ratio*). Control variables for firm financial characteristics

[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 $\frac{\#\text{Molds cleaned}_t}{\#\text{Molds cleaned}_{t-1}}$

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

include the natural logarithm of market capitalization (*ln(Size)*); the natural logarithm of book-to-market ratio (*ln(BM)*); return on assets (*ROA*), calculated as net income divided by total assets; debt to assets ratio (*Leverage*), calculated as total liabilities divided by total assets; sales growth (*Sales growth*), defined as the ratio of sales in the current fiscal year to sales in the last year minus one; financial constraints (*KZ*), defined as the Kaplan-Zingales index; cash ratio (*Cash*), calculated as cash divided by total assets; price momentum (*MOM*), defined as the cumulative 12-month return of a stock, excluding the immediate past month; and quarterly stock returns (*Stock returns*).

4.6. Construction of key variables

To capture the exposure of a firm to nonattainment designations, we construct the variable *NA ratio* which equals to the number of polluting plants located in nonattainment counties for a given firm divided by the total number of plants owned by the given firm. This variable is constrained between zero and one and a higher value indicates a greater exposure of a firm to nonattainment designations. However, not all polluting plants emit ozone and the extent to which a firm is regulated depends on the amount of ozone emitted across its nonattainment plants. Since emission limits in nonattainment counties are based on the *amount* of ozone emissions and not ozone emission *intensity* (i.e., ozone emissions per unit of production), we measure the ozone emissions of a given firm by calculating the variable *NA ozone*, which equals to the natural logarithm of one plus the total amount of ozone air emissions (in pounds) in nonattainment counties of a given firm in a given year. Similarly, to capture a firm's exposure to attainment redesignations, we define the variable *Redesig ratio* which equals to the number of polluting plants located in counties redesignated to attainment for a given firm divided by the total number of polluting plants owned by the firm. *Redesig ozone* is the natural logarithm of one plus the total amount of ozone air emissions (in pounds) in counties redesignated to attainment for a given firm in a given year.

Since a county's monitored ozone pollution levels are observable, attentive shareholders may be able to anticipate a county's nonattainment status. We exploit this feature of our setting and decompose nonattainment designations into an anticipated component and an unexpected component based on county-level DVs. Specifically, we calculate the DVs of each county for each ozone standard and determine whether the county is in nonattainment based on whether the DVs exceed the relevant threshold.[15] We define unexpected nonattainment

[15]We compute DVs using only the data available to shareholders at the time of nonattainment designations. For example, the rule used to calculate the DVs for the 8-Hour Ozone (1997) standard effective on June 15, 2004 is the three-year rolling average of the fourth highest daily ozone reading in each year. Thus, we use

designations as those counties that are predicted to be in attainment based on DVs, but end up in nonattainment on the actual designation date.[16] Similarly, anticipated nonattainment designations refer to those counties that are predicted to be nonattainment based on DVs and do actually end up in nonattainment. We construct the variables *Unexp. NA ratio* and *Antic. NA ratio* to be equal to the number of polluting plants located in unexpected and anticipated nonattainment counties for a given firm divided by the total number of polluting plants owned by the firm, respectively.

4.7. Descriptive statistics

Panels A and B of Table 1 present summary statistics on the firm and plant level variables, respectively. A full list of the variables used in this paper and their data sources can be found in Table A.1 in Appendix A. The mean of *NA ratio* implies that during nonattainment designations, roughly 59.3% of a firm's polluting plants are affected. In addition, approximately 22.8% of a firm's polluting plants are exposed to unexpected nonattainment designations, while 36.5% are exposed to anticipated nonattainment designations. The mean for *NA ozone* indicates that the typical firm in our sample emits roughly 230 pounds of ozone air emissions across all polluting nonattainment plants. Both *NA ratio* and *NA ozone* have sizable standard deviations, indicating that there is substantial variation in the exposure of firms to nonattainment designations and their ozone air emissions. During attainment redesignations, a typical firm has roughly 17.2% of its polluting plants in nonattainment counties redesignated to attainment.

Internet Appendix Table IA.3 breaks down county nonattainment designations and attainment redesignations by state. Most states have counties that were in nonattainment at least once during the sample period; only 11 states never had any counties designated nonattainment. In terms of redesignations to attainment, 20 states have all of their nonattainment counties redesignated back to attainment, while 8 states have never experienced an attainment redesignation event during our sample period. More importantly, there is a low correlation

ozone concentration data from 2001 to 2003 in calculating DVs to predict a county's nonattainment status for the nonattainment designation on June 15, 2004.

[16]The EPA may designate certain counties as nonattainment even though their ozone concentrations were in compliance with the NAAQS threshold. Consider the case of the Metro Atlanta area. On June 15, 2004, only four counties in the center of Metro Atlanta had ozone readings that qualified them for nonattainment status. However, the EPA designated a total of eighteen counties in the Metro Atlanta area as nonattainment. In making their decision, the primary criterion given by the EPA for designating these specific counties as nonattainment was that their polluting activity was expected to contribute to the ozone levels of other counties in the Metro Atlanta area. In other cases, a county that has an ozone concentration below the NAAQS threshold may be designated nonattainment not because it contributes to the pollution of other counties, but because its ozone emissions are trending upwards.

between the number of ozone plants per county and the number of nonattainment counties in each state. This result provides additional support that nonattainment designations are generally unrelated to local county-level economic activities.

5. Empirical methodology

We begin by studying the shareholder wealth effects of nonattainment designation events by using an event study specification (MacKinlay, 1997). We estimate market model parameters for each firm-event date pair using 250 trading days of return data ending 20 days before the event date. The CRSP value-weighted return is used as the proxy for the market return and abnormal returns are computed by subtracting the market-model expected return from the firm's stock return. Daily abnormal stock returns are cumulated to obtain the CAR from day t_1 before the event date to day t_2 after the event date. Becker and Henderson (2000) find that in nonattainment areas, regulators first focus on plants belonging to large firms and then successively incorporate plants owned by smaller firms. Thus, we calculate value-weighted average CARs using a firm's market capitalization in the period before the nonattainment designation.[17] To test for the significance of the mean value-weighted CAR, we calculate t-statistics allowing for event-induced changes in variance following Boehmer, Musumeci, and Poulsen (1991). We also compute a generalized nonparametric Wilcoxon sign-rank test to test for the significance of the median value-weighted CAR. Our focus is on the 7-day $(-3, +3)$ and 11-day $(-5, +5)$ CARs centered on the effective date of nonattainment designations. All CARs are winsorized at the 1st and 99th percentiles to mitigate the effect of outliers. Our sample consists of firms that have at least one polluting plant located in counties designated nonattainment.

Although the event study offers insight into shareholders' average reaction to nonattainment designations on the extensive margin of ozone pollution, a firm can own many plants operating across multiple attainment and nonattainment counties and the extent that an ozone-emitting plant is regulated depends on the intensive margin of emissions. Thus, we use cross-sectional regressions to examine the variation in CARs driven by the interaction between the proportion of plants located in nonattainment counties of a given firm and its total ozone emissions in

[17] Brav, Geczy, and Gompers (2000) argue that value weighting is the correct method to compute average CARs if the goal is to quantify investors' average wealth change subsequent to an event.

nonattainment counties. Specifically, we estimate the following specification:

$$\begin{aligned} CAR_{i,t} &= \beta_0 + \beta_1 NA\ ratio_{i,t} + \beta_2 NA\ ozone_{i,t-1} + \beta_3 NA\ ratio_{i,t} \times NA\ ozone_{i,t-1} \\ &+ \beta_4 X_t + \text{F.E.} + \varepsilon_{i,t} \end{aligned} \tag{1}$$

for firm i and year t. The dependent variable is the 11-day CAR associated with nonattainment designations. We measure *NA ozone* in the year before the event year to reflect the emissions data available to shareholders at the time of nonattainment designations. X_t represents the set of control variables related to a firm's polluting activities and financial characteristics. We include event year fixed effects and following Hsu et al. (2022), we include industry fixed effects based on Fama and French's (1997) 48 industry classifications. Standard errors are clustered at the firm level because facilities are nested within firms. The coefficient of interest is β_3, which measures shareholders' differential reactions to nonattainment designations depending on the exposure of a firm to nonattainment designations and its total amount of ozone air emissions across nonattainment plants. We modify our event study and regression specifications accordingly when examining shareholder reactions to attainment redesignations. These specifications are explained in complete detail when we present the results.

6. Results

6.1. Event study for nonattainment designations

We analyze the statistical properties of the 7-day $(-3, +3)$ and 11-day $(-5, +5)$ CARs around the effective date of nonattainment designations. Table 2 reports the market's reaction to nonattainment designations. Panel A presents the mean and median value-weighted CARs along with the test statistics for the sample of firms impacted by all nonattainment designations. Columns (1) and (2) show the results for firms with at least one polluting plant located in counties that are designated nonattainment. The results indicate that nonattainment designations are associated with positive abnormal stock returns. For firms with at least one polluting nonattainment plant, the average CAR is 0.24% ($t = 2.73$) and 0.62% ($t = 6.93$) for the windows $(-3, +3)$ and $(-5, +5)$, respectively. The sign test statistics for the median value-weighted CARs are also highly significant for both windows. The positive effect on shareholder wealth is also economically meaningful. Given that the average market capitalization of the sample firms used in the nonattainment analysis is approximately \$1.28 billion, the average gain associated with nonattainment designations is approximately \$8 million (0.62% × \$1.28 billion) over the 11-day window.

However, pooling together all firms is a crude way of analyzing the relation between changes in shareholder value and nonattainment designations because this procedure assumes that all firms are equally regulated in a nonattainment county. Recall that only ozone-emitting plants are regulated under ozone NAAQS, while those that emit other pollutants are unaffected by the nonattainment status. Thus, we split firms into those that only own non-ozone nonattainment plants (columns (3) and (4)) and those that own at least one ozone nonattainment plant (columns (5) and (6)). A plant is classified as an ozone emitter based on its ozone emission status in the year prior to the event date because this is the information that is available to shareholders at the time of nonattainment designation. Examining these two subsamples, we find that the positive market reaction appears to be completely driven by those firms that own at least one ozone nonattainment plant. Not only are the mean and median value-weighted CARs statistically significant in columns (5) and (6), but they are also economically larger in magnitude than those in columns (3) and (4). This result also confirms that shareholders only react to nonattainment designations for firms that are impacted by the regulation.

Figure 2 summarizes the evidence from Panel A of Table 2 by plotting the mean value-weighted CARs over the interval $(-20, +20)$. As the graph shows, average CARs are relatively stable prior to the event date and are similar for both subsample of firms. However, on the nonattainment designation effective date, there is a substantial increase in the CAR for the set of firms that own at least one ozone nonattainment plant (solid line) while there is very little movement in the CAR for those firms that only own non-ozone nonattainment plants (dashed line). The gap between the two subsample of firms becomes even more pronounced after the nonattainment designation effective date.

Panel B of Table 2 presents the same set of analysis as in Panel A but for firms impacted by unexpected nonattainment designations, defined to be those firms whose majority of plants are located in unexpected nonattainment counties.[18] The results across all columns mirror those in Panel A and indicate that the market reacts positively to unexpected nonattainment designations, with the effect concentrated in the subsample of firms that own at least one ozone nonattainment plant. Panel C presents the results for firms impacted by anticipated nonattainment designations, defined to be those firms whose majority of plants are located in anticipated nonattainment counties. The statistically significant mean and median value-weighted CARs are generally smaller in magnitude in columns (5) and (6) of Panel C than those in Panel B.

[18] A firm operates a majority of plants in unexpected nonattainment counties if it owns more plants in unexpected nonattainment counties than in anticipated nonattainment counties.

The extent of the market's reaction to nonattainment designation should depend on the size of the discrepancy between investors' predictions of nonattainment status and realized nonattainment designations. Since unexpected nonattainment designations are those where investors' beliefs are opposite to realizations, it comes as no surprise that the positive reaction is larger for unexpected nonattainment designations. Furthermore, even though investors' predictions are in line with realizations for anticipated nonattainment designations, there is still some new information contained in anticipated nonattainment designations since nonattainment designations are not solely based on DVs and may depend on other unobservable factors.[19] Therefore, there is still a degree of uncertainty regarding the designation of nonattainment even if a county's DV exceeds the relevant threshold. This rationale explains why we find smaller but still significant CARs for regulated firms in Panel C. In summary, the results in this section are consistent with *Hypothesis 1(a)*.

6.2. Cross-sectional regressions

6.2.1. Exposure to nonattainment designations and the intensive margin of ozone pollution

To examine *Hypothesis 1(b)*, we present the regression estimates from Equation (1) in Table 3. Column (1) uses the market model CAR $(-5, +5)$ as the dependent variable. The coefficient estimate on the interaction term *NA ratio* × *NA ozone* is negative and statistically significant ($t = -2.14$), indicating that when firms own a high proportion of nonattainment plants and are heavy polluters of ozone in nonattainment counties, investors react less favorably. In economic terms, given a one standard deviation increase in the (log of) ozone air emissions in nonattainment counties, a firm that operates a proportion of nonattainment plants at the median level experiences 0.42 percentage points lower CARs compared with a firm that operates a proportion of nonattainment plants at the 25 percentile level.

To rule out that other non-event characteristics such as size, value, growth, momentum, or industry are driving the presented results, we also compute CARs with respect to alternative benchmark models. In column (2), we use Fama and French's (1997) 48 value-weighted industry return as the benchmark return. In column (3), event returns are risk adjusted using Carhart's (1997) four-factor model. In both columns, the coefficient on the double interaction term remains negative and statistically significant. These alternative ways of

[19] For example, the Winston-Salem/Greensboro metro area was designated nonattainment based on ozone DVs. However, the state of North Carolina petitioned the EPA for a redesignation because the DVs were sharply falling in the metro area and as a result of the naturally occurring declines, they were on pace to meet the standards in coming years without having to comply with the costly regulations that come with nonattainment status. The petition was successful and the counties were designated as attainment in large part because ozone concentrations in the region were on a downward trend.

calculating abnormal returns leave the previous conclusions unaffected, which is in line with prior methodological research on event studies showing that benchmark returns used for risk adjustment rarely matter in the short-run (Brown & Warner, 1985; Kothari & Warner, 2007).

To examine whether the cross-sectional variation in CARs is driven by unexpected or anticipated nonattainment designations, we replace *NA ratio* and its corresponding interaction terms in Equation (1) with *Unexp. NA ratio* and *Antic. NA ratio*. The results are reported in columns (4) to (6) of Table 3. Across all three columns, the coefficients on the interaction terms associated with unexpected nonattainment designations are negative and statistically significant, while the coefficients for the interaction terms related to anticipated nonattainment designations are all statistically insignificant. This decomposition shows that the results obtained earlier in columns (1) to (3) are mainly driven by unexpected nonattainment designations. In particular, investors react less favorably towards heavy ozone-polluting multi-plant firms only if they operate a large fraction of plants in counties that are unexpectedly designated nonattainment. Overall, the results in this section are in line with the predictions of *Hypothesis 1(b)*.

6.2.2. Heterogeneity in cross-sectional variation

In this section, we explore certain firm characteristics that could lead to possible heterogeneity in the cross-sectional variation in the market's reaction to nonattainment designations. To do so, we augment Equation (1) with a variable Z that refers to a set of firm characteristics and its corresponding interactions. Our focus is on the triple interaction term $NA\ ratio \times NA\ ozone \times Z$ that represents the differential effects of a particular firm characteristic on investors' reactions of heavy ozone-polluting firms exposed to nonattainment designations.

We begin by examining the proportion of "young" nonattainment plants that a given firm operates. Becker and Henderson (2001) find that younger plants in nonattainment counties face higher production costs because older plants can escape the stringent regulations on new equipment until they renew equipment or expand operations. Thus, nonattainment designations are most burdensome for heavy ozone-polluting firms that operate a large proportion of young plants which could lead to lower CARs for these firms. Following Becker and Henderson (2001), we define the variable *Young plant ratio* to be the number of nonattainment plants between zero and five years of age for a given firm in a given year divided by the total number of plants owned by the given firm.[20]

[20]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 NETS database.

Next, we examine the distance of a given firm's nonattainment plants to the nearest ozone monitor. During nonattainment designations, firms that operate ozone-emitting plants located closer to monitors are regulated more intensely than those located further away, since regulatory effort is localized in the areas surrounding nonattainment monitors (Auffhammer, Bento, & Lowe, 2009; Bento et al., 2015; Gibson, 2019). Thus, firms with nonattainment plants that are located close to monitors are subject to potentially greater compliance costs relative to those firms with plants located further away, which may lead to lower CARs for the former firms. We introduce the variable *Close monitor ratio* which is equal to the number of nonattainment plants with distances to the nearest monitor in the bottom tercile for a given firm in a given year divided by the total number of plants owned by the given firm.

We then examine whether a firm operates nonattainment plants that own an ozone operating permit. These operating permits are issued by the EPA at the plant-level which specifies the amount and type of pollutants the facility is permitted to emit. During nonattainment designations, we expect heavy ozone-polluting firms that own ozone operating permits at nonattainment plants to experience higher CARs than those that do not own operating permits as the former firms have a lower risk of violating nonattainment standards (Walker, 2013). Thus, we compute the variable *Permit holder ratio* as the number of nonattainment plants with ozone operating permits for a given firm in a given year divided by the total number of plants owned by the given firm.

We also study a firm's risk of distress. Akey and Appel (2021) show that firms with a high risk of distress may benefit from events that reduce potential environmental costs by shifting harm to other stakeholders. Since nonattainment designations represent an increase in potential environmental costs, heavy ozone-polluting firms with a high risk of distress are limited in their ability to benefit from such an event, implying that these firms are likely to experience lower CARs compared to firms with a low risk of distress. Thus, we define *Low z-score* to be a dummy variable equal to one if a given firm's z-score is in the bottom tercile, and zero otherwise.

Finally, we investigate a firm's environmental score obtained from KLD.[21] Firms with higher environment scores are shown to be better protected from negative environmental shocks (Godfrey, Merrill, & Hansen, 2009) and implement superior corporate environmental policies that mitigate environmental risk exposure which leads to higher valuations (Chava, 2014; Fernando et al., 2017). During nonattainment designations, we expect heavy ozone-polluting

[21]This dataset has been used extensively in the finance literature to assess corporate environmental performance (e.g., Deng, Kang, & Low, 2013; Fernando et al., 2017; Sharfman & Fernando, 2008).

firms with low environment scores to be less able to cushion against the regulatory burden imposed upon them, leading to lower CARs for these firms when compared to those with high environment scores. We compute the variable *Low environment score* to be a dummy variable equal to one if the difference between the average strength and concern environment scores for a given firm is in the bottom tercile, and zero otherwise.

We present the results in Table 4. For each specification, the variable included in Z is listed on top of each column. Consistent with our predictions, the triple interaction terms in columns (1), (2), (4), and (5) are all negative and statistically significant indicating that heavy ozone-polluting firms with a high proportion of young nonattainment plants, a high proportion of nonattainment plants located close to monitors, a high risk of distress, and a low environmental score experience lower CARs when exposed to nonattainment designations. The positive and statistically significant coefficient on the triple interaction term in column (3) indicates that firms with a high proportion of nonattainment plants with ozone operating permits experience higher CARs.

6.3. Event study and regression analyses for attainment redesignations

In this section, we examine market reactions to attainment redesignations. Since attainment redesignations represent an easing of regulation, we expect the market to react in the opposite direction to nonattainment designations. Panel A of Table 5 presents the mean and median value-weighted CARs surrounding attainment redesignation events. Overall, the market reacts negatively to attainment redesignations in columns (1) and (2). Splitting the sample into those firms that own only non-ozone plants (columns (3) and (4)) and at least one ozone plant (columns (5) and (6)) in counties that are redesignated to attainment shows that the negative reaction is entirely driven by the latter set of firms. The economic magnitude of the negative reaction is, however, slightly smaller in absolute value than that of nonattainment designations. For example, the average CAR $(-5, +5)$ of -0.22% in column (2) implies that the average loss associated with attainment redesignations is approximately $6.2 million over the 11-day window.[22]

Figure 3 summarizes the evidence from Panel A of Table 5 by plotting the mean value-weighted CARs over the interval $(-20, +20)$. Prior to the attainment redesignation date, average CARs for both subsample of firms move in parallel. However, the evolution of the CARs beginning from the attainment redesignation effective date moves in the opposite

[22]The average market capitalization of the sample firms used in the attainment redesignation analysis is approximately $2.81 billion.

direction compared to that of Figure 2. In particular, the set of firms that own at least one ozone plant in counties redesignated to attainment (solid line) experiences a substantial decrease in CARs compared to those firms that only own non-ozone plants (dashed line). The gap between the two CARs continues to widen in the period after the attainment redesignation effective date.

Given the strikingly opposite investor reactions in Figures 2 and 3, one may wonder why investors do not endogenize the dynamics of regulatory compliance from the onset of nonattainment designations by pricing in the stock price implications of eventual attainment redesignation during the initial nonattainment designations. A plausible explanation is that firms usually operate multiple plants across many counties and each nonattainment county has different plant-specific regulations. For example, in some nonattainment counties, plants are subject to LAER, while plants in other counties may be subject to RACT. Furthermore, depending on the severity of the nonattainment designation, different counties are given different amounts of time to reach attainment. Some counties are allowed only a couple of years, while others are allocated up to 20 years to attain the NAAQS threshold. In many cases, even if a county is unable to meet the attainment deadline, they may apply for an attainment date extension. Thus, given the uncertainty surrounding the impact of attainment redesignations on a firm across all of its polluting plants, it is hard for investors to endogenize the stock price valuations of attainment redesignations from the onset.

Panels B and C of Table 5 present investor reactions to unexpected and anticipated attainment redesignations, respectively. In nonattainment counties where monitored data demonstrate that the NAAQS has been achieved, the EPA may issue a “clean data determination” indicating that the air quality has met the required standard. Thus, attentive investors who observe which counties receive clean data determinations may be able to predict attainment redesignations. We define unexpected attainment redesignations as those counties that are predicted to remain in nonattainment because they do not receive a clean data determination, but end up redesignated to attainment on the event date. Similarly, anticipated attainment redesignations are those counties that are predicted to be redesignated to attainment because they receive a clean data determination and do actually end up redesignated to attainment. Unlike nonattainment designations, the negative market reaction to attainment redesignations is driven only by unexpected attainment redesignations since the CARs are negative and statistically significant only in Panel B. This result is consistent with the interpretation that there is minimal new information content in anticipated attainment redesignations. Receiving a clean data determination requires attaining the relevant ozone standard, which occurs only after a lengthy period of emissions reduction. Redesignation to attainment is then only a matter of complying with additional non-emissions related statutes. Therefore, there is little uncertainty left to be resolved on the event date for anticipated attainment redesignation, leading to a muted reaction.

To examine cross-sectional variation in CARs surrounding attainment redesignations, we estimate the following equation:

$$\begin{aligned} CAR_{i,t} = \beta_0 + \beta_1 \textit{Redesig ratio}_{i,t} + \beta_2 \textit{Redesig ozone}_{i,t-1} + \beta_3 \textit{Redesig ratio}_{i,t} \\ \times \textit{Redesig ozone}_{i,t-1} + \beta_4 X_t + \text{F.E.} + \varepsilon_{i,t} \end{aligned} \tag{2}$$

for firm i and year t. The dependent variable is the 11-day CAR associated with attainment redesignations. The coefficient of interest is β_3, which measures shareholders' differential reactions to heavy ozone-polluting firms experiencing attainment redesignations.

We present the estimation results for Equation (2) in columns (1) to (3) of Table 6. The coefficients on the double interaction term *Redesig ratio* × *Redesig ozone* are all positive and statistically significant, indicating that investors react more favorably for firms that operate a greater proportion of plants in counties redesignated to attainment and are heavy ozone polluters in those areas. In economic terms, given a one standard deviation increase in the (log of) ozone air emissions in counties redesignated to attainment, a firm that operates a proportion of plants in counties redesignated to attainment at the median level experiences 0.11 percentage points higher CARs compared with a firm that operates a proportion of plants in counties redesignated to attainment at the 25 percentile level.

Columns (4) to (6) report the coefficient estimates from Equation (2) by replacing *Redesig ratio* and its interactions with *Unexp. redesig ratio* and *Antic. redesig ratio*, defined to be equal to the number of polluting plants located in unexpected and anticipated attainment redesignation counties for a given firm divided by the total number of polluting plants owned by the firm, respectively. Only the coefficient on the unexpected attainment redesignation interaction term is statistically significant, implying that investors only react more favorably during redesignations where their predictions are opposite to realizations and hence where the new information content is most relevant. Overall, the results in this section largely support the predictions of *Hypothesis 2(a)* and *2(b)*.

7. Mechanisms

As discussed in Section 3.1, there are three potential market forces that interact together to influence the market's reaction to nonattainment designations. In this section, we provide evidence of the mechanisms for each of these market forces.

7.1. Competition

We begin by examining the competitive advantages of nonattainment designations for incumbent firms. Specifically, we study whether nonattainment designations reduce the overall competition of incumbent firms at the county-level and at the firm-level.

7.1.1. County-level measures

We measure competition at the county-level by computing the Herfindahl-Hirschman Index (HHI) based on the dollar amount of sales and number of employees at the facility-level using data from NETS. We define *Sales HHI* and *Emp HHI* to be the sum of the squared facility-level sales and employee shares, respectively, of all polluting plants that operate in a given county in a given year. A greater value indicates that the amount of sales and number of employees across polluting plants in a given county is more concentrated and hence serves as a measure of competition at the county-level.

To examine how county-level competition changes around nonattainment designations, we use a difference-in-differences specification. Our focus is on the two-year window centered on the nonattainment designation year. For instance, if the nonattainment designation occurs in year t, then $t-2$ and $t-1$ are the pre-nonattainment designation years, while t, $t+1$, and $t+2$ are the post-nonattainment designation years. Formally, the baseline specification is:

$$\begin{aligned} &\mathit{Sales\ HHI}_{c,t} \text{ or } \mathit{Emp\ HHI}_{c,t} = \beta_0 + \beta_1 NA_{c,t} + \beta_2 \mathit{Post\ NA}_t + \beta_3 NA_{c,t} \times \mathit{Post\ NA}_t \\ &+ \beta_4 X_{c,t-1} + \text{F.E.} + \varepsilon_{c,t} \end{aligned} \tag{3}$$

for county c and event year t. NA_t is a dummy variable equal to one if a given county is designated nonattainment in year t, and zero otherwise. *Post* NA_t is a dummy variable equal to one for the nonattainment designation year and the two following years, and zero otherwise. $X_{c,t-1}$ is a set of county-level control variables including the natural logarithm of one plus the population levels, the natural logarithm of one plus the total personal income, the natural logarithm of one plus the number of establishments, NO_x emissions to employment ratio, the change in employment levels, and a dummy variable equal to one if the county is located in a MSA.[23] We include county fixed effects to absorb all time-invariant differences across counties and year fixed effects to control for aggregate macroeconomic shocks. If nonattainment designations create barriers to entry and reduce competition for incumbents, then we expect $\beta_3 > 0$.

We present the results in Table 7. Both columns (1) and (3) show that the coefficient on *NA* × *Post NA* is positive and statistically significant, indicating that the amount of sales and number of employees across polluting plants in counties designated nonattainment are more concentrated in the post-nonattainment period. We also examine the temporal dynamics of the changes in *Sales HHI* and *Emp HHI* to confirm the absence of pre-trends (i.e., differential response before nonattainment designations), which is a necessary condition for the validity of our difference-in-differences setting. Specifically, we extend the window length and focus on four years before to four years after the nonattainment designation. Then, we replace $Post\ NA_t$ with a set of year dummy variables, *Post NA(k)*, which is equal to one for the kth year relative to the nonattainment designation year, and zero otherwise. The year before the nonattainment designation is the omitted category. As shown in columns (2) and (4), there are no significant differences in *Sales HHI* and *Emp HHI* between attainment and nonattainment counties in the pre-nonattainment designation period. Then, starting in the event year, competition among polluting plants begins to decrease for counties designated nonattainment and continues up to four years after the designation.

7.1.2. Firm-level measures

Recall from Sections 6.1 and 6.2 that the market reaction to nonattainment designations is primarily driven by the sample of firms operating ozone-emitting plants. Thus, to capture the fact that firms may operate both ozone and non-ozone plants, we examine the competition among incumbents at the firm-level. We use two measures of firm-level product market competition. First, we employ the product market fluidity measure (*Fluidity*) constructed by Hoberg, Phillips, and Prabhala (2014). This measure reflects both the degree of product similarity of a given firm with its competitors and the product market's instabilities arising from competitor actions. A higher value is associated with a more significant competitive threat for the firm. The second measure is the total product similarity score (*Similarity*) constructed by Hoberg and Phillips (2010, 2016), which reflects the amount of competition a given firm faces and the product relatedness to each competitor. A higher value is associated

[23] Data is obtained from the U.S. Census Bureau

with more competitive pressure for the firm.[24]

We use a triple difference-in-differences specification as follows:

$$
\begin{aligned}
&\textit{Fluidity}_{i,t} \text{ or } \textit{Similarity}_{i,t} = \beta_0 + \beta_1 \textit{Firm NA}_{i,t} + \beta_2 \textit{Firm ozone ratio}_{i,t-1} + \beta_3 \textit{Post NA}_t \\
&+ \beta_4 \textit{Firm NA}_{i,t} \times \textit{Firm ozone ratio}_{i,t-1} + \beta_5 \textit{Firm NA}_{i,t} \times \textit{Post NA}_t \\
&+ \beta_6 \textit{Firm ozone ratio}_{i,t-1} \times \textit{Post NA}_t + \beta_7 \textit{Firm NA}_{i,t} \times \textit{Firm ozone ratio}_{i,t-1} \\
&\times \textit{Post NA}_t + \beta_8 X_{i,t} + \text{F.E.} + \varepsilon_{i,t}
\end{aligned}
\tag{4}
$$

for firm i and event year t. $\textit{Firm NA}_t$ is a dummy variable equal to one if a given firm operates a polluting plant in a county that is designated nonattainment in year t, and zero otherwise. $\textit{Firm ozone ratio}_{t-1}$ is the ozone air emissions for a given plant as a proportion of the plant's overall air emissions averaged across all plants owned by a given firm in year $t-1$. This variable captures the dependence of a given firm on ozone emissions; it is constrained between zero and one and a higher value indicates a greater proportion of the firm's emission is ozone. $\textit{Post NA}_t$ is a dummy variable equal to one for the nonattainment designation year and the two following years, and zero otherwise. $X_{i,t}$ is a set of firm-level control variables. If nonattainment designations decrease competition among ozone-dependent firms, then we expect $\beta_7 < 0$.

The results are shown in Table 8. For brevity, only the coefficients on the triple interaction term are presented. In columns (1) and (3), the coefficient on *Firm NA* × *Firm ozone ratio* × *Post NA* is negative and statistically significant, implying that ozone-dependent firms exposed to nonattainment designations face less competitive pressures in the post-nonattainment period. We also confirm the absence of pre-trends in columns (2) and (4). Specifically, none of the coefficients involving the year dummy variables prior to the nonattainment designation event year are statistically significant. In summary, the competition analyses suggest that, on average, nonattainment designations decrease county-level competition among polluting plants, with ozone-dependent firms experiencing the most benefits from the decrease in competitive pressure.

7.2. Environmental performance

In this section, we conduct a series of analysis at the facility-level to determine whether nonattainment designations can create shareholder value for incumbent firms through improved environmental performance. We estimate panel regressions that study the effect of

[24] Data on both measures can be obtained from `https://hobergphillips.tuck.dartmouth.edu/`.

nonattainment designation on ozone-dependent incumbent plants using a variety of plant-level outcome variables. These regressions are of the following specification:

$$y_{p,c,i,t+1} = \beta_0 + \beta_1 Ozone\ ratio_{p,t} + \beta_2 NA_{c,t} \times Ozone\ ratio_{p,t} + \text{F.E.} + \varepsilon_{p,c,i,t+1} \quad (5)$$

for plant p, located in county c, belonging to parent firm i, and in year t. The variable $NA_{c,t}$ is a dummy variable that equals to one if county c is in nonattainment in year t, and zero otherwise. To measure the dependence of a given plant on ozone emissions, we define $Ozone\ ratio_{p,t}$ to be equal to the total ozone air emissions for plant p in year t as a proportion of the plant's overall air emissions across all chemicals. This variable is constrained between zero and one and a higher value indicates a greater proportion of the facility's pollution is ozone. The dependent variables ($y_{p,c,i,t+1}$) are defined in detail when we present the results. Following Gibson (2019), we examine one-year forward measures of the outcome variables because state regulations may not take effect in the first nonattainment year and some firm responses plausibly require substantial time to implement. The coefficient of interest is β_2, which measures the effect of nonattainment status for ozone-dependent plants on the outcome variable.

We include plant fixed effects since a county's attainment/nonattainment status varies over time. Consequently, individual plants might be subject to NAAQS regulations in one period but not in a different one. Plant fixed effects, thus, use variation from within-plant comparisons under the attainment and nonattainment regulation regimes. We also use county–year fixed effects to exploit the intracounty variation that exists because only plants that emit ozone are subject to ozone NAAQS. The inclusion of county–year fixed effects, thus, controls for time-varying factors common to all plants within a county to ensure that these factors are not confounded with the effects of nonattainment status.[25] Additionally, we include parent firm–year fixed effects and industry–year fixed effects, defined using the primary three-digit NAICS code for each plant, to control for time-varying heterogeneity at the parent firm and industry levels. Standard errors are clustered at the county-level.

7.2.1. Emissions

One possible channel through which nonattainment designations can create positive value is the reduction of plant-level ozone emissions. For example, Kim and Kim (2020) show that firms that reduce toxic chemical emissions experience positive investor reactions. Similarly, King

[25] A main effect for $NA_{c,t}$ is unnecessary because it is absorbed by the county–year fixed effects.

and Lenox (2002) find that pollution reduction through waste prevention leads to greater firm profitability. Hart and Ahuja (1996) argue that the biggest bottom line benefits of pollution reduction accrue to the high polluters since there are more low-cost improvements to be made. Thus, to examine whether nonattainment regulations reduce ozone emissions, we analyze the effect of nonattainment status on the quantity and toxicity of plant-level ozone emissions.

We present the estimation results of Equation (5) for ozone emissions in Figure 4. The horizontal axis shows the point estimates and the corresponding 95% confidence intervals for the interaction term $NA \times Ozone\ ratio$. The dependent variables are listed on the vertical axis. The first outcome variable, *Ozone emissions*, is the natural logarithm of one plus the total amount of ozone air emissions (in pounds) at the plant-level in year $t+1$. The point estimate (≈ -0.30) on the interaction term is negative and statistically significant ($t = -2.60$), indicating that nonattainment status is associated with a future decrease in ozone emissions for incumbent plants that are more dependent on ozone chemicals. The decrease in emissions is economically large; given a one standard deviation increase in *Ozone ratio*, a plant that operates in a nonattainment county decreases its ozone emissions by roughly 12% in the following year.

We also examine the types of ozone chemicals emitted by plants. By definition, the ozone chemicals included in the TRI database are toxic, though not all have adverse effects on humans. If nonattainment status truly improves environmental outcomes, then nonattainment regulation should reduce emissions of ozone chemicals that are hazardous to humans. In the remaining rows of Figure 4, we show that nonattainment status decreases ozone-dependent incumbent plants' emissions for chemicals that are known to have biological impact to human critical systems including the nervous and respiratory systems. There is also a decrease in ozone emissions that have harmful human effects especially those related to chronic health effects. Overall, the results in this section show that decreases in ozone emissions is a possible channel through which nonattainment status can create positive shareholder value for incumbent plants.

7.2.2. Penalties

We next test the effects of nonattainment status on the environmental legal liabilities of ozone-dependent incumbent plants. Xu and Kim (2022) show that higher total toxic releases increase the likelihood of positive legal liabilities and make legal liabilities costlier. Karpoff et al. (2005) demonstrate that the loss in market value for environmental violators mainly reflect these firms' legal penalties while market-induced reputation penalties are negligible.

Since nonattainment designations are associated with reductions in ozone emissions, we expect a decrease in future legal liabilities, which could plausibly lead to an upward revision in shareholder value.

We present the estimation results of Equation (5) for legal liabilities in Figure 5. The horizontal axis shows the point estimates and the corresponding 95% confidence intervals for the interaction term *NA* × *Ozone ratio*. The dependent variables are listed on the vertical axis. The outcome variables in the first four rows are the natural logarithm of one plus the number of judicial actions, federal penalties, compliance actions, and SEPs of a given plant in year $t+1$, respectively.[26] The coefficients on all four interaction terms are negative and statistically significant (at the 10% level or better). The outcome variables in the last three rows are the natural logarithm of one plus the dollar amount (in millions) of federal penalties, compliance actions, and SEPs of a given plant in year $t+1$, respectively. The coefficients are again all negative and statistically significant. Overall, the results in Figure 5 indicate that ozone-dependent plants located in nonattainment counties experience fewer total number and smaller monetary value of legal liabilities.

7.2.3. High priority violations

In this section, we study the relation between nonattainment designations and the environmental compliance status of ozone-dependent plants. Serious plant violations may lead to HPVs,[27] where the facility is subject to the threat of high fines, additional reporting, and intense regulatory oversight. Since the gravity of a HPV is much higher when a plant is located in a nonattainment county (Blundell et al., 2020), nonattainment status may incentivize ozone-dependent plants to avoid HPVs to minimize the risk of facing higher regulatory burdens, which may positively impact on shareholder value.

To test whether enhanced environmental compliance is valued by the market, we focus on firms that operate nonattainment plants involved in ozone-related HPVs and compute the CARs surrounding each HPV event. Our empirical specification is:

$$\begin{aligned} CAR_{i,t} &= \beta_0 + \beta_1 NA\ HPV_{i,t} + \beta_2 HPV\ ozone_{i,t-1} + \beta_3 NA\ HPV_{i,t} \times HPV\ ozone_{i,t-1} \\ &+ \beta_4 X_t + \text{F.E.} + \varepsilon_{i,t} \end{aligned} \tag{6}$$

for firm i and year t. The dependent variable is the 11-day CAR associated with the HPVs.

[26] SEPs are projects included as part of an enforcement settlement that provide a tangible environmental or public health benefit.

[27] HPVs cover a broad range of issues including excess emissions, failure to install plant modifications, and violating an operating parameter, among others.

$NA\ HPV_{i,t}$ is a dummy variable equal to one if firm i operates nonattainment plants involved in ozone-related HPVs in event year t, and zero otherwise. $HPV\ ozone_{i,t-1}$ is the natural logarithm of one plus the total amount of ozone air emissions (in pounds) across all plants that experience a HPV for firm i in year $t-1$. The coefficient of interest is β_3, which measures the degree to which the market penalizes heavy ozone-polluting firms that operate nonattainment plants involved in ozone-related HPVs. If the market values environmental compliance, then we expect $\beta_3 < 0$.

The estimation results are reported in columns (1) to (3) of Table 9. The coefficients on $NA\ HPV \times HPV\ ozone$ are all negative and statistically significant, indicating that heavy ozone-polluting firms operating nonattainment plants involved in ozone-related HPVs experience lower CARs. The loss in shareholder value is also economically significant. Given a one standard deviation increase in the (log of) ozone air emissions across HPV plants, a firm that operates nonattainment plants involved in ozone-related HPVs experiences 1.03 percentage points lower CARs compared with a firm that do not operate such plants.

Since HPV status triggers a period of intense oversight by the EPA that includes frequent inspections and explicit deadlines, conditional on nonattainment, we expect plant HPVs to be resolved in less time to avoid high fines. Column (4) of Table 9 reports the regression results from a proportional hazard Cox model where the dependent variable is a firm's maximum number of days taken to resolve the HPV across all HPV plants for a given firm. The hazard ratio corresponding to the interaction term is significantly greater than one,[28] suggesting that heavy ozone-polluting firms that operate nonattainment plants involved in ozone-related HPVs take less time to resolve HPVs. Column (5) uses a probit model and shows that these firms are unlikely to take more than six months to resolve HPVs.

7.3. Compliance costs

Lastly, we examine the potential compliance costs that facilities are subject to during nonattainment designations. Since there is no available data directly on plant-level pollution abatement costs, we proxy for the potential compliance costs associated with nonattainment designations by examining facilities' observable regulatory enforcement and pollution abatement efforts through source reduction activities. The intuition is that facilities with more regulatory enforcements and engage in more source reduction activities presumably have higher compliance costs. Our specification is similar to that of Equation (5), except the dependent variables measure a plant's regulatory enforcement and source reduction activities.

[28] The coefficient on the interaction term is 0.022 which corresponds to a hazard ratio of $\exp(0.022) \approx 1.022$.

In our analysis, we specifically distinguish between incumbent plants that are young and old because as discussed in Section 3.1, newer plants are subject to costly LAER requirements and bear the brunt of nonattainment regulations, while older plants are grandfathered and escape regulation until they expand operations. In particular, Becker and Henderson (2001) estimate that total compliance costs are 17.7% higher for young ozone-emitting plants between zero and five years of age in nonattainment counties relative to similar plants in attainment counties, while the difference for older ozone-emitting plants beyond five years of age is considerably lower at 9.5%. Thus, the degree to which an incumbent plant is grandfathered from compliance costs depends crucially on its age. Following Becker and Henderson's (2001) definition, we define *Young plant* to be a dummy variable equal to one if a given plant is between zero and five years of age in a given year, and zero otherwise. We augment Equation (5) by including *Young plant* and its interactions with *NA* and *Ozone ratio* as additional explanatory variables.

7.3.1. Regulatory enforcement

We examine the effect of nonattainment status on four types of plant-level regulatory enforcement including HPVs, Title V inspections, stack tests, and compliance evaluations. The latter three enforcement activities are plant-level evaluation tests conducted for the purposes of determining and demonstrating compliance with CAA regulations. Failing these tests has potential negative consequences in that the plant could be labeled as a high priority violator.

In Table 10, the dependent variables in columns (1), (2), (3) and (5) are the natural logarithm of one plus the number of HPVs, Title V inspections, stack tests, and full compliance evaluations of a given facility in year $t + 1$, respectively. In column (4), we use a dummy variable equal to one if a given facility fails a stack test, and zero otherwise. Across all columns, the coefficients on the triple interaction term *NA* × *Ozone ratio* × *Young plant* are all positive and statistically significant, indicating that ozone-dependent young plants in nonattainment counties are subject to more regulatory enforcements than otherwise similar but older plants. We also note that the coefficient on *NA* × *Ozone ratio* in column (1) is negative and statistically significant, implying that older ozone-dependent plants experience significantly fewer HPVs. This result coupled with the findings of the previous section that regulatory compliance is positively valued by the market provides further evidence for the positive shareholder value effects of nonattainment status through improved environmental performance.

7.3.2. Pollution abatement

We now examine the effect of nonattainment status on observable plant-level source reduction activities. Plants reporting to the TRI database are required to document the amount of source reduction activities at the chemical level that limit the amount of hazardous substances being released. Ozone emissions can either undergo treatment, recycling, or recovery before being released into the environment, with treatment being the primary form of abatement. Plants are also required to report the type of abatement activities that they engage in, the most common being "good operating practices", which comprises actions such as improved maintenance scheduling, record keeping, or procedures.

Columns (1) and (2) of Table 11 use the natural logarithm of one plus the amount of ozone air emissions (in pounds) that are treated and undergo source reduction (the sum of treated, recycled, and recovered), respectively. Columns (3) and (4) use a dummy variable equal to one if a given facility undertakes good operating practices and source reduction activities in general, respectively, and zero otherwise. The coefficients on *NA* × *Ozone ratio* × *Young plant* are all positive and statistically significant, implying that ozone-dependent young plants are investing more in pollution abatement in nonattainment counties than otherwise similar but older plants. This result is consistent with the grandfathering of older incumbent plants since only newer plants are required to install state-of-the-art pollution abatement technology in nonattainment counties to limit emissions. In summary, the analyses on regulatory enforcements and pollution abatement activities suggest that the compliance costs for ozone-dependent plants during nonattainment designations appear to be borne by younger plants.

8. Additional robustness tests

We perform a number of robustness checks and falsification tests. For brevity, we report a concise summary of these tests, while the detailed descriptions and corresponding tables can be found on the Internet Appendix.

In the cross-sectional analysis of CARs for nonattainment designations, we use toxicity-weighted ozone air emissions to control for the inherent heterogeneity of each chemical. We also use alternative independent variables to measure a firm's exposure to nonattainment designations. Specifically, to reflect the relative importance of a firm's various polluting plants, we use plant-level employee- and sales-weighted *NA ratio* in our baseline regressions. To control for firms self-selecting into nonattainment counties, we use Heckman's (1979) two-stage least squares for correction. Our results remain qualitatively similar when implementing all of these changes. In another robustness test, we control for possible information leakage prior to nonattainment designations by examining state recommendations of nonattainment to the EPA. Our findings relating to nonattainment designations and shareholder value are robust, after taking into account any potential information leakages.

We conduct falsification tests by using offsite ozone emissions and particulate matter emissions, both of which are not regulated under ozone nonattainment status. As expected, during nonattainment designations, there are no market reactions to these types of emissions nor do plants adjust their emissions of these types. In another falsification test, we examine market reactions to events that do not change a county's current nonattainment status by studying revocations of ozone standards. As expected, the market does not react to such events.

We also study the cross-sectional variation in CARs around regulatory events that increase the stringency of local environmental regulations, conditional on nonattainment status. Consistent with investors proportionately revising their beliefs downwards for heavy ozone-polluting multi-plant firms that are subject to even greater compliance costs due to an increase in the stringency of nonattainment regulations, we find that multi-plant firms that operate a greater proportion of ozone plants in nonattainment counties experiencing an increase in the stringency of regulation and are heavy polluters of ozone in these areas experience lower CARs. Lastly, we examine the possibility of intrafirm reallocation, whereby the positive reaction to nonattainment designations may be driven by multi-plant firms who plausibly have an advantage in that they can reallocate ozone emissions to plants located in attainment counties. However, we show that there are no spillover effects from nonattainment counties on the ozone emissions, production, and solvency of attainment ozone plants for multi-plant firms.

9. Conclusion

In this paper, we examine the effects of local environmental regulation and firm pollution on shareholder value. Using nonattainment designations induced by discrete policy changes in the NAAQS threshold as an exogenous source of variation in local regulatory stringency, we document that the stock market internalizes the perceived benefits and costs of local environmental regulation. Our results indicate that investors, on average, react positively to nonattainment designations on the extensive margin of ozone pollution. However, in the cross-section, heavy ozone-polluting multi-plant firms experience less favorable stock market reactions, consistent with the rationale that the greater compliance costs these firms face proportionately offset the benefits associated with nonattainment status. Reversals occur during attainment redesignations, whereby the overall stock market reaction is negative on the extensive margin of ozone pollution, but investors revise their beliefs upwards for heavy ozone-polluting multi-plant firms, who now experience more favorable stock market reactions.

We also document the mechanisms of three potential market forces that have implications on the benefits and costs of incumbents and new entrants in nonattainment counties. In particular, we show that nonattainment designations decrease county-level competition among polluting plants, with ozone-dependent firms experiencing the most benefits from the decrease in competitive pressure. Nonattainment designations also create shareholder value through improvements in plant-level environmental performance. We show that ozone-dependent plants in nonattainment counties decrease their ozone emissions, suffer fewer legal liabilities, and experience fewer ozone-related HPVs. On the side of costs, we demonstrate that nonattainment designations impose additional compliance costs on ozone-dependent plants, but these costs are borne by younger plants.

These results also have potentially important policy implications. Currently, there are no federal regulations aimed at mitigating global pollutants that contribute to climate change. The findings in this paper demonstrate that local environmental regulations contain value-relevant information that have stock-price implications for polluting firms. Thus, any cost-benefit analysis of new climate policy must take into account the impact on financial markets.

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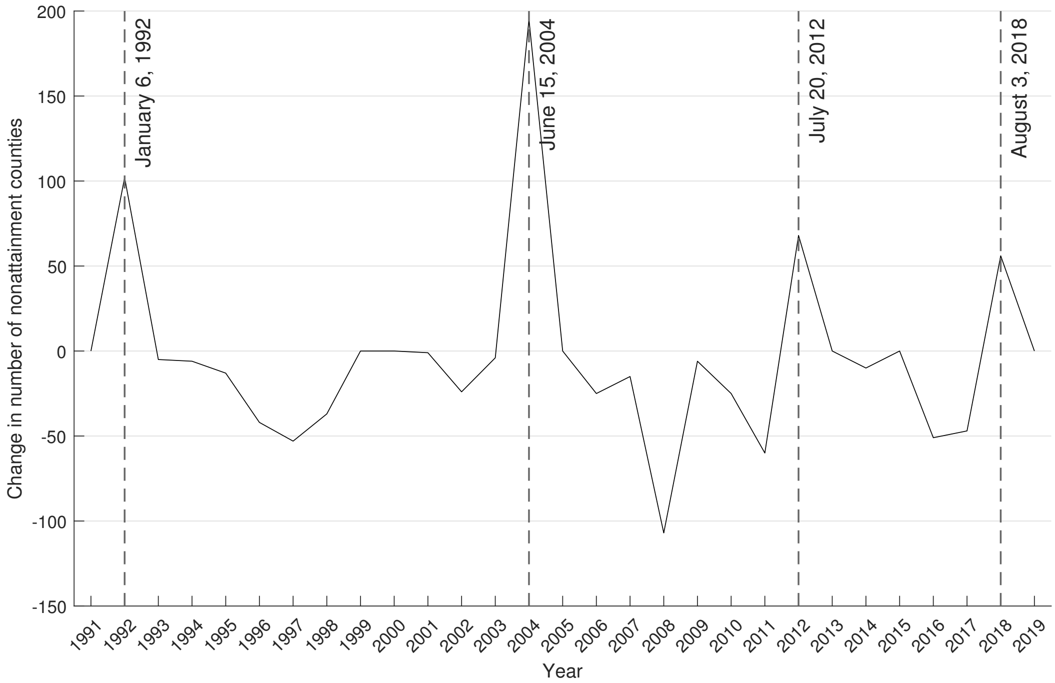
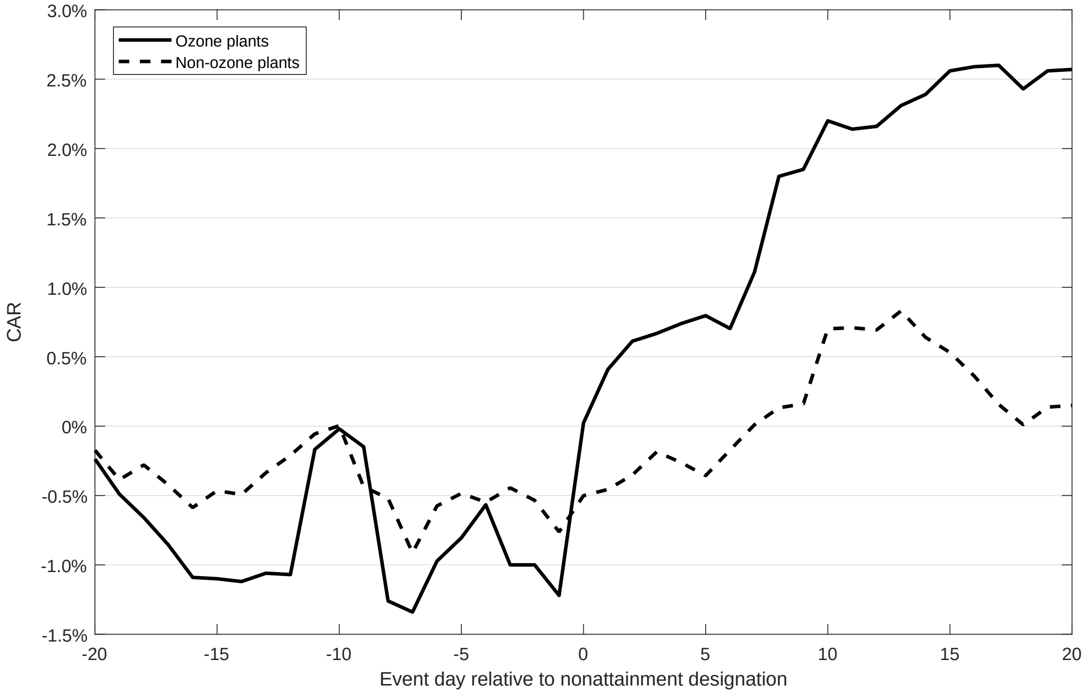
Figure 1

Policy changes in the NAAQS threshold and change in the number of nonattainment counties.



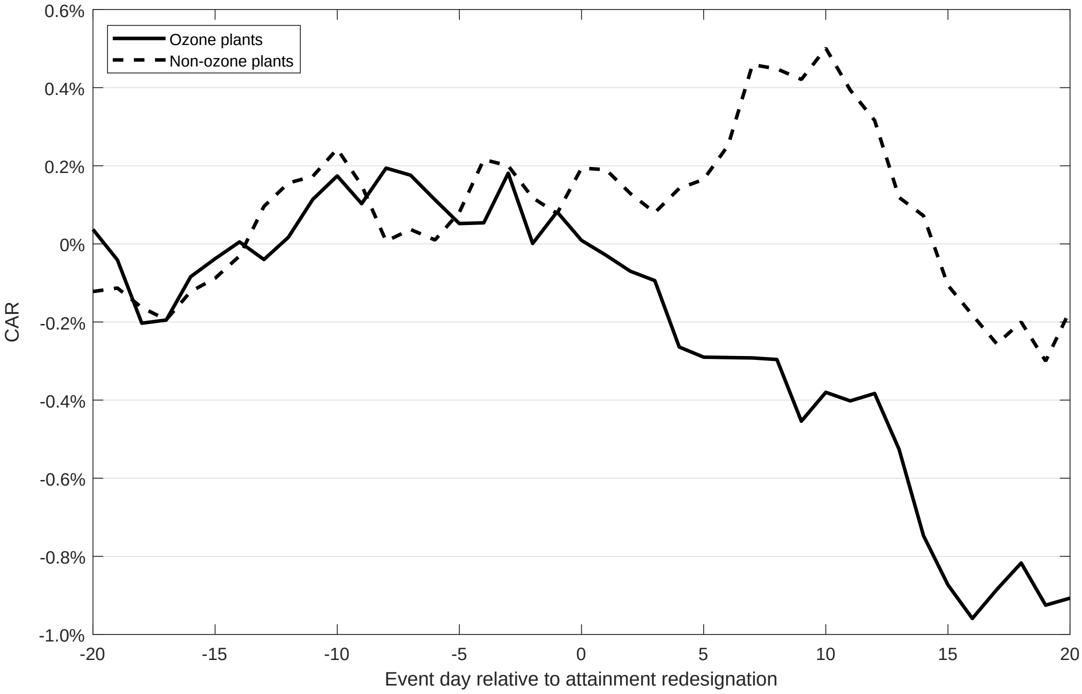
This figure shows the four discrete policy changes in the NAAQS threshold and the yearly change in the number of nonattainment counties during the sample period 1992 to 2019. In chronological order, the revisions to the NAAQS threshold include the 1-Hour Ozone (1979) standard effective on January 6, 1992, 8-Hour Ozone (1997) standard effective on June 15, 2004, 8-Hour Ozone (2008) standard effective on July 20, 2012, and 8-Hour Ozone (2015) standard effective on August 3, 2018. Each of these revisions is represented by a dashed vertical line. For more details, see Table IA.1 of the Internet Appendix. The solid black lines represent the difference in the number of nonattainment counties between the current year and the previous year.

Figure 2
Cumulative abnormal returns surrounding nonattainment designations.



This figure shows the mean value-weighted market model CARs over the event window $(-20, +20)$ for nonattainment designations. The solid line plots the CARs for firms that own at least one ozone nonattainment plant and the dashed line plots the CARs for firms that only own non-ozone nonattainment plants.

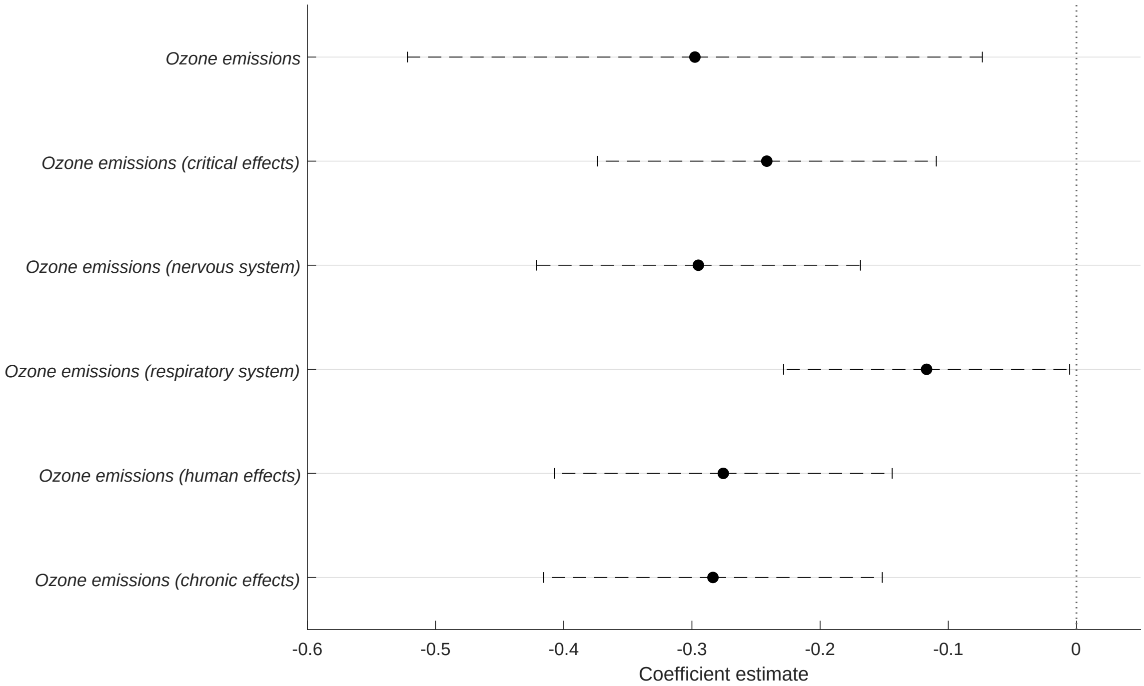
Figure 3
Cumulative abnormal returns surrounding attainment redesignations.



This figure shows the mean value-weighted market model CARs over the event window $(-20, +20)$ for attainment redesignations. The solid line plots the CARs for firms that own at least one ozone plant in counties that are redesignated to attainment and the dashed line plots the CARs for firms that only own non-ozone plants in counties that are redesignated to attainment.

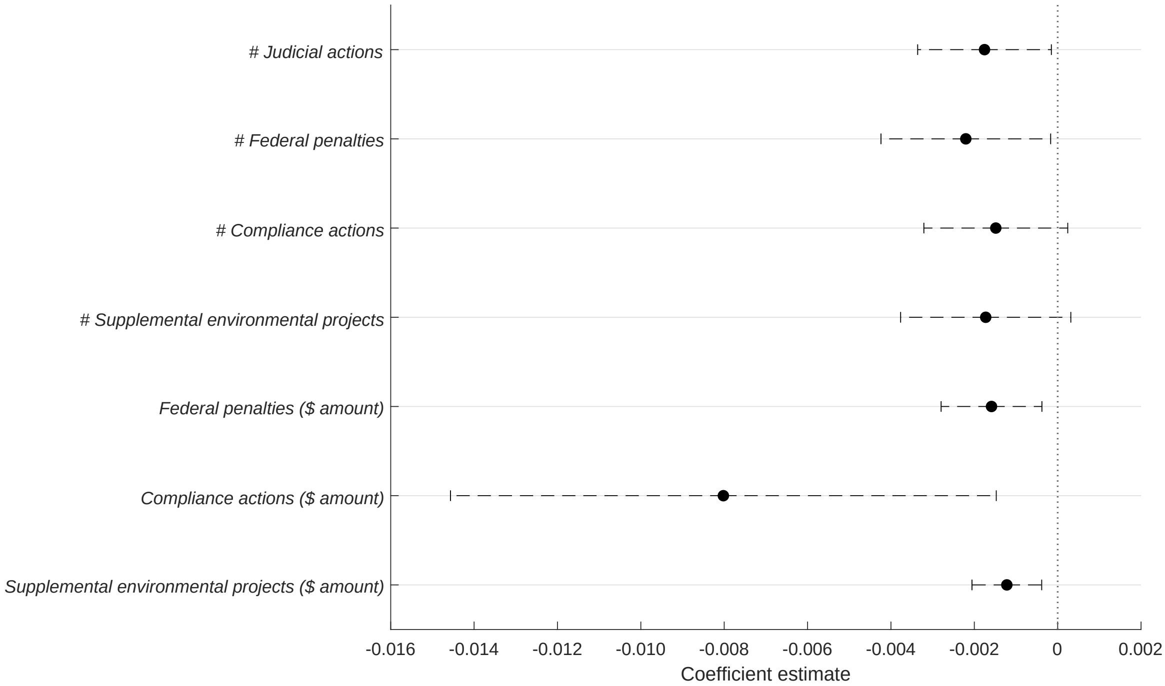
Figure 4

Nonattainment status and plant-level ozone emissions.



This figure shows the point estimates (black dot) and 95% confidence intervals (dashed lines) of the coefficients for the interaction term $NA_t \times \textit{Ozone ratio}_t$. For each specification, the dependent variable is listed on the vertical axis and is measured in year $t + 1$. *Ozone emissions* is the natural logarithm of one plus the total amount of ozone air emissions (in pounds) of a given plant in a given year. Other dependent variables are defined similarly but are restricted to those ozone air emissions that have critical effects on biological systems (e.g., nervous or respiratory systems) and those that have harmful human effects (e.g., chronic health effects). NA_t is a dummy variable equal to one if a given county is designated nonattainment in year t, and zero otherwise. $\textit{Ozone ratio}_t$ is the total ozone air emissions for a given plant in year t as a proportion of the given plant's overall air emissions across all chemicals.

Figure 5
Nonattainment status and plant-level penalties.



This figure shows the point estimates (black dot) and 95% confidence intervals (dashed lines) of the coefficients for the interaction term $NA_t \times Ozone\ ratio_t$. For each specification, the dependent variable is listed on the vertical axis and is measured in year $t+1$. # *Judicial actions*, # *Federal penalties*, # *Compliance actions*, and # *Supplemental environmental projects* are the natural logarithm of one plus the number of judicial actions, federal penalties, compliance actions, and supplemental environmental projects of a given plant in a given year, respectively. *Federal penalties ($ amount)*, *Compliance actions ($ amount)*, and *Supplemental environmental projects ($ amount)* are the natural logarithm of one plus the dollar amount (in millions) of federal penalties, compliance actions, and supplemental environmental projects of a given plant in a given year, respectively. NA_t is a dummy variable equal to one if a given county is designated nonattainment in year t, and zero otherwise. $Ozone\ ratio_t$ is the total ozone air emissions for a given plant in year t as a proportion of the given plant's overall air emissions across all chemicals.

Table 1
Summary statistics: firms and plants.

Variables	Mean	Median	Std. dev.	P25	P75	Obs.
Panel A: Firm-level variables						
NA ratio	0.593	0.500	0.307	0.333	1.000	1,698
Unexp. NA ratio	0.228	0.111	0.300	0.000	0.333	1,698
Antic. NA ratio	0.365	0.294	0.328	0.095	0.500	1,698
NA ozone	5.441	5.896	5.077	0.000	10.124	1,698
Redesig ratio	0.172	0.077	0.238	0.036	0.200	1,822
Unexp. redesig ratio	0.124	0.037	0.223	0.000	0.125	1,822
Antic. redesig ratio	0.048	0.000	0.137	0.000	0.034	1,822
Redesig ozone	3.653	0.000	4.603	0.000	8.284	1,822
NA HPV	0.170	0.000	0.376	0.000	0.000	3,191
HPV ozone	7.328	9.366	5.144	0.003	11.541	3,191
Firm NA	0.576	1.000	0.494	0.000	1.000	11,358
Firm ozone ratio	0.343	0.276	0.330	0.001	0.570	11,358
Fluidity	5.349	4.607	3.241	3.215	6.595	14,106
Similarity	2.179	1.172	3.546	1.039	1.743	14,332
Core chemical	0.633	1.000	0.482	0.000	1.000	19,691
Permit	0.709	1.000	0.454	0.000	1.000	19,691
Source reduction	0.287	0.000	0.452	0.000	1.000	19,691
Production ratio	0.944	0.990	0.327	0.840	1.088	13,955
ln(Size)	6.694	6.784	2.285	5.216	8.198	97,215
ln(BM)	0.527	0.538	0.161	0.421	0.635	96,923
ROA	0.028	0.032	0.941	0.021	0.045	97,289
Leverage	0.278	0.228	0.228	0.098	0.411	94,406
Sales growth	0.345	0.054	37.862	-0.037	0.164	104,049
KZ	0.864	1.016	63.375	0.343	1.633	94,754
Cash	0.091	0.043	0.125	0.014	0.118	104,970
Momentum	1.162	1.093	0.588	0.874	1.331	91,893
Stock returns	0.041	0.027	0.245	-0.081	0.140	91,890
z-score	0.510	0.897	24.025	0.424	1.337	96,527
Environment score	0.054	0.000	0.228	0.000	0.167	9,965
Panel B: Plant-level variables						
NA	0.350	0.000	0.477	0.000	1.000	139,508
Ozone ratio	0.298	0.000	0.417	0.000	0.750	139,508
Close monitor (km)	28.701	15.201	45.143	7.231	34.932	144,036
Young plant	0.307	0.000	0.461	0.000	1.000	139,508
Sales HHI	0.747	0.878	0.281	0.502	1.000	37,446
Emp HHI	0.738	0.862	0.287	0.500	1.000	37,446
ln(HPV)	0.020	0.000	0.139	0.000	0.000	126,156
ln(Title V ins.)	0.156	0.000	0.351	0.000	0.000	126,156
ln(Stack test)	0.127	0.000	0.470	0.000	0.000	126,156
Fail stack test	0.008	0.000	0.086	0.000	0.000	126,156
ln(Compliance eval.)	0.152	0.000	0.309	0.000	0.000	126,156
ln(Treated)	2.124	0.000	4.360	0.000	0.000	126,156
ln(Total SR)	3.855	0.000	5.301	0.000	9.146	126,156
Good operating practices	0.039	0.000	0.193	0.000	0.000	126,156
SR activity	0.086	0.000	0.280	0.000	0.000	126,156
Ozone emissions	3.262	0.000	4.487	0.000	7.511	126,156
# Judicial actions	0.002	0.000	0.038	0.000	0.000	126,156
# Federal penalties	0.004	0.000	0.052	0.000	0.000	126,156
# Compliance actions	0.003	0.000	0.049	0.000	0.000	126,156
# SEP	0.001	0.000	0.039	0.000	0.000	126,156
Federal penalties ($ amount)	0.002	0.000	0.050	0.000	0.000	126,156
Compliance actions ($ amount)	0.008	0.000	0.206	0.000	0.000	126,156
SEP ($ amount)	0.001	0.000	0.026	0.000	0.000	126,156

Panel A reports summary statistics for firm-level variables. Panel B reports summary statistics for plant-level variables. Variable definitions are presented in Table A.1 in Appendix A. Std. dev. displays the standard deviation, P25 the first and P75 the third quartile of the respective variable. The sample period is from 1992 to 2019.

Table 2
Cumulative abnormal returns for nonattainment designations.

Panel A: All nonattainment designations						
	All polluting plants		Non-ozone plants		Ozone plants	
Event window	(−3, +3)	(−5, +5)	(−3, +3)	(−5, +5)	(−3, +3)	(−5, +5)
	(1)	(2)	(3)	(4)	(5)	(6)
Mean (%)	0.24***	0.62***	-0.04	0.16	0.45***	0.70***
t-statistic	(2.73)	(6.93)	(-0.31)	(1.11)	(4.26)	(5.49)
Median (%)	0.39***	0.48***	0.12	0.03	0.44***	0.53***
Generalized sign test	(4.13)	(7.76)	(0.47)	(0.01)	(3.90)	(4.49)
Observations	1,460	1,460	533	533	927	927
Panel B: Unexpected nonattainment designations						
	All polluting plants		Non-ozone plants		Ozone plants	
Event window	(−3, +3)	(−5, +5)	(−3, +3)	(−5, +5)	(−3, +3)	(−5, +5)
	(1)	(2)	(3)	(4)	(5)	(6)
Mean (%)	0.51***	0.63**	0.04	0.25	0.81***	1.34***
t-statistic	(2.69)	(2.56)	(0.12)	(0.56)	(3.29)	(4.88)
Median (%)	0.49***	0.31**	0.26	0.14	0.57***	0.75***
Generalized sign test	(2.78)	(2.50)	(1.01)	(0.80)	(2.71)	(6.87)
Observations	407	407	128	128	279	279
Panel C: Anticipated nonattainment designations						
	All polluting plants		Non-ozone plants		Ozone plants	
Event window	(−3, +3)	(−5, +5)	(−3, +3)	(−5, +5)	(−3, +3)	(−5, +5)
	(1)	(2)	(3)	(4)	(5)	(6)
Mean (%)	0.10	0.18	0.11	0.08	0.33**	0.43***
t-statistic	(0.92)	(1.45)	(0.66)	(0.11)	(2.56)	(2.84)
Median (%)	0.03	0.13	0.03	0.20	0.44**	0.33***
Generalized sign test	(0.56)	(1.45)	(0.40)	(1.61)	(2.26)	(3.11)
Observations	1,053	1,053	516	516	537	537

This table reports the mean and median value-weighted CARs for nonattainment designation events. We consider event windows of 7 (−3, +3) and 11 (−5, +5) days. Panel A uses firms impacted by all nonattainment designations. Panel B (C) uses firms impacted by unexpected (anticipated) nonattainment designations, defined to be those firms whose majority of plants are located in unexpected (anticipated) nonattainment counties. All polluting plants refer to those firms with at least one polluting plant located in counties that are designated nonattainment, non-ozone plants refer to those firms that only own non-ozone nonattainment plants, and ozone plants refer to those firms that own at least one ozone nonattainment plant. The t-statistics account for event-induced changes in volatility and are calculated according to Boehmer et al. (1991). The generalized sign test reports the test statistic of a generalized nonparametric Wilcoxon sign-rank test for medians. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

Table 3

Cross-sectional variation in cumulative abnormal returns during nonattainment designations.

Dep. variable:	CAR	CAR (FF48)	CAR (FFM)	CAR	CAR (FF48)	CAR (FFM)
	(1)	(2)	(3)	(4)	(5)	(6)
NA ratio$_t$	0.011	0.015	0.009			
	(0.95)	(1.27)	(0.78)			
Unexp. NA ratio$_t$				0.029	0.021	0.025
				(1.41)	(1.11)	(1.25)
Antic. NA ratio$_t$				-0.010	-0.007	-0.013
				(-0.83)	(-0.59)	(-1.06)
NA ozone$_{t-1}$	0.003**	0.004**	0.003*	0.003**	0.003***	0.003**
	(2.03)	(2.10)	(1.81)	(2.48)	(2.61)	(2.05)
NA ratio$_t$ × *NA ozone*$_{t-1}$	-0.005**	-0.005**	-0.004**			
	(-2.14)	(-2.34)	(-2.03)			
Unexp. NA ratio$_t$ × *NA ozone*$_{t-1}$				-0.009***	-0.008***	-0.008**
				(-2.60)	(-2.66)	(-2.29)
Antic. NA ratio$_t$ × *NA ozone*$_{t-1}$				-0.003	-0.003	-0.002
				(-1.33)	(-1.32)	(-0.97)
Core chemical	-0.011	-0.011	-0.014	-0.011	-0.013	-0.013
	(-1.00)	(-0.98)	(-1.34)	(-0.96)	(-1.24)	(-1.21)
Permit	0.009	0.008	0.010	0.010	0.009	0.011*
	(1.37)	(1.16)	(1.46)	(1.59)	(1.43)	(1.74)
Production ratio	0.005	0.003	0.001	0.005	0.002	0.000
	(0.65)	(0.42)	(0.18)	(0.57)	(0.28)	(0.03)
Source reduction	-0.013*	-0.014*	-0.008	-0.010	-0.011	-0.006
	(-1.70)	(-1.89)	(-1.06)	(-1.43)	(-1.52)	(-0.87)
ln(Size)	-0.007*	-0.007**	-0.005	-0.007**	-0.006	-0.005
	(-1.83)	(-2.02)	(-1.33)	(-2.03)	(-1.48)	(-1.47)
ln(BM)	-0.051	-0.068	-0.036	-0.110*	-0.027	-0.080
	(-0.81)	(-1.07)	(-0.53)	(-1.79)	(-0.42)	(-1.22)
ROA	0.181	0.166	0.127	-0.114	0.108	-0.130
	(0.94)	(0.87)	(0.69)	(-0.63)	(0.60)	(-0.76)
Leverage	0.067	0.062	0.052	0.050	0.019	0.030
	(1.48)	(1.38)	(1.13)	(1.06)	(0.41)	(0.61)
Sales growth	-0.008	-0.010	-0.016	0.030	0.024	0.028
	(-0.29)	(-0.36)	(-0.58)	(1.35)	(1.05)	(1.33)
KZ	-0.001	-0.000	-0.000	0.000	0.001	0.000
	(-0.30)	(-0.24)	(-0.24)	(0.09)	(0.74)	(0.14)
Cash	0.028	0.028	0.029	0.015	0.025	0.017
	(0.83)	(0.84)	(0.80)	(0.48)	(0.82)	(0.51)
Momentum	-0.027***	-0.026***	-0.028***	-0.024***	-0.020***	-0.024***
	(-4.64)	(-4.30)	(-4.71)	(-4.50)	(-3.38)	(-4.51)
Stock returns	-0.037	-0.040	-0.034	-0.045	-0.047	-0.042
	(-0.87)	(-0.92)	(-0.81)	(-1.04)	(-1.04)	(-0.99)
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,305	1,305	1,305	1,305	1,305	1,305
Adj R^2	0.10	0.09	0.07	0.11	0.08	0.07

This table reports the regression estimates from Equation (1) for nonattainment designations. The dependent variables are the 11-day CARs $(-5, +5)$. Columns (1) and (4) use the market model CAR. In columns (2) and (5), CARs are calculated using Fama and French's (1997) 48 value-weighted industry return as the benchmark return. In columns (3) and (6), CARs are risk adjusted using Carhart's (1997) four-factor model. *NA ratio*$_t$ is the number of polluting plants located in nonattainment counties for a given firm in event year t divided by the total number of plants owned by the given firm. *Unexp. NA ratio*$_t$ (*Antic. NA ratio*$_t$) is the number of polluting plants located in unexpected (anticipated) nonattainment counties for a given firm in event year t divided by the total number of plants owned by the given firm. *NA ozone*$_{t-1}$ is the natural logarithm of one plus the total amount of ozone air emissions (in pounds) in nonattainment counties of a given firm in year $t-1$. 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
Heterogeneous cross-sectional variation in cumulative abnormal returns during nonattainment designations.

$Z =$	*Young plant ratio*	*Close monitor ratio*	*Permit holder ratio*	*Low z-score*	*Low environment score*
Dep. variable: CAR	(1)	(2)	(3)	(4)	(5)
$NA\ ratio_t$	0.006	0.010	0.013	-0.003	0.007
	(0.38)	(0.55)	(0.43)	(-0.22)	(0.52)
$NA\ ozone_{t-1}$	0.000	-0.001	0.004	-0.000	-0.000
	(0.29)	(-0.24)	(1.65)	(-0.37)	(-0.48)
Z	-0.006	-0.111*	0.061*	-0.022*	-0.029**
	(-0.36)	(-1.96)	(1.66)	(-1.73)	(-2.01)
$NA\ ratio_t \times NA\ ozone_{t-1}$	0.001	-0.001	-0.001	0.001	0.000
	(0.40)	(-0.34)	(-0.28)	(0.69)	(0.12)
$NA\ ratio_t \times Z$	0.058	0.090	-0.128***	0.073**	0.052*
	(1.57)	(1.62)	(-2.71)	(2.03)	(1.74)
$NA\ ozone_{t-1} \times Z$	0.002	0.018**	-0.013**	0.004*	0.004**
	(0.68)	(1.98)	(-2.23)	(1.85)	(2.49)
$NA\ ratio_t \times NA\ ozone_{t-1} \times Z$	-0.012**	-0.018**	0.018**	-0.011**	-0.009**
	(-2.13)	(-1.97)	(2.15)	(-2.35)	(-2.41)
Controls	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes
Observations	1,305	1,305	1,305	1,244	679
Adj R^2	0.08	0.08	0.07	0.10	0.11

This table reports the regression estimates by including a set of firm characteristics Z and its interactions with the variables in Equation (1) for nonattainment designations. The dependent variable is the 11-day market model CAR $(-5, +5)$. $NA\ ratio_t$ is the number of polluting plants located in nonattainment counties for a given firm in event year t divided by the total number of plants owned by the given firm. $NA\ ozone_{t-1}$ is the natural logarithm of one plus the total amount of ozone air emissions (in pounds) in nonattainment counties of a given firm in year $t-1$. For each specification, the variable included in Z is listed on top of each column. *Young plant ratio* is the number of nonattainment plants between zero and five years of age for a given firm in a given year divided by the total number of plants owned by the given firm. *Close monitor ratio* is the number of nonattainment plants with distances to the nearest monitor in the bottom tercile for a given firm in a given year divided by the total number of plants owned by the given firm. *Permit holder ratio* is the number of nonattainment plants with ozone operating permits for a given firm in a given year divided by the total number of plants owned by the given firm. *Low z-score* is a dummy variable equal to one if a given firm's z-score is in the bottom tercile, and zero otherwise. *Low environment score* is a dummy variable equal to one if the difference between the average strength and concern environment scores for a given firm is in the bottom tercile, and zero otherwise. 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
Cumulative abnormal returns for attainment redesignations.

Panel A: All attainment redesignations

	All polluting plants		Non-ozone plants		Ozone plants	
Event window	$(-3,+3)$	$(-5,+5)$	$(-3,+3)$	$(-5,+5)$	$(-3,+3)$	$(-5,+5)$
	(1)	(2)	(3)	(4)	(5)	(6)
Mean (%)	-0.17***	-0.22***	-0.14	-0.14	-0.24***	-0.46***
t-statistic	(-5.28)	(-4.26)	(-1.46)	(-1.01)	(-4.66)	(-3.90)
Median (%)	-0.39***	-0.28***	-0.03	-0.03	-0.55***	-0.28**
Generalized sign test	(-5.42)	(-2.90)	(-0.90)	(-0.20)	(-6.67)	(-2.14)
Observations	1,684	1,684	876	876	808	808

Panel B: Unexpected attainment redesignations

	All polluting plants		Non-ozone plants		Ozone plants	
Event window	$(-3,+3)$	$(-5,+5)$	$(-3,+3)$	$(-5,+5)$	$(-3,+3)$	$(-5,+5)$
	(1)	(2)	(3)	(4)	(5)	(6)
Mean (%)	-0.22***	-0.33***	-0.11	-0.17	-0.25***	-0.55***
t-statistic	(-4.56)	(-4.35)	(-0.84)	(-1.37)	(-3.56)	(-5.72)
Median (%)	-0.55***	-0.47***	-0.16	-0.28	-0.60***	-0.53***
Generalized sign test	(-9.24)	(-5.17)	(-0.29)	(-1.34)	(-3.68)	(-5.31)
Observations	1,010	1,010	522	522	488	488

Panel C: Anticipated attainment redesignations

	All polluting plants		Non-ozone plants		Ozone plants	
Event window	$(-3,+3)$	$(-5,+5)$	$(-3,+3)$	$(-5,+5)$	$(-3,+3)$	$(-5,+5)$
	(1)	(2)	(3)	(4)	(5)	(6)
Mean (%)	-0.03	-0.11	-0.01	-0.02	-0.13	-0.13
t-statistic	(-0.38)	(-1.02)	(-0.03)	(-0.17)	(-1.12)	(-1.05)
Median (%)	-0.10	-0.12	0.08	-0.16	-0.23	-0.12
Generalized sign test	(-1.07)	(-0.86)	(0.49)	(-1.14)	(-1.32)	(-1.11)
Observations	674	674	354	354	320	320

This table reports the mean and median value-weighted CARs for attainment redesignation events. We consider event windows of 7 $(-3,+3)$ and 11 $(-5,+5)$ days. Panel A uses firms impacted by all attainment redesignations. Panel B (C) uses firms impacted by unexpected (anticipated) attainment redesignations, defined to be those firms whose majority of plants are located in unexpected (anticipated) attainment redesignation counties. All polluting plants refer to those firms with at least one polluting plant located in counties that are redesignated to attainment, non-ozone plants refer to those firms that only own non-ozone plants in counties redesignated to attainment, and ozone plants refer to those firms that own at least one ozone plant in counties redesignated to attainment. The t-statistics account for event-induced changes in volatility and are calculated according to Boehmer et al. (1991). The generalized sign test reports the test statistic of a generalized nonparametric Wilcoxon sign-rank test for medians. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

Table 6
Cross-sectional variation in cumulative abnormal returns during attainment redesignations.

Dep. variable:	CAR	CAR (FF48)	CAR (FFM)	CAR	CAR (FF48)	CAR (FFM)
	(1)	(2)	(3)	(4)	(5)	(6)
Redesig ratio$_t$	-0.032**	-0.028**	-0.025**			
	(-2.45)	(-2.08)	(-1.87)			
Unexp. redesig ratio$_t$				-0.028**	-0.028**	-0.026*
				(-2.08)	(-2.03)	(-1.91)
Antic. redesig ratio$_t$				-0.031*	-0.020	-0.016
				(-1.75)	(-1.03)	(-0.99)
Redesig ozone$_{t-1}$	-0.001**	-0.001***	-0.001**	-0.001**	-0.002***	-0.001**
	(-2.03)	(-2.59)	(-2.13)	(-2.21)	(-2.78)	(-2.14)
Redesig ratio$_t$ × *Redesig ozone*$_{t-1}$	0.006**	0.006**	0.006**			
	(1.97)	(2.25)	(2.10)			
Unexp. redesig ratio$_t$ × *Redesig ozone*$_{t-1}$				0.006**	0.007**	0.006**
				(1.98)	(2.31)	(2.00)
Antic. redesig ratio$_t$ × *Redesig ozone*$_{t-1}$				0.005	0.005	0.005
				(1.51)	(1.59)	(1.65)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,203	1,203	1,203	1,203	1,203	1,203
Adj R^2	0.02	0.01	0.03	0.02	0.02	0.04

This table reports the regression estimates from Equation (2) for attainment redesignations. The dependent variables are the 11-day CARs $(-5, +5)$. Columns (1) and (4) use the market model CAR. In columns (2) and (5), CARs are calculated using Fama and French's (1997) 48 value-weighted industry return as the benchmark return. In columns (3) and (6), CARs are risk adjusted using Carhart's (1997) four-factor model. *Redesig ratio*$_t$ is the number of polluting plants located in counties redesignated to attainment for a given firm in event year t divided by the total number of plants owned by the given firm. *Unexp. redesig ratio*$_t$ (*Antic. redesig ratio*$_t$) is the number of polluting plants located in unexpected (anticipated) attainment redesignation counties for a given firm in event year t divided by the total number of plants owned by the given firm. *Redesig ozone*$_{t-1}$ is the natural logarithm of one plus the total amount of ozone air emissions (in pounds) in counties redesignated to attainment for a given firm in year $t-1$. 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
County-level competition surrounding nonattainment designations.

Dep. variable:	*Sales HHI*		*Emp HHI*	
	(1)	(2)	(3)	(4)
NA_t	-0.026	-0.046*	-0.010	-0.025
	(-0.94)	(-1.87)	(-0.36)	(-1.04)
NA_t				
× *Post* NA_t	0.010***		0.020***	
	(3.21)		(2.97)	
× *Post NA(0)*		0.009**		0.012***
		(2.74)		(3.04)
× *Post NA(1)*		0.014***		0.017***
		(5.32)		(7.63)
× *Post NA(2)*		0.013**		0.016***
		(2.73)		(6.03)
× *Post NA(3)*		0.018***		0.016***
		(3.00)		(3.26)
× *Post NA(4)*		0.015**		0.010
		(2.36)		(1.30)
× *Post NA(-2)*		-0.002		-0.002
		(-0.26)		(-0.25)
× *Post NA(-3)*		0.003		-0.004
		(0.26)		(-0.61)
× *Post NA(-4)*		0.002		0.005
		(0.27)		(0.85)
County controls	Yes	Yes	Yes	Yes
County F.E.	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
Observations	15,446	26,757	15,446	26,757
Adj R^2	0.74	0.75	0.74	0.76

This table reports the regression estimates from Equation (3) using county-level measures of competition as the outcome variables. In columns (1) and (3), we focus on two years before to two years after the nonattainment designation. We increase the window length in Columns (2) and (4), and focus on four years before to four years after the nonattainment designation. The dependent variable in columns (1) and (2) (columns (3) and (4)) is *Sales HHI* (*Emp HHI*), defined to be the sum of the squared facility-level sales (employee) shares of all polluting plants that operate in a given county in a given year. NA_t is a dummy variable equal to one if a given county is designated nonattainment in year t, and zero otherwise. *Post* NA_t is a dummy variable equal to one for the nonattainment designation year and the two following years, and zero otherwise. *Post NA(k)* is a dummy variable equal to one for the kth year relative to the nonattainment designation year, and zero otherwise. The year before the nonattainment designation is the omitted category. We use data from the U.S. Census Bureau to construct county controls, including the natural logarithm of one plus the population levels, the natural logarithm of one plus the total personal income, the natural logarithm of one plus the number of establishments, NO_x emissions to employment ratio, the change in employment levels, and a dummy variable equal to one if the county is located in a MSA. For all specifications, standard errors are robust to heteroskedasticity and clustered at the county-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
Firm-level competition surrounding nonattainment designations.

Dep. variable:	*Fluidity*		*Similarity*	
	(1)	(2)	(3)	(4)
Firm NA_t × *Firm ozone* $ratio_{t-1}$				
× *Post* NA_t	-1.014***		-0.491**	
	(-2.66)		(-2.15)	
× *Post NA(0)*		-1.034***		-0.598***
		(-4.19)		(-4.24)
× *Post NA(1)*		-1.613***		-0.796**
		(-5.22)		(-2.11)
× *Post NA(2)*		-0.599**		-1.686**
		(-2.71)		(-2.71)
× *Post NA(3)*		-1.115*		-0.366
		(-1.88)		(-1.48)
× *Post NA(4)*		-1.308**		-0.478
		(-2.57)		(-0.89)
× *Post NA(-2)*		0.018		-0.025
		(0.05)		(-0.06)
× *Post NA(-3)*		-0.378		-0.084
		(-0.65)		(-0.21)
× *Post NA(-4)*		0.102		-0.079
		(0.18)		(-0.29)
Firm controls	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes
Observations	5,698	8,829	5,698	8,829
Adj R^2	0.49	0.51	0.42	0.44

This table reports the regression estimates from Equation (4) using firm-level measures of competition as the outcome variables. For brevity, only the coefficients on the triple interaction term is shown. In columns (1) and (3), we focus on two years before to two years after the nonattainment designation. We increase the window length in Columns (2) and (4), and focus on four years before to four years after the nonattainment designation. The dependent variable in columns (1) and (2) is *Fluidity*, which is constructed by Hoberg et al. (2014) and reflects both the degree of product similarity of a given firm with its competitors and the product market's instabilities arising from competitor actions. A higher value is associated with a more significant competitive threat for the firm. The dependent variable in columns (3) and (4) is *Similarity*, which is constructed by Hoberg and Phillips (2010, 2016) and reflects the amount of competition a given firm faces and the product relatedness to each competitor. A higher value is associated with more competitive pressure for the firm. *Firm* NA_t is a dummy variable equal to one if a given firm operates a polluting plant in a county that is designated nonattainment in year t, and zero otherwise. *Firm ozone* $ratio_{t-1}$ is the ozone air emissions for a given plant as a proportion of the plant's overall air emissions averaged across all plants owned by a given firm in year $t-1$. *Post* NA_t is a dummy variable equal to one for the nonattainment designation year and the two following years, and zero otherwise. *Post NA(k)* is a dummy variable equal to one for the kth year relative to the nonattainment designation year, and zero otherwise. The year before the nonattainment designation is the omitted category. 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
Nonattainment status and high priority violations.

Dep. variable:	CAR	CAR (FF48)	CAR (FFM)	Days res.	Days res. $\geq$ 6 mons.
	(1)	(2)	(3)	(4)	(5)
$NA\ HPV_t$	0.014*	0.007	0.016**	-0.227**	0.498**
	(1.78)	(1.12)	(1.97)	(-2.01)	(2.55)
$HPV\ ozone_{t-1}$	0.000	-0.000	0.000	-0.010**	0.045***
	(0.69)	(-0.01)	(0.69)	(-2.10)	(2.75)
$NA\ HPV_t \times HPV\ ozone_{t-1}$	-0.002**	-0.002***	-0.002**	0.022*	-0.048**
	(-1.99)	(-2.72)	(-2.21)	(1.87)	(-2.29)
Controls	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes
Observations	2,847	2,847	2,847	2,866	2,866
Adj R^2	0.03	0.02	0.02		

This table examines the market's reaction to nonattainment status and ozone-related HPVs. Columns (1) to (3) use ordinary least squares regressions using the 11-day CARs $(-5, +5)$ surrounding the HPV event as the dependent variables. Column (1) uses the market model CAR. In column (2), CARs are calculated using Fama and French's (1997) 48 value-weighted industry return as the benchmark return. In column (3), CARs are risk adjusted using Carhart's (1997) four-factor model. In column (4), we use a nonparametric Cox model to estimate the regression where the dependent variable is a firm's maximum number of days taken to resolve the HPV across all HPV plants. In column (5), we use a probit model where the dependent variable is a dummy variable equal to one if it takes more than six months to resolve the HPVs. $NA\ HPV_t$ is a dummy variable equal to one if a firm operates nonattainment plants involved in ozone-related HPVs in event year t, and zero otherwise. $HPV\ ozone_{t-1}$ is the natural logarithm of one plus the total amount of ozone air emissions (in pounds) across all plants that experience a HPV for a given firm in year $t-1$. 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
Nonattainment status and plant-level regulatory enforcement.

Dep. variable:	*ln(HPV)*$_{t+1}$	*ln(Title V ins.)*$_{t+1}$	*ln(Stack test)*$_{t+1}$	*Fail stack test*$_{t+1}$	*ln(Compliance eval.)*$_{t+1}$
	(1)	(2)	(3)	(4)	(5)
Ozone ratio$_t$	0.006***	0.017***	-0.003	0.003*	0.011**
	(2.98)	(3.92)	(-0.45)	(1.70)	(2.08)
Young plant$_t$	-0.003*	0.048***	0.020***	0.003***	0.019***
	(-1.66)	(15.28)	(4.00)	(2.64)	(3.54)
$NA_t \times$ *Ozone ratio*$_t$	-0.012***	-0.003	0.001	-0.003	-0.007
	(-3.45)	(-0.45)	(0.12)	(-1.21)	(-0.97)
$NA_t \times$ *Young plant*$_t$	0.002	-0.016***	-0.021***	-0.004**	-0.002
	(0.60)	(-4.04)	(-3.11)	(-2.57)	(-0.31)
Ozone ratio$_t \times$ *Young plant*$_t$	-0.006*	-0.066***	-0.010	-0.003	-0.017*
	(-1.89)	(-11.25)	(-1.06)	(-1.21)	(-1.93)
$NA_t \times$ *Ozone ratio*$_t \times$ *Young plant*$_t$	0.013***	0.048***	0.030**	0.007**	0.033**
	(2.62)	(5.73)	(2.33)	(2.18)	(2.55)
Plant F.E.	Yes	Yes	Yes	Yes	Yes
County × Year F.E.	Yes	Yes	Yes	Yes	Yes
Firm × Year F.E.	Yes	Yes	Yes	Yes	Yes
Industry× Year F.E.	Yes	Yes	Yes	Yes	Yes
Observations	119,966	119,966	119,966	119,966	119,966
Adj R^2	0.27	0.67	0.54	0.09	0.42

This table examines the effect of nonattainment status on plant-level regulatory enforcement. The dependent variable in column (1) is the natural logarithm of one plus the number of high priority violations of a given facility. The dependent variable in column (2) is the natural logarithm of one plus the number of Title V inspections of a given facility. The dependent variable in column (3) is the natural logarithm of one plus the number of stack tests of a given facility. The dependent variable in column (4) is a dummy variable equal to one if a given facility fails a stack test, and zero otherwise. The dependent variable in column (5) is the natural logarithm of one plus the number of full compliance evaluations of a given facility. All dependent variables are measured in year $t+1$. NA_t is a dummy variable equal to one if a given county is designated nonattainment in year t, and zero otherwise. *Ozone ratio*$_t$ is the total ozone air emissions for a given plant in year t as a proportion of the given plant's overall air emissions across all chemicals. *Young plant*$_t$ is a dummy variable equal to one if a given plant is between zero and five years of age in year t, and zero otherwise. For all specifications, standard errors are robust to heteroskedasticity and clustered at the county-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 11
Nonattainment status and plant-level source reduction.

Dep. variable:	*ln(Treated)*$_{t+1}$	*ln(Total SR)*$_{t+1}$	*Good operating practices*$_{t+1}$	*SR activity*$_{t+1}$
	(1)	(2)	(3)	(4)
Ozone ratio$_t$	1.384***	2.827***	0.034***	0.105**
	(3.08)	(3.39)	(9.38)	(2.50)
Young plant$_t$	-0.119***	-0.065	-0.009***	-0.020***
	(-3.04)	(-1.58)	(-4.34)	(-6.81)
$NA_t \times$ *Ozone ratio*$_t$	0.054	-0.128	-0.012**	-0.005
	(0.69)	(-1.51)	(-2.16)	(-0.63)
$NA_t \times$ *Young plant*$_t$	0.040	-0.166***	-0.003	-0.005
	(0.74)	(-3.12)	(-1.14)	(-1.10)
Ozone ratio$_t \times$ *Young plant*$_t$	-0.394***	-0.274***	0.009*	0.027***
	(-4.76)	(-3.34)	(1.66)	(3.79)
$NA_t \times$ *Ozone ratio*$_t \times$ *Young plant*$_t$	0.401***	0.352***	0.019**	0.025**
	(3.47)	(2.94)	(2.33)	(2.03)
Plant F.E.	Yes	Yes	Yes	Yes
County × Year F.E.	Yes	Yes	Yes	Yes
Firm × Year F.E.	Yes	Yes	Yes	Yes
Industry× Year F.E.	Yes	Yes	Yes	Yes
Observations	119,966	119,966	119,966	119,966
Adj R^2	0.83	0.82	0.39	0.44

This table examines the effect of nonattainment status on plant-level source reduction. The dependent variable in column (1) is the natural logarithm of one plus the amount of ozone air emissions (in pounds) that are treated of a given facility. The dependent variable in column (2) is the natural logarithm of one plus the amount of ozone air emissions (in pounds) that undergo source reduction of a given facility. The dependent variable in column (3) is a dummy variable equal to one if a given facility undertakes good operating practices related to ozone, and zero otherwise. The dependent variable in column (4) is a dummy variable equal to one if a given facility undertakes source reduction activities related to ozone, and zero otherwise. All dependent variables are measured in year $t+1$. NA_t is a dummy variable equal to one if a given county is designated nonattainment in year t, and zero otherwise. *Ozone ratio*$_t$ is the total ozone air emissions for a given plant in year t as a proportion of the given plant's overall air emissions across all chemicals. *Young plant*$_t$ is a dummy variable equal to one if a given plant is between zero and five years of age in year t, and zero otherwise. For all specifications, standard errors are robust to heteroskedasticity and clustered at the county-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
Firm-level variables		
CAR	Cumulative abnormal returns calculated based on the CRSP value-weighted return index over a 250-day estimation period ending 20 days before the event date.	CRSP
NA ratio	The number of polluting plants located in nonattainment counties for a given firm in a given year divided by the total number of plants owned by the given firm.	TRI, Federal Register
Unexp. NA ratio	The number of polluting plants located in unexpected nonattainment counties for a given firm in a given year divided by the total number of plants owned by the given firm.	TRI, Federal Register, AQS
Antic. NA ratio	The number of polluting plants located in anticipated nonattainment counties for a given firm in a given year divided by the total number of plants owned by the given firm.	TRI, Federal Register, AQS
NA ozone	The natural logarithm of one plus the total amount of ozone air emissions (in pounds) in nonattainment counties of a given firm in a given year.	TRI, Federal Register
Redesig ratio	The number of polluting plants located in counties redesignated to attainment for a given firm in a given year divided by the total number of plants owned by the given firm.	TRI, Federal Register
Unexp. redesig ratio	The number of polluting plants located in unexpected attainment redesignation counties for a given firm in a given year divided by the total number of plants owned by the given firm.	TRI, Federal Register
Antic. redesig ratio	The number of polluting plants located in anticipated attainment redesignation counties for a given firm in a given year divided by the total number of plants owned by the given firm.	TRI, Federal Register
Redesig ozone	The natural logarithm of one plus the total amount of ozone air emissions (in pounds) in counties redesignated to attainment for a given firm in a given year.	TRI, Federal Register
NA HPV	A dummy variable equal to one if a given firm operates nonattainment plants involved in ozone-related HPVs in a given year.	ICIS-Air
HPV ozone	The natural logarithm of one plus the total amount of ozone air emissions (in pounds) across all plants that experience a HPV for a given firm in a given year.	TRI, ICIS-Air
Firm NA	A dummy variable equal to one if a given firm operates a polluting plant in a county that is designated nonattainment in a given year.	TRI, Federal Register
Firm ozone ratio	The ozone air emissions for a given plant as a proportion of the plant's overall air emissions averaged across all plants owned by a given firm in a given year.	TRI
Fluidity	The product market fluidity measure constructed by Hoberg et al. (2014). A higher value is associated with a more significant competitive threat for the firm.	Hoberg et al. (2014)
Similarity	The total product similarity score constructed by Hoberg and Phillips (2010, 2016). A higher value is associated with more competitive pressure for the firm..	Hoberg and Phillips (2010, 2016)
Core chemical	A dummy variable equal to one if a given firm operates plants that emit ozone core chemicals as defined by TRI.	TRI
Permit	A dummy variable equal to one if a given firm operates plants that hold operating permits for ozone emissions.	ICIS-Air
Source reduction	A dummy variable equal to one if a given firm operates plants that engage in ozone source reduction activities.	TRI P2
Production ratio	A given firm's average ozone production ratio across all plants.	TRI P2
ln(Size)	The natural logarithm of market equity.	Compustat
ln(BM)	The natural logarithm of one plus the book-to-market ratio.	Compustat
ROA	Net income divided by total assets.	Compustat
Leverage	Total liabilities divided by total assets.	Compustat
Sales growth	The ratio of sales in the current fiscal year to sales in the last year minus one.	Compustat
KZ	Kaplan-Zingales index.	Compustat
Cash	Cash divided by total assets.	Compustat

Table A.1 continued

Variable	Definitions	Data source
Momentum	Cumulative 12-month return of a stock, excluding the immediate past month.	CRSP
Stock returns	Firm-level quarterly stock returns.	CRSP
z-score	Altman's unlevered z-score.	Compustat
Environment score	The difference between the average strength and concern environment scores for a given firm.	KLD
Plant-level variables		
NA	A dummy variable equal to one if a given county is designated nonattainment in a given year.	Federal Register
Ozone ratio	The total ozone air emissions for a given plant in a given year as a proportion of the given plant's overall air emissions across all chemicals.	TRI
Close monitor	The distance (in km) between a given plant to the nearest monitor.	TRI, AQS
Young plant	A dummy variable equal to one if a given plant is between zero and five years of age in a given year.	NETS, TRI
Sales HHI	The sum of the squared facility-level sales shares of all polluting plants that operate in a given county in a given year.	NETS
Emp HHI	The sum of the squared facility-level employee shares of all polluting plants that operate in a given county in a given year.	NETS
ln(HPV)	The natural logarithm of one plus the number of high priority violations of a given facility.	ICIS-Air
ln(Title V ins.)	The natural logarithm of one plus the number of Title V inspections of a given facility.	ICIS-Air
ln(Stack test)	The natural logarithm of one plus the number of stack tests of a given facility.	ICIS-Air
Fail stack test	A dummy variable equal to one if a given facility fails a stack test.	ICIS-Air
ln(Compliance eval.)	The natural logarithm of one plus the number of full compliance evaluations of a given facility.	ICIS-Air
ln(Treated)	The natural logarithm of one plus the amount of ozone air emissions (in pounds) that are treated of a given facility.	TRI
ln(Total SR)	The natural logarithm of one plus the amount of ozone air emissions (in pounds) that undergo source reduction of a given facility.	TRI
Good operating practices	A dummy variable equal to one if a given facility undertakes good operating practices related to ozone.	TRI P2
SR activity	A dummy variable equal to one if a given facility undertakes source reduction activities related to ozone.	TRI P2
Ozone emissions	The natural logarithm of one plus the total amount of ozone air emissions (in pounds) of a given plant in a given year.	TRI
# *Judicial actions*	The natural logarithm of one plus the number of judicial actions of a given plant in a given year.	ICIS FE&C
# *Federal penalties*	The natural logarithm of one plus the number of federal penalties of a given plant in a given year.	ICIS FE&C
# *Compliance actions*	The natural logarithm of one plus the number of compliance actions of a given plant in a given year.	ICIS FE&C
# *SEP*	The natural logarithm of one plus the number of SEPs of a given plant in a given year.	ICIS FE&C
Federal penalties ($ amount)	The natural logarithm of one plus the dollar amount (in millions) of federal penalties of a given plant in a given year.	ICIS FE&C
Compliance actions ($ amount)	The natural logarithm of one plus the dollar amount (in millions) of compliance actions of a given plant in a given year.	ICIS FE&C
SEP ($ amount)	The natural logarithm of one plus the dollar amount (in millions) of SEPs of a given plant in a given year.	ICIS FE&C

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Appendix IA. Additional robustness tests

IA.1. Toxicity-weighted ozone emissions

Since the toxicity of each chemical varies, we account for the inherent heterogeneity of each chemical by multiplying the mass of each chemical by its toxicity, which is obtained from EPA's Risk-Screening Environmental Indicator model. Since we only focus on air emissions, we follow Gamper-Rabindran (2006) and use the inhalation toxicity weight. We define *NA TW ozone* as the natural logarithm of one plus the total amount of toxicity-weighted ozone air emissions (in pounds) in nonattainment counties of a given firm. We replicate the analysis on the cross-sectional variation in CARs during nonattainment designations using *NA TW ozone* in Internet Appendix Table IA.4 and find robust results.

IA.2. Offsite ozone emissions

Since nonattainment designations regulate a facility's onsite ozone emissions, cross-sectional variation in CARs should not depend on a polluting firm's offsite ozone emissions. To test this, we construct the variable *NA offsite ozone*, which is the natural logarithm of one plus the total amount of offsite ozone air emissions (in pounds) in nonattainment counties of a given firm. All interaction terms involving *NA offsite ozone* are statistically insignificant in Internet Appendix Table IA.5, confirming the falsification test.

IA.3. Particulate matter emissions

Investors should only react less favorably for firms that are heavy polluters of ozone and operate a high proportion of plants in nonattainment areas since only ozone-emitting plants are regulated under ozone NAAQS. Thus, firms that are heavy polluters of particulate matter in ozone nonattainment counties should not be affected by regulation, implying that there should be no market reaction for these firms. In Internet Appendix Table IA.6, we examine the cross-sectional variation in nonattainment CARs using a firm's total amount of particulate matter air emissions (in pounds) in nonattainment counties and find no significant results.

IA.4. Alternative measures of exposure to nonattainment designations

One potential concern in our main analysis is that the independent variable that measures a firm's exposure to nonattainment designations, *NA ratio*, 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. As robustness checks, we construct two additional independent variables by using employee- and sales-weighted *NA ratio*. Specifically, we use plant-level employee and sales data from

NETS to construct the variables *Employee NA ratio* and *Sales NA ratio*. The former equals to the employee-weighted number of polluting plants located in nonattainment counties for a given firm divided by the total number of employees across all polluting plants owned by the firm. The latter equals to the sales-weighted number of polluting plants located in nonattainment counties for a given firm divided by the total amount of sales across all polluting plants owned by the firm. Internet Appendix Table IA.7 shows that our main results remain intact when using these two variables in place of *NA ratio* in the estimation of Equation (1).

IA.5. Self-selection

Although nonattainment designations are typically regarded as exogenous events in the environmental economics literature (Greenstone, 2002; Walker, 2011, 2013), firms may self-select into nonattainment counties if they expect the regulation to be implemented. For example, firms that are already equipped with RACT/LAER technology may expect an implementation of mandatory pollution requirement that increases the cost of its local competitors. To address the potential self-selection problem, we conduct a Heckman (1979) two-stage least squares estimation for correction. In the first stage, we use a probit model to predict realized nonattainment status. The main independent variable is the county's hypothetical nonattainment status based on prior year DVs and following Curtis (2020), we include four additional predictors of nonattainment status. These variables are measured pre-nonattainment and include the county's employment levels, employment changes, NO_x emissions to employment ratio, and MSA status. Column (1) of Internet Appendix Table IA.8 presents the first-stage estimation results. As expected, a county's hypothetical nonattainment status based on prior year DVs positively predicts future realized nonattainment status. Consistent with Curtis (2020), we also find that employment levels, NO_x emissions to employment ratio, and MSA status are all positive predictors of nonattainment status.

In the second stage, we use the predicted probability of a county's nonattainment status to compute the inverse Mills ratio $IMR_{c,t}$ for county c in event year t. Since the IMR absorbs hidden factors that may affect a county's implementation of regulation, a firm's proportion of nonattainment plants is affected by the hidden factors in all counties where it operates polluting plants. To aggregate these factors' effect at the firm-level, we construct the firm-event year weighted average Heckman correction variable $HC_{i,t}$ using county-event year level IMR as follows:

$$HC_{i,t} = \frac{\sum_c \#Plant_{i,c,t} \times IMR_{c,t}}{\sum_c \#Plant_{i,c,t}} \tag{IA.1}$$

for firm i, county c, and year t. The variable $\#Plant_{i,c,t}$ is the number of polluting plants that firm i owns in county c in year t. Then, we include the variable $HC_{i,t}$ in our estimation of Equation (1). The results are presented in columns (2) to (7) of Internet Appendix Table IA.8. The findings are qualitatively unchanged from Table 3 and more importantly, the Heckman correction variable enters insignificantly in all specifications, indicating that the self-selection problem is not a major concern in these analyses.

IA.6. Potential information leakage preceding nonattainment designations

We explore the possibility that market participants have preemptive information about impending nonattainment designations preceding their actual effective date, by examining market reactions to pre-nonattainment designation events. Prior to nonattainment designations, each state has the opportunity to submit county designation recommendations to the EPA.[29] While state recommendations are taken into consideration by the EPA in determining whether a county should be designated nonattainment, the EPA also takes into account other factors such as emission trends, traffic patterns, population density, meteorology, geography, and area growth. As a result, the EPA may not follow the recommendations provided by the states and a degree of uncertainty exists surrounding a county's designation status until the EPA arrives at its final conclusion. Therefore, a state's recommendation of nonattainment reveals the possibility of future nonattainment designation by the EPA, and is the most newsworthy pre-nonattainment designation event.

We employ the same event study methodology and compute CARs surrounding each state's recommendation event date.[30] Internet Appendix Table IA.9 presents the market's reaction to nonattainment recommendations and shows that the market does not react to nonattainment recommendations. We also re-run our cross-sectional regressions in Equation (1) by using a modified dependent variable whereby we aggregate the CARs across the recommendation date and the effective designation date.[31] The results are reported in Internet Appendix Table IA.10. The estimated coefficients and statistical significance of the key double interaction terms remain substantively similar to those reported in Table 3. These results indicate that our findings relating to nonattainment designations and shareholder value are robust, after taking into account any potential information leakages.

IA.7. Revocations of ozone standards

We conduct another falsification test by studying the revocation of ozone standards. During our sample period, two ozone standards were revoked by the EPA. These are the 1-Hour Ozone (1979) and 8-Hour Ozone (1997) standards, which were revoked on September 2, 2005 and April 6, 2015, respectively. Revocations are different from attainment redesignations in that the former prevents future nonattainment designations if counties violate the revoked ozone standard, while counties that were historically designated nonattainment for the revoked standard remain in nonattainment until they demonstrate enough improvement to be redesignated to attainment. Therefore, revocation events do not change the nonattainment status of a county and plants operating in these areas are still subject to nonattainment regulations. Revocations offer an opportunity to conduct a falsification test since there is no

[29]For example, states were able to submit nonattainment/attainment recommendations to the EPA before the deadline of July 15, 2003 for the 8-Hour Ozone (1997) standard effective June 15, 2004.

[30]We obtain each state's recommendation date and each county's recommended designation from EPA's docket associated with each nonattainment designation event.

[31]Not all counties designated nonattainment are recommended nonattainment by states, so if no recommendation event dates are available, we treat the recommendation event CAR as zero and observe only the effective designation date CAR for that observation.

information content contained in revocation events that affects a county's current regulatory status, implying that the market should not react to such events. We compute the CARs surrounding revocations and present the results in Internet Appendix Table IA.11. None of the CARs are statistically significant, suggesting that investors do not react to revocation events.

IA.8. Bump-up classifications

In this section, we examine the cross-sectional variation in CARs around regulatory events that increase the stringency of local environmental regulations, conditional on nonattainment status. In particular, the 1990 CAAA introduced a classification system for ozone which ranks the severity of a county's nonattainment status from marginal to extreme. Nonattainment counties for ozone with a more severe classification are given more time to meet the NAAQS but face greater regulatory stringency. The EPA has authority to bump up nonattainment counties ("bump-ups") from a lower classification to a higher one if the state fails to demonstrate attainment by the given date as specified in the SIP. Thus, bump-ups represent an increase in the stringency of local nonattainment regulation.

For multi-plant firms, specific requirements on pollution abatement capital and emission offsets are increasing in stringency with respect to the bump-up classification. For example, ozone RACT requirements only apply to plants located in counties classified as moderate and above (Sheriff, Ferris, & Shadbegian, 2019). Additionally, in these counties, a unit of emission from new sources must be offset by more than a unit of emission from existing sources (Congressional Research Service, 2020). Thus, multi-plant firms operating a greater proportion of heavy ozone-emitting plants located in nonattainment counties facing bump-ups may experience even greater compliance costs than otherwise similar firms, which proportionately offsets the benefits associated with nonattainment status when compared to initial nonattainment designations and should lead to lower CARs.

To test this, we estimate the following specification:

$$\begin{aligned} CAR_{i,t} = \beta_0 + \beta_1 Bump\ ratio_{i,t} + \beta_2 Bump\ ozone_{i,t-1} + \beta_3 Bump\ ratio_{i,t} \\ \times Bump\ ozone_{i,t-1} + \beta_4 X_t + \text{F.E.} + \varepsilon_{i,t} \end{aligned} \quad \text{(IA.2)}$$

for firm i and year t. The dependent variable is the 11-day CAR associated with bump-ups.[32] *Bump ratio* equals to the number of polluting plants located in nonattainment counties experiencing bump-ups for a given firm divided by the total number of nonattainment plants owned by the given firm. *Bump ozone* is defined as the natural logarithm of one plus the total amount of ozone air emissions (in pounds) in nonattainment counties experiencing bump-ups for a given firm. The coefficient of interest is β_3, which captures the differential market reaction to heavy ozone-polluting firms operating plants in nonattainment counties exposed to bump-ups.

We present the estimation results of Equation (IA.2) in Internet Appendix Table IA.12. In

[32]We obtain the effective dates of bump-ups from the Federal Register.

columns (1) to (3), the coefficient estimates on the interaction term *Bump ratio* × *Bump ozone* are all negative and statistically significant, suggesting that investors react less favorably towards firms that operate a large proportion of nonattainment plants in bumped up counties and are heavy polluters of ozone in those areas. Economically, given a one standard deviation increase in the (log of) ozone air emissions in counties experiencing a bump-up, a firm that operates a proportion of plants in bumped up counties at the median level experiences 0.43 percentage points lower CARs compared with a firm that operates a proportion of plants in bumped up counties at the 25 percentile level.

Next, we decompose market reactions to bump-ups into an unexpected and anticipated component. Nonattainment counties that do not improve their DVs to a specified level by the attainment deadline set forth in the SIP are likely to be bumped up to a higher classification. Thus, attentive investors may anticipate a bump-up if they closely track the DVs of the county over time. We define unexpected bump-ups as those counties that are predicted to not experience bump-ups because they see an improvement in DVs, but end up receiving a bump-up on the effective date. Similarly, anticipated bump-ups are those counties that are predicted to be bumped up because they do not see an improvement in DVs and do actually end up experiencing a bump-up on the effective date.

We construct the variables *Unexp. bump ratio* and *Antic. bump ratio* to be equal to the number of polluting plants located in unexpected and anticipated bump-up counties for a given firm divided by the total number of nonattainment polluting plants owned by the firm, respectively. Then, we replace *Bump ratio* and its corresponding interaction terms in Equation (IA.2) with *Unexp. bump ratio* and *Antic. bump ratio*. Columns (4) to (6) of Internet Appendix Table IA.12 decompose the market's reaction into an unexpected and anticipated component. Across all three columns, only the coefficient estimate on the unexpected component's double interaction term is negative and statistically significant, while that of the anticipated component is statistically insignificant. This result is in line with earlier findings on nonattainment designations in that investors only react to unexpected bump-ups.

IA.9. Plant-level ozone emissions: falsification tests

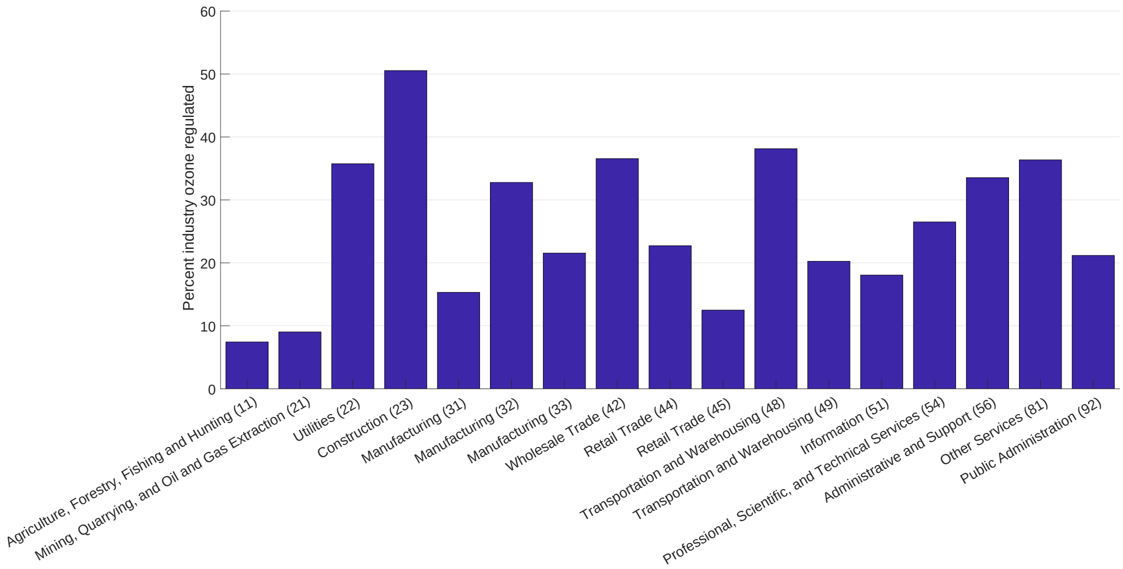
We conduct the same analysis as in Figure 4, except we use plant-level offsite ozone emissions and particulate matter emissions as the outcome variables. We do not expect ozone-dependent plants located in nonattainment counties to adjust their emissions of the aforementioned types since nonattainment designations do not regulate these types of emissions. Similarly, if nonattainment status lead to better environmental outcomes by reducing plants' emissions of hazardous chemicals, then it should not impact on those chemical emissions that do not have harmful human effects or impact on biological critical systems. The findings in Internet Appendix Figure IA.2 largely confirms our predictions.

IA.10. Intrafirm reallocation

Lastly, we test the possibility that the positive reaction to nonattainment designations is driven by multi-plant firms who plausibly have an advantage in that they can reallocate ozone emissions to plants located in attainment counties. For example, multi-plant firms may time their investment cycles to expand into attainment counties to benefit from the less stringent regulatory environment there. To do so, we restrict our sample to only plants in attainment counties and estimate a similar regression to Equation (5), except we replace *NA* with *Other NA*, which is a dummy variable equal to one if a given plant belongs to a firm that operates one or more plants located in nonattainment counties in the same year and three-digit NAICS industry, and zero otherwise. Internet Appendix Figure IA.3 shows that there is virtually no intrafirm reallocation of ozone emissions from nonattainment counties to attainment counties for multi-plant firms. Our results are consistent with the results of Cui and Ji (2016), who could not find any significant evidence of intrafirm ozone emissions leakage for multi-plant firms operating in nonattainment and attainment counties.

We also examine whether nonattainment designations impact the production and solvency of ozone plants in attainment counties belonging to multi-plant firms. As proxies for plant-level production, we use the production ratio, the natural logarithm of facility employment, and the natural logarithm of facility sales. To measure plant-level solvency, we use the paydex score from NETS. The paydex score ranges from 0 to 100 and is a business credit score based on a facility's trade credit performance. We define the variable *Plant credit risk* to be a dummy variable equal to one if a given facility's paydex score is between 0 and 49 (high risk of late repayment), and zero otherwise. As shown in Internet Appendix Figure IA.4, nonattainment designations have no spillover effects on the production and solvency of attainment ozone plants for multi-plant firms.

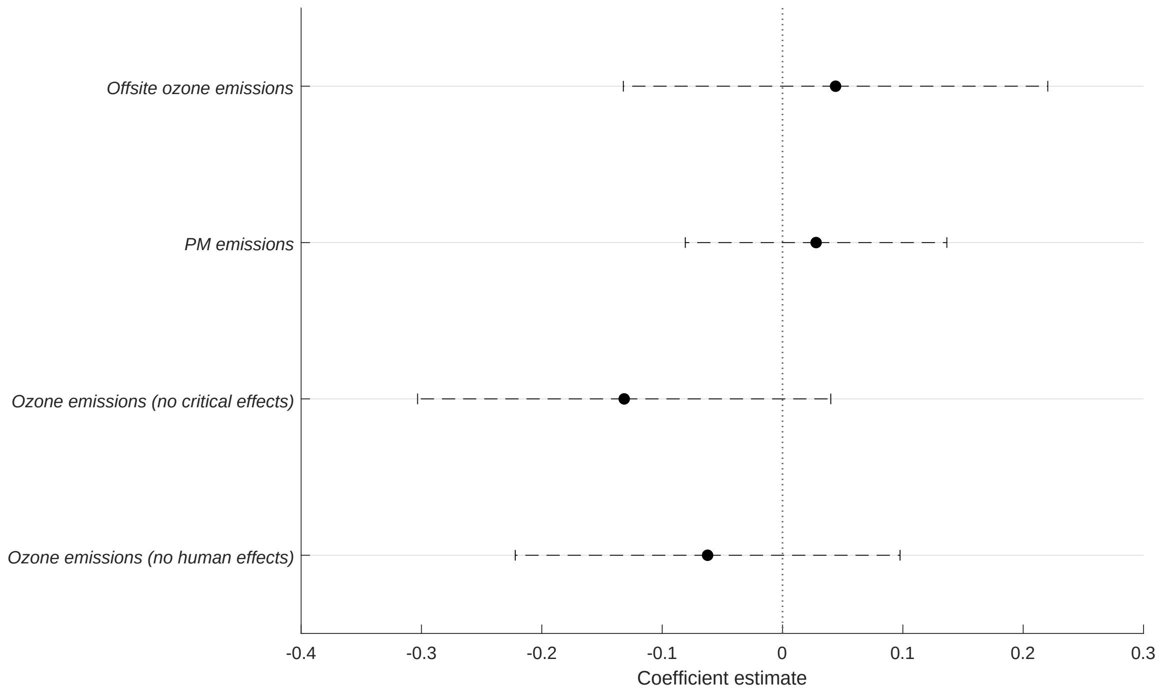
Figure IA.1
Fraction of ozone plants by industry in nonattainment counties.



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

Figure IA.2

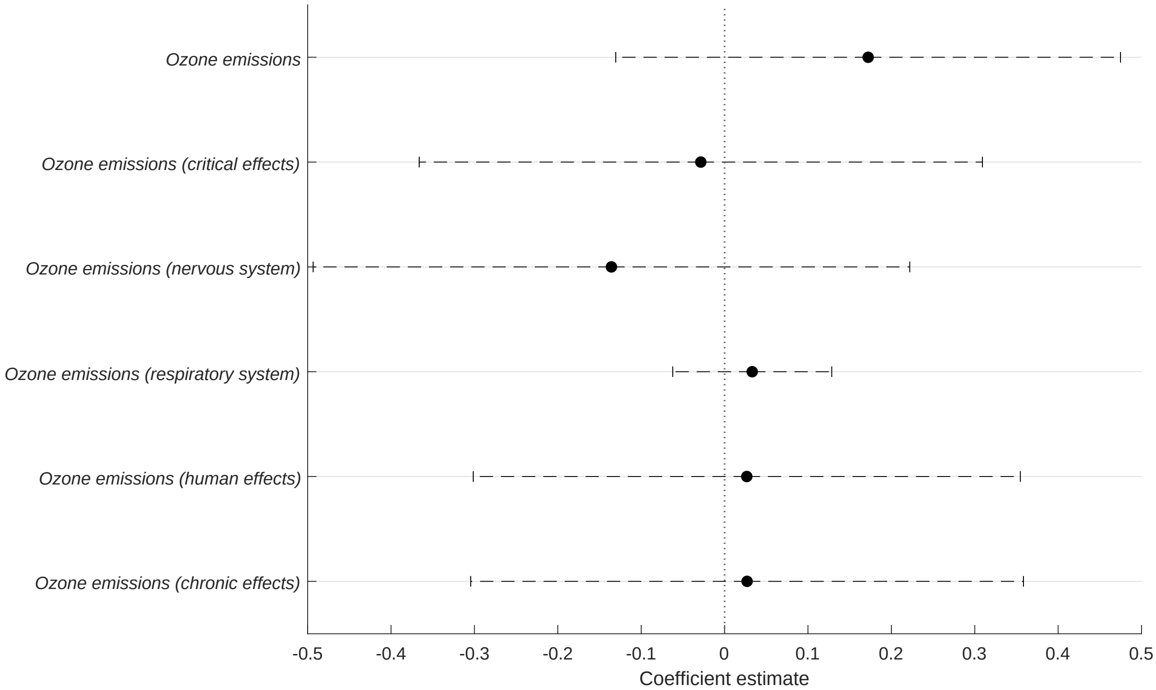
Nonattainment status and plant-level ozone emissions: falsification tests.



This figure shows the point estimates (black dot) and 95% confidence intervals (dashed lines) of the coefficients for the interaction term $NA_t \times Ozone\ ratio_t$. For each specification, the dependent variable is listed on the vertical axis and is measured in year $t+1$. *Offsite ozone emissions* is the natural logarithm of one plus the total amount of offsite ozone air emissions (in pounds) of a given plant in a given year. *PM emissions* is the natural logarithm of one plus the total amount of particulate matter air emissions (in pounds) of a given plant in a given year. *Ozone emissions (no critical effects)* is the natural logarithm of one plus the total amount of ozone air emissions (in pounds) that do not have critical effects on biological systems of a given plant in a given year. *Ozone emissions (no human effects)* is the natural logarithm of one plus the total amount of ozone air emissions (in pounds) that do not have harmful human effects of a given plant in a given year. NA_t is a dummy variable equal to one if a given county is designated nonattainment in year t, and zero otherwise. $Ozone\ ratio_t$ is the total ozone air emissions for a given plant in year t as a proportion of the given plant's overall air emissions across all chemicals.

Figure IA.3

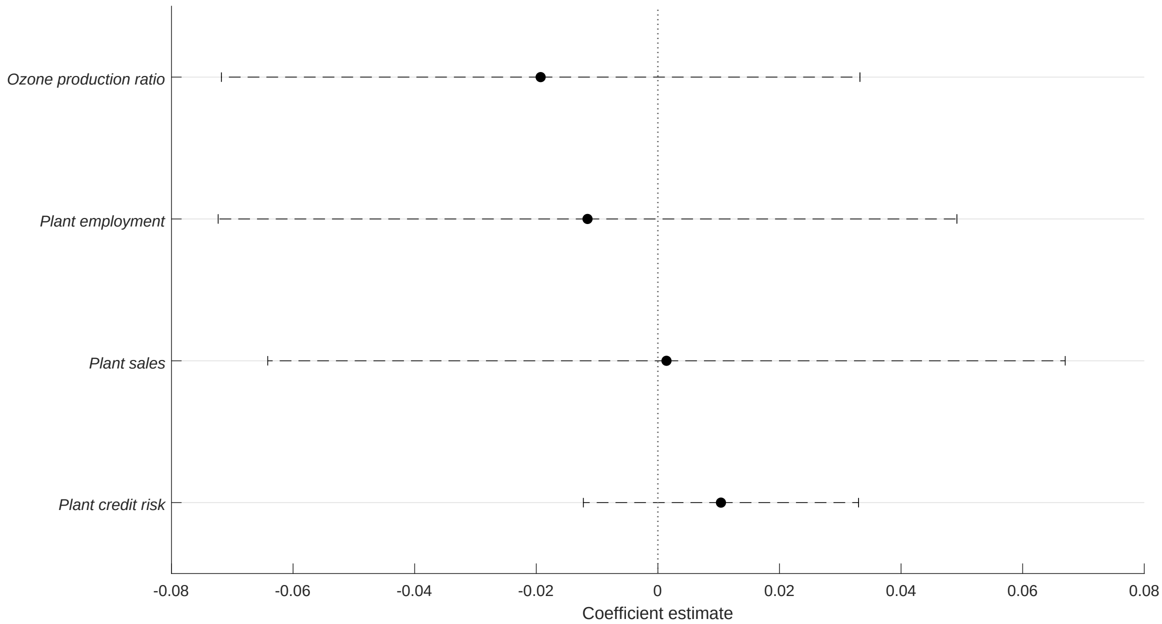
Nonattainment status and plant-level ozone emissions: intrafirm reallocation.



This figure shows the point estimates (black dot) and 95% confidence intervals (dashed lines) of the coefficients for the interaction term *Other* NA_t × *Ozone* $ratio_t$. The sample consists only of plants in attainment counties. For each specification, the dependent variable is listed on the vertical axis and is measured in year $t+1$. *Ozone emissions* is the natural logarithm of one plus the total amount of ozone air emissions (in pounds) of a given plant in a given year. Other dependent variables are defined similarly but are restricted to those ozone air emissions that have critical effects on biological systems (e.g., nervous or respiratory systems) and those that have harmful human effects (e.g., chronic health effects). *Other* NA_t is a dummy variable equal to one if a given plant belongs to a firm that operates one or more plants located in nonattainment counties in the same year t and three-digit NAICS industry, and zero otherwise. *Ozone* $ratio_t$ is the total ozone air emissions for a given plant in year t as a proportion of the given plant's overall air emissions across all chemicals.

Figure IA.4

Nonattainment status and plant-level production, employment, and solvency: intrafirm effects.



This figure shows the point estimates (black dot) and 95% confidence intervals (dashed lines) of the coefficients for the interaction term *Other* NA_t × *Ozone* $ratio_t$. The sample consists only of plants in attainment counties. For each specification, the dependent variable is listed on the vertical axis and is measured in year $t+1$. *Ozone production ratio* is the ozone production ratio of a given facility. *Plant employment* is the natural logarithm of one plus the total number of employees of a given facility. *Plant sales* is the natural logarithm of one plus the total amount of sales of a given facility. *Plant credit risk* is a dummy variable equal to one if a given facility's paydex score is between 0 and 49, and zero otherwise. *Other* NA_t is a dummy variable equal to one if a given plant belongs to a firm that operates one or more plants located in nonattainment counties in the same year t and three-digit NAICS industry, and zero otherwise. *Ozone* $ratio_t$ is the total ozone air emissions for a given plant in year t as a proportion of the given plant's overall air emissions across all chemicals.

Table IA.1
Ozone NAAQS.

Standard	Effective date	Averaging time	Threshold (ppm)	Form
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
1997	June 15, 2004	8 hours	0.08	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
2008	July 20, 2012	8 hours	0.075	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
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 effective date of the final rule for the ozone standard 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. This table is adapted from `https://www.epa.gov/ground-level-ozone-pollution/timeline-ozone-national-ambient-air-quality-standards-naaqs`.

Table IA.2
TRI industry composition.

NAICS	Description	Proportion (%)
325	Chemical Manufacturing	12.970
332	Fabricated Metal Product Manufacturing	12.644
336	Transportation Equipment Manufacturing	8.222
311	Food Manufacturing	7.942
333	Machinery Manufacturing	7.252
331	Primary Metal Manufacturing	6.733
334	Computer and Electronic Product Manufacturing	5.665
221	Utilities	4.958
327	Nonmetallic Mineral Product Manufacturing	4.709
326	Plastics and Rubber Products Manufacturing	4.430
424	Merchant Wholesalers, Nondurable Goods	3.531
321	Wood Product Manufacturing	3.144
322	Paper Manufacturing	3.128
335	Electrical Equipment, Appliance, and Component Manufacturing	3.044
324	Petroleum and Coal Products Manufacturing	2.740
562	Waste Management and Remediation Services	2.020
339	Miscellaneous Manufacturing	1.739
337	Furniture and Related Product Manufacturing	1.407
212	Mining (except Oil and Gas)	0.819
323	Printing and Related Support Activities	0.814
313	Textile Mills	0.614
312	Beverage and Tobacco Product Manufacturing	0.585
314	Textile Product Mills	0.299
316	Leather and Allied Product Manufacturing	0.110
811	Repair and Maintenance	0.090
454	Nonstore Retailers	0.079
315	Apparel Manufacturing	0.052
541	Professional, Scientific, and Technical Services	0.052
213	Support Activities for Mining	0.029
488	Support Activities for Transportation	0.027
113	Forestry and Logging	0.025
112	Animal Production and Aquaculture	0.024
493	Warehousing and Storage	0.020
486	Pipeline Transportation	0.013
532	Rental and Leasing Services	0.013
551	Management of Companies and Enterprises	0.009
481	Air Transportation	0.008
237	Heavy and Civil Engineering Construction	0.005
423	Merchant Wholesalers, Durable Goods	0.005
425	Wholesale Electronic Markets and Agents and Brokers	0.005
444	Building Material and Garden Equipment and Supplies Dealers	0.004
445	Food and Beverage Stores	0.004
561	Administrative and Support Services	0.004
531	Real Estate	0.003
211	Oil and Gas Extraction	0.002
442	Furniture and Home Furnishings Stores	0.002
484	Truck Transportation	0.002
511	Publishing Industries (except Internet)	0.002
812	Personal and Laundry Services	0.002
115	Support Activities for Agriculture and Forestry	0.002

This table reports the three-digit NAICS industries in TRI that are included in our sample. Proportion refers to the fraction that is represented in our sample.

Table IA.3

Distribution of county nonattainment designations and attainment redesignations by state.

State	# TRI parent firms per county	# TRI ozone plants per county	# TRI non-ozone plants per county	# Counties nonattainment	# Counties redesignated	# Counties total
Alaska	0.12	0.10	0.04	0	0	29
Alabama	1.51	0.75	0.91	2	2	67
Arkansas	1.19	0.53	0.85	1	1	75
Arizona	3.03	1.78	1.83	4	2	15
California	4.23	2.46	2.73	42	5	58
Colorado	0.69	0.32	0.44	9	7	64
Connecticut	6.44	4.00	4.03	8	0	8
District of Columbia	1.80	0.00	2.40	1	1	1
Delaware	4.67	3.01	1.76	3	0	3
Florida	1.66	0.81	0.94	7	7	67
Georgia	0.90	0.46	0.52	23	23	159
Hawaii	1.40	2.08	0.53	0	0	5
Iowa	0.93	0.54	0.47	0	0	99
Idaho	0.26	0.13	0.14	0	0	44
Illinois	1.79	1.04	1.01	12	12	102
Indiana	2.00	1.14	1.13	24	24	92
Kansas	0.57	0.30	0.31	2	2	105
Kentucky	0.77	0.43	0.38	16	16	120
Louisiana	1.34	0.97	0.56	17	17	64
Massachusetts	5.19	2.67	3.02	14	0	14
Maryland	1.39	0.63	0.88	14	7	24
Maine	1.21	0.73	0.56	12	11	16
Michigan	1.69	1.07	1.07	39	39	83
Minnesota	1.18	0.59	0.67	0	0	87
Missouri	0.94	0.44	0.56	8	8	115
Mississippi	0.86	0.40	0.57	1	1	82
Montana	0.18	0.14	0.07	0	0	56
North Carolina	1.61	0.81	0.94	23	23	100
North Dakota	0.27	0.15	0.12	0	0	53
Nebraska	0.43	0.20	0.29	0	0	93
New Hampshire	2.23	0.90	1.55	7	6	10
New Jersey	3.56	2.02	1.75	21	0	21
New Mexico	0.54	0.32	0.30	1	0	33
Nevada	1.18	0.59	0.69	2	1	17
New York	1.92	0.95	1.11	30	0	62
Ohio	2.99	1.63	1.75	34	34	88
Oklahoma	0.93	0.41	0.61	0	0	77
Oregon	1.18	0.69	0.69	5	3	36
Pennsylvania	2.96	1.55	1.77	49	32	67
Rhode Island	3.22	1.51	1.79	5	0	5
South Carolina	2.03	1.09	1.01	2	2	46
South Dakota	0.24	0.11	0.16	0	0	66
Tennessee	1.43	0.64	0.88	14	14	95
Texas	1.27	0.73	0.82	23	4	254
Utah	1.29	0.66	0.83	7	2	29
Virginia	0.70	0.29	0.44	37	36	133
Vermont	0.38	0.19	0.30	0	0	14
Washington	1.24	0.63	0.77	4	4	39
Wisconsin	1.94	1.13	1.08	11	11	72
West Virginia	0.72	0.50	0.27	10	10	55
Wyoming	0.55	0.43	0.16	3	0	23

This table reports the average number of TRI parent firms per county, the average number of TRI ozone plants per county, the average number of TRI non-ozone plants per county, the number of counties ever obtained a nonattainment designation, the number of counties ever obtained an attainment redesignation, and the total number of counties. The sample period is from 1992 to 2019.

Table IA.4

Cross-sectional variation in cumulative abnormal returns during nonattainment designations using toxicity-weighted ozone emissions.

Dep. variable:	CAR	CAR (FF48)	CAR (FFM)	CAR	CAR (FF48)	CAR (FFM)
	(1)	(2)	(3)	(4)	(5)	(6)
NA ratio$_t$	0.010	0.013	0.011			
	(0.78)	(1.04)	(0.98)			
Unexp. NA ratio$_t$				0.031	0.030	0.024
				(1.45)	(1.42)	(1.13)
Antic. NA ratio$_t$				-0.014	-0.008	-0.017
				(-1.17)	(-0.69)	(-1.37)
NA TW ozone$_{t-1}$	0.001**	0.002**	0.001	0.001**	0.002***	0.001*
	(2.17)	(2.38)	(1.32)	(2.43)	(2.64)	(1.71)
NA ratio$_t$ × *NA TW ozone*$_{t-1}$	-0.002**	-0.003**	-0.002*			
	(-2.01)	(-2.36)	(-1.88)			
Unexp. NA ratio$_t$ × *NA TW ozone*$_{t-1}$				-0.005**	-0.005**	-0.004**
				(-2.46)	(-2.48)	(-2.05)
Antic. NA ratio$_t$ × *NA TW ozone*$_{t-1}$				-0.001	-0.001	-0.000
				(-0.75)	(-1.24)	(-0.24)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,305	1,305	1,305	1,305	1,305	1,305
Adj R^2	0.10	0.09	0.06	0.13	0.12	0.09

This table reports the regression estimates from Equation (1) for nonattainment designations using toxicity-weighted ozone emissions. The dependent variables are the 11-day CARs $(-5, +5)$. Columns (1) and (4) use the market model CAR. In columns (2) and (5), CARs are calculated using Fama and French's (1997) 48 value-weighted industry return as the benchmark return. In columns (3) and (6), CARs are risk adjusted using Carhart's (1997) four-factor model. *NA ratio*$_t$ is the number of polluting plants located in nonattainment counties for a given firm in event year t divided by the total number of plants owned by the given firm. *Unexp. NA ratio*$_t$ (*Antic. NA ratio*$_t$) is the number of polluting plants located in unexpected (anticipated) nonattainment counties for a given firm in event year t divided by the total number of plants owned by the given firm. *NA TW ozone*$_{t-1}$ is the natural logarithm of one plus the total amount of toxicity-weighted ozone air emissions (in pounds) in nonattainment counties of a given firm in year $t-1$. 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.5

Cross-sectional variation in cumulative abnormal returns during nonattainment designations using offsite ozone emissions.

Dep. variable:	CAR	CAR (FF48)	CAR (FFM)	CAR	CAR (FF48)	CAR (FFM)
	(1)	(2)	(3)	(4)	(5)	(6)
NA ratio$_t$	-0.009	-0.009	-0.011			
	(-0.76)	(-0.73)	(-0.91)			
Unexp. NA ratio$_t$				-0.001	-0.002	-0.004
				(-0.04)	(-0.15)	(-0.30)
Antic. NA ratio$_t$				-0.018	-0.015	-0.019
				(-1.42)	(-1.25)	(-1.53)
NA offsite ozone$_{t-1}$	0.000	0.000	-0.001	0.000	0.000	-0.001
	(0.06)	(0.27)	(-0.40)	(0.02)	(0.21)	(-0.45)
NA ratio$_t$ $\times$ *NA offsite ozone*$_{t-1}$	0.000	-0.000	0.002			
	(0.09)	(-0.03)	(0.82)			
Unexp. NA ratio$_t$ $\times$ *NA offsite ozone*$_{t-1}$				0.004	0.004	0.006
				(0.73)	(0.67)	(1.15)
Antic. NA ratio$_t$ $\times$ *NA offsite ozone*$_{t-1}$				-0.001	-0.002	0.000
				(-0.48)	(-0.60)	(0.17)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,305	1,305	1,305	1,305	1,305	1,305
Adj R^2	0.10	0.09	0.07	0.11	0.10	0.07

This table reports the regression estimates from Equation (1) for nonattainment designations using offsite ozone emissions. The dependent variables are the 11-day CARs $(-5, +5)$. Columns (1) and (4) use the market model CAR. In columns (2) and (5), CARs are calculated using Fama and French's (1997) 48 value-weighted industry return as the benchmark return. In columns (3) and (6), CARs are risk adjusted using Carhart's (1997) four-factor model. *NA ratio*$_t$ is the number of polluting plants located in nonattainment counties for a given firm in event year t divided by the total number of plants owned by the given firm. *Unexp. NA ratio*$_t$ (*Antic. NA ratio*$_t$) is the number of polluting plants located in unexpected (anticipated) nonattainment counties for a given firm in event year t divided by the total number of plants owned by the given firm. *NA offsite ozone*$_{t-1}$ is the natural logarithm of one plus the total amount of offsite ozone air emissions (in pounds) in nonattainment counties of a given firm in year $t-1$. 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
Cross-sectional variation in cumulative abnormal returns during nonattainment designations using particulate matter emissions.

Dep. variable:	CAR	CAR (FF48)	CAR (FFM)	CAR	CAR (FF48)	CAR (FFM)
	(1)	(2)	(3)	(4)	(5)	(6)
NA ratio$_t$	-0.011	-0.010	-0.015			
	(-0.87)	(-0.76)	(-1.13)			
Unexp. NA ratio$_t$				-0.006	-0.007	-0.012
				(-0.39)	(-0.46)	(-0.78)
Antic. NA ratio$_t$				-0.028**	-0.025*	-0.032**
				(-2.04)	(-1.82)	(-2.36)
NA PM$_{t-1}$	-0.001	-0.001	-0.002	-0.001	-0.001	-0.003
	(-0.49)	(-0.35)	(-1.39)	(-0.65)	(-0.57)	(-1.63)
NA ratio$_t$ × *NA PM*$_{t-1}$	0.001	0.000	0.004			
	(0.40)	(0.08)	(1.36)			
Unexp. NA ratio$_t$ × *NA PM*$_{t-1}$				-0.001	-0.001	0.002
				(-0.23)	(-0.29)	(0.44)
Antic. NA ratio$_t$ × *NA PM*$_{t-1}$				0.002	0.001	0.005
				(0.74)	(0.42)	(1.64)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,305	1,305	1,305	1,305	1,305	1,305
Adj R^2	0.10	0.09	0.07	0.10	0.09	0.07

This table reports the regression estimates from Equation (1) for nonattainment designations using particulate matter emissions. The dependent variables are the 11-day CARs $(-5, +5)$. Columns (1) and (4) use the market model CAR. In columns (2) and (5), CARs are calculated using Fama and French's (1997) 48 value-weighted industry return as the benchmark return. In columns (3) and (6), CARs are risk adjusted using Carhart's (1997) four-factor model. *NA ratio*$_t$ is the number of polluting plants located in nonattainment counties for a given firm in event year t divided by the total number of plants owned by the given firm. *Unexp. NA ratio*$_t$ (*Antic. NA ratio*$_t$) is the number of polluting plants located in unexpected (anticipated) nonattainment counties for a given firm in event year t divided by the total number of plants owned by the given firm. *NA PM*$_{t-1}$ is the natural logarithm of one plus the total amount of particulate matter air emissions (in pounds) in nonattainment counties of a given firm in year $t-1$. 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

Cross-sectional variation in cumulative abnormal returns during nonattainment designations using employee- and sales-weighted *NA ratio*.

Panel A: Employee-weighted NA ratio			
Dep. variable:	CAR	CAR (FF48)	CAR (FFM)
	(1)	(2)	(3)
$\textit{Employee NA ratio}_t$	0.001	0.004	0.002
	(0.11)	(0.34)	(0.16)
$\textit{NA ozone}_{t-1}$	0.004**	0.004**	0.004**
	(2.09)	(2.34)	(2.01)
$\textit{Employee NA ratio}_t \times \textit{NA ozone}_{t-1}$	-0.005**	-0.006**	-0.005*
	(-1.99)	(-2.26)	(-1.90)
Controls	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes
Observations	1,159	1,159	1,159
Adj R^2	0.12	0.12	0.09

Panel B: Sales-weighted NA ratio			
Dep. variable:	CAR	CAR (FF48)	CAR (FFM)
	(1)	(2)	(3)
$\textit{Sales NA ratio}_t$	0.002	0.005	0.002
	(0.13)	(0.36)	(0.17)
$\textit{NA ozone}_{t-1}$	0.004**	0.004**	0.003*
	(2.06)	(2.27)	(1.94)
$\textit{Sales NA ratio}_t \times \textit{NA ozone}_{t-1}$	0.005**	-0.006**	-0.005*
	(-2.00)	(-2.19)	(-1.84)
Controls	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes
Observations	1,159	1,159	1,159
Adj R^2	0.12	0.11	0.09

This table reports the regression estimates from Equation (1) for nonattainment designations using employee- and sales-weighted *NA ratio* in panels A and B, respectively. The dependent variables are the 11-day CARs $(-5, +5)$. In both panels, column (1) uses the market model CAR, column (2) uses CARs calculated using Fama and French's (1997) 48 value-weighted industry return as the benchmark return, and column (3) uses CARs risk adjusted using Carhart's (1997) four-factor model. *Employee NA ratio* equals to the employee-weighted number of polluting plants located in nonattainment counties for a given firm divided by the total number of employees across all polluting plants owned by the firm. *Sales NA ratio* equals to the sales-weighted number of polluting plants located in nonattainment counties for a given firm divided by the total amount of sales across all polluting plants owned by the firm. $\textit{NA ozone}_{t-1}$ is the natural logarithm of one plus the total amount of ozone air emissions (in pounds) in nonattainment counties of a given firm in year $t-1$. 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

Cross-sectional variation in cumulative abnormal returns during nonattainment designations using Heckman correction.

	First stage		Second stage					
Dep. variable:	NA_t		CAR	CAR (FF48)	CAR (FFM)	CAR	CAR (FF48)	CAR (FFM)
	(1)		(2)	(3)	(4)	(5)	(6)	(7)
$NA\ DV_{t-1}$	0.753***	$NA\ ratio_t$	0.003	0.008	0.008			
	(10.81)		(0.22)	(0.62)	(0.71)			
$ln(County\ emp)_{t-1}$	0.823***	$Unexp.\ NA\ ratio_t$				0.045**	0.042**	0.038*
	(3.40)					(2.12)	(1.96)	(1.84)
$NOx\text{-}county\ emp\ ratio_{t-1}$	0.153**	$Antic.\ NA\ ratio_t$				-0.003	0.001	-0.006
	(2.02)					(-0.35)	(0.10)	(-0.73)
$\Delta County\ emp_{t-1}$	0.002	$NA\ ozone_{t-1}$	0.003**	0.003**	0.002	0.003**	0.003***	0.003**
	(0.26)		(2.04)	(2.29)	(1.54)	(2.56)	(2.62)	(2.13)
MSA	3.397***	$NA\ ratio_t \times NA\ ozone_{t-1}$	-0.005**	-0.005**	-0.004**			
	(21.30)		(-2.00)	(-2.33)	(-2.06)			
		$Unexp.\ NA\ ratio_t \times NA\ ozone_{t-1}$				-0.009**	-0.009**	-0.008**
						(-2.51)	(-2.46)	(-2.16)
Year F.E.	Yes	$Antic.\ NA\ ratio_t \times NA\ ozone_{t-1}$				-0.003	-0.003	-0.003
County F.E.	Yes					(-1.62)	(-1.47)	(-1.26)
Observations	16,707	HC	0.009	0.003	0.001	-0.003	-0.007	-0.004
Adj R^2	0.27		(0.33)	(0.12)	(0.04)	(-0.25)	(-0.52)	(-0.31)
		Controls	Yes	Yes	Yes	Yes	Yes	Yes
		Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
		Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
		Observations	1,305	1,305	1,305	1,305	1,305	1,305
		Adj R^2	0.10	0.09	0.06	0.10	0.09	0.06

This table reports the first- and second-stage estimation results for cross-sectional regressions of CARs for nonattainment designations using Heckman correction. Column (1) presents the first-stage results using a probit model where the dependent variable, NA_t, is a dummy variable equal to one if a given county is in nonattainment in year t. The explanatory variables are $NA\ DV_{t-1}$, which is a dummy variable equal to one if the county is hypothetically in nonattainment based on DVs; $ln(County\ emp)_{t-1}$, defined as the natural logarithm of one plus the employment levels in a given county; $NOx\text{-}county\ emp\ ratio_{t-1}$, defined as a given county's NO_x emissions to employment ratio; $\Delta County\ emp_{t-1}$, equal to the change in a given county's employment levels; and MSA, which is a dummy variable equal to one if the county is located in a MSA. Columns (2) to (7) present the second-stage results where a Heckman correction variable, HC, is included in all regressions. The dependent variables are the 11-day CARs $(-5,+5)$. Columns (2) and (5) use the market model CAR. In columns (3) and (6), CARs are calculated using Fama and French's (1997) 48 value-weighted industry return as the benchmark return. In columns (4) and (7), CARs are risk adjusted using Carhart's (1997) four-factor model. $NA\ ratio_t$ is the number of polluting plants located in nonattainment counties for a given firm in event year t divided by the total number of plants owned by the given firm. $Unexp.\ NA\ ratio_t$ ($Antic.\ NA\ ratio_t$) is the number of polluting plants located in unexpected (anticipated) nonattainment counties for a given firm in event year t divided by the total number of plants owned by the given firm. $NA\ ozone_{t-1}$ is the natural logarithm of one plus the total amount of ozone air emissions (in pounds) in nonattainment counties of a given firm in year $t-1$. 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
Cumulative abnormal returns for states' recommendations of nonattainment.

	All polluting plants		Non-ozone plants		Ozone plants	
Event window	$(-3,+3)$	$(-5,+5)$	$(-3,+3)$	$(-5,+5)$	$(-3,+3)$	$(-5,+5)$
	(1)	(2)	(3)	(4)	(5)	(6)
Mean (%)	0.06	0.04	0.01	0.02	0.13	0.12
t-statistic	(0.58)	(0.29)	(0.04)	(0.08)	(0.88)	(0.72)
Median (%)	0.04	0.03	0.15	0.24	0.13	0.07
Generalized sign test	(0.34)	(0.15)	(0.57)	(1.59)	(1.25)	(0.23)
Observations	1,805	1,805	869	869	936	936

This table reports the mean and median value-weighted CARs for states' recommendations of nonattainment. We consider event windows of 7 $(-3,+3)$ and 11 $(-5,+5)$ days. All polluting plants, non-ozone plants, and ozone plants refer to firms with at least one polluting plant, only non-ozone plants, and at least one ozone plant, respectively, located in counties that are recommended nonattainment by their state. The t-statistics account for event-induced changes in volatility and are calculated according to Boehmer et al. (1991). The generalized sign test reports the test statistic of a generalized nonparametric Wilcoxon sign-rank test for medians. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

Table IA.10
Cross-sectional variation in cumulative abnormal returns during nonattainment designations controlling for potential information leakage.

Dep. variable:	CAR	CAR (FF48)	CAR (FFM)	CAR	CAR (FF48)	CAR (FFM)
	(1)	(2)	(3)	(4)	(5)	(6)
NA ratio$_t$	0.001	0.007	-0.001			
	(0.10)	(0.55)	(-0.08)			
Unexp. NA ratio$_t$				0.038*	0.036*	0.033
				(1.82)	(1.70)	(1.61)
Antic. NA ratio$_t$				-0.010	-0.006	-0.013
				(-1.30)	(-0.70)	(-1.62)
NA ozone$_{t-1}$	0.003**	0.003*	0.003	0.004***	0.003**	0.003*
	(2.17)	(1.96)	(1.64)	(2.58)	(2.32)	(1.93)
NA ratio$_t$ × *NA ozone*$_{t-1}$	-0.005**	-0.005**	-0.004*			
	(-2.04)	(-1.99)	(-1.79)			
Unexp. NA ratio$_t$ × *NA ozone*$_{t-1}$				-0.009***	-0.008**	-0.008**
				(-2.78)	(-2.52)	(-2.35)
Antic. NA ratio$_t$ × *NA ozone*$_{t-1}$				-0.003	-0.003	-0.002
				(-1.37)	(-1.51)	(-1.10)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,305	1,305	1,305	1,305	1,305	1,305
Adj R^2	0.08	0.06	0.05	0.08	0.07	0.04

This table reports the regression estimates from Equation (1) for nonattainment designations while controlling for potential information leakage preceding the effective date. The dependent variables are the 11-day CARs $(-5, +5)$ aggregated across the recommendation date and the effective designation date. Columns (1) and (4) use the market model CAR. In columns (2) and (5), CARs are calculated using Fama and French's (1997) 48 value-weighted industry return as the benchmark return. In columns (3) and (6), CARs are risk adjusted using Carhart's (1997) four-factor model. *NA ratio*$_t$ is the number of polluting plants located in nonattainment counties for a given firm in event year t divided by the total number of plants owned by the given firm. *Unexp. NA ratio*$_t$ (*Antic. NA ratio*$_t$) is the number of polluting plants located in unexpected (anticipated) nonattainment counties for a given firm in event year t divided by the total number of plants owned by the given firm. *NA ozone*$_{t-1}$ is the natural logarithm of one plus the total amount of ozone air emissions (in pounds) in nonattainment counties of a given firm in year $t-1$. 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.11
Cumulative abnormal returns for ozone standard revocations.

	All polluting plants		Non-ozone plants		Ozone plants	
Event window	$(-3,+3)$	$(-5,+5)$	$(-3,+3)$	$(-5,+5)$	$(-3,+3)$	$(-5,+5)$
	(1)	(2)	(3)	(4)	(5)	(6)
Mean (%)	-0.04	0.05	0.01	0.02	-0.00	-0.01
t-statistic	(-0.33)	(0.42)	(0.05)	(0.09)	(-0.03)	(-0.05)
Median (%)	-0.07	-0.06	-0.00	-0.00	-0.10	-0.09
Generalized sign test	(-1.06)	(-0.65)	(-0.01)	(-0.01)	(-1.41)	(-1.63)
Observations	523	523	233	233	290	290

This table reports the mean and median value-weighted CARs for ozone standard revocations. We consider event windows of 7 $(-3,+3)$ and 11 $(-5,+5)$ days. All polluting plants, non-ozone plants, and ozone plants refer to firms with at least one polluting plant, only non-ozone plants, and at least one ozone plant, respectively, located in counties that are in nonattainment for a given ozone standard but the standard is revoked. The t-statistics account for event-induced changes in volatility and are calculated according to Boehmer et al. (1991). The generalized sign test reports the test statistic of a generalized nonparametric Wilcoxon sign-rank test for medians. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

Table IA.12
Cross-sectional variation in cumulative abnormal returns during bump-up classifications.

Dep. variable:	CAR	CAR (FF48)	CAR (FFM)	CAR	CAR (FF48)	CAR (FFM)
	(1)	(2)	(3)	(4)	(5)	(6)
Bump ratio$_t$	0.011	0.011	0.013			
	(1.09)	(1.08)	(1.32)			
Unexp. bump ratio$_t$				0.010	0.005	0.009
				(0.97)	(0.51)	(0.87)
Antic. bump ratio$_t$				0.013	0.020	0.011
				(0.91)	(1.47)	(0.76)
Bump ozone$_{t-1}$	0.002**	0.002**	0.002**	0.002**	0.002**	0.002*
	(2.05)	(2.04)	(2.01)	(2.18)	(2.56)	(1.67)
Bump ratio$_t$ × *Bump ozone*$_{t-1}$	-0.005***	-0.005***	-0.005***			
	(-2.70)	(-3.03)	(-2.87)			
Unexp. bump ratio$_t$ × *Bump ozone*$_{t-1}$				-0.004***	-0.004**	-0.004**
				(-2.63)	(-2.50)	(-2.29)
Antic. bump ratio$_t$ × *Bump ozone*$_{t-1}$				-0.002	-0.003	-0.002
				(-1.20)	(-1.51)	(-0.88)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,001	1,001	1,001	1,001	1,001	1,001
Adj R^2	0.05	0.04	0.05	0.12	0.11	0.11

This table reports the regression estimates from Equation (IA.2) for bump-up classifications. The dependent variables are the 11-day CARs $(-5, +5)$. Columns (1) and (4) use the market model CAR. In columns (2) and (5), CARs are calculated using Fama and French's (1997) 48 value-weighted industry return as the benchmark return. In columns (3) and (6), CARs are risk adjusted using Carhart's (1997) four-factor model. *Bump ratio*$_t$ is the number of polluting plants located in nonattainment counties experiencing bump-ups for a given firm in event year t divided by the total number of nonattainment plants owned by the given firm. *Unexp. bump ratio*$_t$ (*Antic. bump ratio*$_t$) is the number of polluting plants located in unexpected (anticipated) bump-up counties for a given firm in event year t divided by the total number of nonattainment plants owned by the given firm. *Bump ozone*$_{t-1}$ is the natural logarithm of one plus the total amount of ozone air emissions (in pounds) in nonattainment counties experiencing bump-ups for a given firm in year $t-1$. 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.