Environmental regulatory risks, firm pollution, and mutual funds' portfolio choices*

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Abstract

This paper examines how mutual funds' portfolio holdings respond to environmental regulations. Using county-level ozone nonattainment designations induced by discrete policy changes in the National Ambient Air Quality Standards as a source of exogenous variation in local regulatory stringency, we find that funds underweight (overweight) those polluting stocks whose cash flows covary negatively (positively) with the regulatory shock. Our results are consistent with active portfolio rebalancing in response to expected changes in firm fundamentals due to negative cash flow shocks stemming from the costs of nonattainment regulation. Further analyses in the post-nonattainment period show that stocks with high exposure to nonattainment designations exhibit worse operating performance and increased regulatory compliance costs. The most underweighted of such firms also exhibit worse abnormal stock return performance. Funds that reduce their portfolio exposure to nonattainment designations see an improvement in their investment performance.

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1. Introduction

Recently, institutional investors have become increasingly concerned about the environmental risks embedded in their portfolio choices (e.g., Bolton & Kacperczyk, 2021; Cao, Titman, Zhan, & Zhang, 2021; Ilhan, Krueger, Sautner, & Starks, 2023; Starks, Venkat, & Zhu, 2020). In particular, environmental *regulatory* risks have been identified by both academics and practitioners to be of paramount importance over the next five years (Stroebel & Wurgler, 2021), and are widely believed to have already started to materialize (Krueger, Sautner, & Starks, 2020). Although research has shown that environmental regulatory risks affect 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), there has been relatively less work that explores how the interplay between environmental regulations and firm pollution impacts on investors' rational investment decisions. We fill this gap by focusing on an important group of investors whose trading we can observe, namely mutual funds, and examine how they rebalance their portfolio holdings of polluting firms in response to environmental regulations.

The institutional setting employed in this paper centers on 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 noncompliant (nonattainment), while those with pollution levels below the threshold are in compliance (attainment). Firms that operate ozone-polluting plants located in nonattainment counties face stringent regulations and mandatory pollution abatement requirements, which substantially increases their compliance costs, compared to those in attainment counties. Our empirical strategy exploits discrete policy changes in the NAAQS thresholds that induce nonattainment designations as an exogenous source of variation in local regulatory stringency that represents a negative shock to the cash flows of polluting firms exposed to these regulations.

The recent literature has primarily focused on investors' portfolio adjustments of polluting and non-polluting stocks driven by environmental, social, and governance (ESG) demand (Baker, Hollifield, & Osambela, 2022; Pástor, Stambaugh, & Taylor, 2021, 2022; Pedersen, Fitzgibbons, & Pomorski, 2021). In this study, we identify negative shocks to the cash flows of polluting firms exposed to nonattainment designations and examine the impact on mutual funds' active changes in portfolio holdings. The underlying economic mechanism is that ozone-polluting firms with a greater exposure to nonattainment designations experience greater regulatory costs (Ryan, 2012), which negatively impact on their firm fundamentals through a negative shock to operating cash flows (Bolton & Kacperczyk, 2021; Hsu, Li, & Tsou, 2023; Jouvenot & Krueger, 2021). Funds then rebalance their portfolio holdings depending on how the cash flows of the stock covary with the regulatory shock. Stocks that predicted to perform poorly in the post-nonattainment period are actively sold ("underweighted") in response to the nonattainment designation. Vice versa, stocks that are expected to outperform are actively bought ("overweighted"). We call this the "rational hypothesis".

Our unique setting that exploits local variation in regulatory stringency allows us to precisely identify which stocks plausibly experience additional regulatory costs given a nonattainment designation because not all firms are regulated uniformly. For example, a firm that operates many ozone-polluting plants, but are all located in attainment counties, is unaffected by the regulation. Similarly, a firm that operates many polluting plants in nonattainment counties, but none of the plants emit ozone, is also unaffected. To capture a firm's exposure to nonattainment designations, we first manually map plant-level chemical emissions into ozone and non-ozone pollutants to determine regulatory treatment at the plant-level based on the amount of ozone emissions. Then, we combine plant-level regulatory status with the geographic distribution of a firm's plants across attainment and nonattainment counties to create an aggregate measure of firm-level exposure to nonattainment designations.

Our empirical design relies on nonattainment designations induced by discrete policy changes in the NAAQS threshold from 1991 to 2019. Given an exogenous revision in the NAAQS threshold that defines noncompliance, many counties suddenly found themselves in nonattainment relative to the year prior even if their pollution levels remained constant. To empirically test the rational hypothesis, we examine active changes in portfolio holdings of stocks exposed to nonattainment designations in a difference-in-differences specification. We find that funds underweight heavy ozone-polluting stocks exposed to nonattainment designations up to four quarters after the regulatory shock. Economically, a one standard deviation increase in the nonattainment exposure of the median stock in a median fund's portfolio leads to a 1.50% decrease in the dollar value of holdings. Our results build upon the findings documented in the existing literature that *multi-plant* and *heavy ozone-polluting* firms in nonattainment counties face higher production costs and air pollution abatement expenditures (Becker, 2005; Becker & Henderson, 2000, 2001) by showing that such costs have direct consequences for fund's portfolio allocations.

Since the monitored pollution levels used to determine nonattainment status are observable, attentive fund managers may be able to anticipate a county's nonattainment status, which may bias downwards the estimated portfolio responses (Borochin, Celik, Tian, & Whited, 2022). Our analysis controls for event anticipation by using a regression discontinuity design (RDD) to decompose regulatory shocks into an unexpected and anticipated component based on whether managers' predictions of nonattainment status are in line with or differ to realized nonattainment designations. We find that funds only underweight heavy ozone-polluting stocks exposed to unexpected nonattainment designations. This result is consistent with the interpretation that funds actively rebalance in response to unexpected cash flow shocks that has not been priced by the market, while any portfolio changes spurred by the anticipated component have already been endogenized by fund portfolios before the nonattainment designation event.

We further explore possible cross-sectional heterogeneity in portfolio responses to nonattainment designations by focusing on certain firm characteristics that impose additional costs due to the heterogeneous application of nonattainment regulations, and hence, lead to a more negative shock to cash flows. Specifically, we argue that the regulatory costs of nonattainment are greater for firms that do not own an ozone operating permit (Walker, 2013), operate plants that are located close to nonattainment monitors (Auffhammer, Bento, & Lowe, 2009; Bento, Freedman, & Lang, 2015; Gibson, 2019), and operate young plants (Becker & Henderson, 2000, 2001). In terms of fund characteristics, we posit that more concentrated funds have greater incentives to rebalance holdings in response to nonattainment regulatory shocks due to their higher idiosyncratic risks (Kacperczyk, Sialm, & Zheng, 2005). In line with the predictions of the rational hypothesis, we find that the aforementioned firm and fund characteristics are associated with more underweighting of heavy ozone-polluting firms exposed to nonattainment designations.

To validate the main findings, we study portfolio responses to two related types of regulatory shocks that are conditional on nonattainment status: bump-up classifications and redesignations to attainment. Bump-ups occur when a nonattainment county fails to demonstrate attainment by a specified date and is "bumped-up" from a lower classification of nonattainment to a more severe one. Thus, bump-ups represent an increase in the intensity of regulation, which represents a further negative shock to cash flows. On the other hand, redesignations to attainment occur when a county has attained the NAAQS and represent an easing of regulation. Thus, attainment redesignations lead to a positive shock to the cash flows of heavy ozone-polluting firms operating plants in existing nonattainment counties due to a reduction in compliance costs (Ramelli, Wagner, Zeckhauser, & Ziegler, 2021). Consistent with the predictions of the rational hypothesis, we find that funds underweight heavy ozone-polluting firms exposed to bump-ups and overweight such firms exposed to attainment redesignations. Importantly, portfolio responses are driven completely by the unexpected component of the regulatory shocks.

Although the underweighting of stocks exposed to nonattainment designations is consistent with fund managers rebalancing portfolio holdings in response to expected changes in firm fundamentals due to negative cash flow shocks, we recognize that such underweighting could also be a result of salience bias (Alekseev, Giglio, Maingi, Selgrad, & Stroebel, 2022; Alok, Kumar, & Wermers, 2020; Foroughi, Marcus, & Nguyen, 2021; Huynh, Li, & Xia, 2021). In our setting, the so-called “salience hypothesis” implies that fund managers with a *local* exposure to ozone-polluting firms may overestimate the costs of nonattainment regulations on these firms, and consequently, underweight such stocks in their portfolio holdings due to an overreaction.

To distinguish between these two interpretations, we examine the different implications that these hypotheses have on the future performance of stocks exposed to nonattainment designations and associated fund portfolio performance in the post-nonattainment period. Consistent with the rational hypothesis, we find that heavy ozone-polluting firms exposed to unexpected nonattainment designations experience a decrease in quarterly changes in operating performance up to three years after the designation when compared to less-exposed firms. Such firms also exert greater pollution abatement efforts and face more regulatory enforcement in the post-nonattainment years, which presumably increases their regulatory compliance costs.

In terms of abnormal stock returns, we find that the most underweighted stocks with high unexpected nonattainment exposure persistently exhibit worse abnormal return performance in the post-nonattainment period. A hypothetical zero-investment trading strategy with a long position in the portfolio consisting of the most underweighted high unexpected nonattainment exposure stocks and a short position in the least underweighted generates cumulative abnormal returns (CARs) of -8.1% up to three years after the designation, with no signs of return reversals. Finally, funds that reduce their portfolio exposure to unexpected nonattainment designations exhibit superior portfolio performance in the post-nonattainment period. Overall, our results are consistent with funds actively rebalancing their holdings in response to negative cash flow shocks and not due to managers' overreaction to the costs of nonattainment designations.

Our paper contributes to the burgeoning literature that examines mutual funds' portfolio choice in response to environmental risks. Recent studies document portfolio changes in response to climate risks through ESG demand and preferences (Baker et al., 2022; Pástor et al., 2021, 2022; Pedersen et al., 2021), while others focus on local exposure to environmental risks to provide behavioral explanations based on salience bias for the portfolio choice decisions of mutual funds (Alok et al., 2020; Foroughi et al., 2021; Huynh et al., 2021) and individual investors (Bharath & Cho, 2022; Choi, Gao, & Jiang, 2020; Li, Massa, Zhang, & Zhang, 2021). Given the importance of environmental risk in institutional investors' portfolio decisions (Gibson, Krueger, & Mitali, 2021; Hoepner, Oikonomou, Sautner, Starks, & Zhou, 2022; Jagannathan, Ravikumar, & Sammon, 2022), our paper adds to the literature by examining the relatively underexplored topic of environmental *regulatory* risks and showing that funds actively rebalance their holdings based on how the cash flows of polluting firms covary with regulatory shocks.

Our study also contributes to the literature that examines the environmental regulatory determinants of institutional investors' stock holdings. Recent work in this area has examined the effect of regulation on institutional investors' holdings through the lens of climate policy, such as the Paris Agreement (Bolton & Kacperczyk, 2021, 2022; Cao, Li, Zhan, Zhang, & Zhou, 2022; Monasterolo & de Angelis, 2020), and mandatory carbon disclosure law (Jouvenot & Krueger, 2021). While global climate policies may represent a shock to the overall awareness of environmental risks, it is unclear how individual firms or their polluting plants are impacted by such policies because they often do not have any enforcement mechanisms. Similarly, disclosure laws may not necessarily impose any costly emission restrictions on polluting firms. Nonattainment designations, on the other hand, are federally-enforced legally binding regulations that impose significant regulatory costs on polluting firms because they have a material impact on a firm's emission behavior (Greenstone, 2002, 2003).

Finally, this study makes an important contribution to the real impact of environmental regulations on the capital allocation in financial markets. The environmental economics literature has utilized county-level nonattainment designations to study the effect of environmental regulations on health outcomes (Bishop, Ketcham, & Kuminoff, 2022), industrial activity (Becker & Henderson, 2000; Greenstone, 2002; List, McHone, & Millimet, 2004; List, Millimet, Fredriksson, & McHone, 2003), housing prices (Bento et al., 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 the best of our knowledge, we provide the first empirical analysis that uses nonattainment designations to show that environmental regulations have a material impact on the capital allocation of polluting firms in the financial markets.

2. Background on pollution and environmental regulations

The CAA requires the EPA to set NAAQS for six pollutants: carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, particulate matter, and lead. We focus on ozone because counties most often fail to meet NAAQS standards by exceeding ozone limits, rather than by violating the NAAQS for the other pollutants (Curtis, 2020). As a result, ozone offers a much larger treatment group of counties for our analyses.

Each year, the CAA also requires the EPA to designate each county either as being in attainment or out of attainment (nonattainment) with the NAAQS. A county can move from the attainment to the nonattainment designation in two ways. First, the county's ozone emissions can rise, pass the NAAQS threshold, and trigger the nonattainment designation. Second, the EPA can lower the NAAQS threshold, triggering the nonattainment designation for some counties. During our sample period, the EPA lowered the NAAQS threshold for ozone four times, as reported in Table IA.1 of the Internet Appendix.[1] As explained in the following section, we focus only on these four changes in NAAQS when evaluating the impact of the nonattainment designation on mutual funds' portfolio holdings.

For nonattainment counties, the EPA requires the state to submit a SIP (state implementation plan) and also implements its own requirements. SIPs indicate how the state will bring nonattainment counties back into compliance with NAAQS (US EPA, 2013). While SIPs may vary from state to state, they must follow EPA's guidelines and be approved by the EPA. Failure to submit and execute an acceptable SIP can result in federal sanctions, including withholding federal grants, penalties, and construction bans on new polluting establishments.

The EPA imposes regulatory restrictions on economic activity in noncompliant counties. The regulations require that any newly constructed large pollution sources or major modifications to existing large pollution sources satisfy the standard of "lowest achievable emission rate" (LAER). LAER requires 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

[1]In this table, the name of each ozone standard is based on the year in which the new NAAQS was proposed. The effective date is when the EPA actually implemented that standard.

located in the same county before commencing operations. For existing pollution sources in nonattainment counties, the EPA requires those sources to meet "reasonably available control technology" (RACT) standards, which are emission limits with minimal economic feasibility (US EPA, 2006).

The EPA also has the authority to bump up an existing nonattainment county from a lower classification to a higher one ("bump-up classifications") if the county fails to demonstrate an improvement in air quality by the given date as specified in the SIP. Bump-ups represent an increase in the regulation intensity since requirements on pollution abatement capital and emission offsets are increasing in stringency with respect to the classification. For example, a unit of emissions from new sources must be offset by more than a unit of emissions from existing sources in nonattainment counties classified as moderate or above (Sheriff, Ferris, & Shadbegian, 2019).

In attainment counties, plants face significantly less expensive environmental standards than those in non-attainment counties. New plants and major modifications to existing plants are subject to the installation of "best available control technology" (BACT). Under BACT, the EPA considers the technology's economic burden on the plant as the foremost priority in determining an acceptable emissions technology. As a result, large-scale investments in attainment counties typically involve less expensive pollution abatement equipment and the EPA does not require emissions offsets.

Taken together, the costs of operating plants that emit ozone differ across counties and among firms within the same county. On capital expenditures, the costs are lowest in attainment counties (BACT) and highest in nonattainment counties (LAER/RACT). Beyond capital expenditures, SIPs typically impose more costly regulatory burdens on plants operating in nonattainment counties, such as requirements to use materials and alter operating and maintenance procedures in ways that reduce emissions (Becker, 2005; Becker & Henderson, 2000, 2001). Regulatory intensity and hence operating costs can also differ across firms within nonattainment counties. For example, the EPA regulates plants operating closer to ozone monitors more intensely than those located further away, potentially boosting compliance costs (Auffhammer et al., 2009; Bento et al., 2015; Gibson, 2019). As another example, plants in nonattainment counties with pre-existing ozone operating permits tend to have lower risks of violating nonattainment standards (Walker, 2013), potentially reducing compliance costs. Therefore, the nonattainment designation not only triggers a discrete, "extensive margin" change in environmental regulations among all plants in nonattainment counties relative to those in attainment counties, but also triggers cross-plant, "intensive margin" changes in the intensity of environmental regulations, and potentially in operation costs within nonattainment counties. We exploit both the extensive and intensive margins triggered by the nonattainment designation.

2.1. Nonattainment designations as a research design

Existing studies show that nonattainment designations are effective at reducing pollution levels, and much of this reduction is a result of increased firm compliance because nonattainment designations are federally-enforced legally binding regulations for polluting plants (Chay & Greenstone, 2003; Henderson, 1996). Thus, our identification strategy uses nonattainment designations as exogenous shocks to local regulatory stringency to study how mutual funds adjust their holdings of polluting firms affected by such shocks.

A potential concern is that air pollution is driven by industrial activity, so 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.[2] Over our sample period, the EPA revised downwards the NAAQS threshold four times.[3] Given an exogenous revision in the NAAQS threshold, many counties suddenly found themselves in nonattainment relative to the year prior, even if their ozone emissions did not change by all that much. Therefore, the switch to nonattainment is triggered by the lowering of the NAAQS threshold that defines noncompliance, as opposed to rising ozone emissions.

This regulatory design is illustrated 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 1991 to 2019. As can be seen, there are four peaks that coincide with the implementation of a revised NAAQS threshold, which leads to a large number of counties falling into nonattainment.[4] In between the peaks, counties move in and out of nonattainment designations due to changes in their ozone pollution level. During this period, there are generally more counties redesignated to attainment rather than entering into nonattainment, suggesting

[2] 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.

[3] The revised thresholds are based on new scientific research that reflects the ongoing health effects of air pollution during that period of time (Gibson, 2019).

[4] 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.

that revisions to the NAAQS thresholds drive most of the nonattainment designations.[5] Thus, our empirical specifications focus on the nonattainment designations that occurred during the four policy changes.

We further exploit this regulatory design to control for potential anticipation of nonattainment designations. Recently, Borochin et al. (2022) show that estimated market reactions in event studies may be biased downwards due to event anticipation. In our setting, attentive fund managers may be able to anticipate a county's nonattainment status by calculating the underlying ozone concentrations. For example, counties that have an ozone pollution level well above the NAAQS threshold are likely to be designated nonattainment, regardless of the revisions in thresholds. To account for event anticipation, we use a RDD to define an optimal "narrow" window around the NAAQS thresholds, which allows us to decompose nonattainment designations into an "unexpected" and "anticipated" component. We discuss this procedure in more detail in Section 4.2.

3. Data and variables

3.1. Mutual funds

We collect our mutual fund data from the Center for Research in Security Prices (CRSP) Survivor-Bias-Free U.S. Mutual Fund Database. The holdings of mutual funds are obtained from Thomson Reuters mutual fund holdings, which is merged with CRSP mutual fund data using the MFLINKS files from the Wharton Research Data Services. Since most funds report their holdings every quarter, our analysis will be conducted at quarterly intervals. Our sample focuses on domestic actively managed equity mutual funds because we wish to identify deliberate portfolio rebalancing in response to nonattainment regulatory shocks.[6] Funds with multiple share classes are aggregated as a single fund, given that they have the same portfolio holdings. We apply a number of filters. The funds that have missing names in CRSP are deleted (Amihud & Goyenko, 2013; Cremers & Petajisto, 2009) and those with a total net asset value of less than $15 million are excluded from our sample (Elton, Gruber, & Blake, 2001). We also eliminate underdiversified funds with less than 10 stock holdings (Doshi, Elkamhi, & Simutin, 2015). Our final sample consists of 3,271 unique funds from 1991 to 2019.

[5]It is very rare for a county to be designated as nonattainment for a second time once it has been redesignated to attainment. Nonattainment designations are fairly persistent; the mean duration of nonattainment for the sample of counties that we study is around 16 years. There is also 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.

[6]We exclude index, municipal bonds, balanced, sector, bond, and money market mutual funds.

3.2. *Firms' ozone pollution*

Firms' plant-level ozone pollution data comes from the EPA's TRI database. The TRI data file contains information on the disposal and release of over 650 toxic chemicals from more than 50,000 plants in the U.S. since 1987. Industrial facilities that fall within a specific industry (e.g., manufacturing, waste management, mining, etc), have ten or more full time employees, and handle amounts of toxic chemicals above specified thresholds must submit detailed annual reports on their releases of toxins to the TRI. The TRI provides self-reported toxic emissions at the plant-level along with identifying information about the facility such as the plant's name, county of location, industry, and parent company's name.[7] 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 (measured in pounds) 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 fund holdings of public stocks, 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

[7] 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 1990 from our analysis.

[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.

company names to those in Compustat and CRSP. The final sample consists of 1,625 unique firms from 1991 to 2019.

3.3. Environmental regulation events

We examine three types of environmental regulation at the county-level: i) nonattainment designations; ii) bump-up classifications; and iii) redesignations to attainment. We manually search the Federal Register and hand-collect the effective dates of every event. 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 sample of events from 1991 to 2019 consists of 1,286 nonattainment designation county-event-quarters involving 896 firms, 330 bump-up county-event-quarters involving 363 firms, and 472 attainment redesignation county-event-quarters involving 503 firms.

3.4. 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 the primary statistics that the EPA uses to determine whether a county is in compliance with the NAAQS. Specifically, counties with DVs that are above the relevant threshold are designated nonattainment, while those below the threshold remain in attainment. Although other factors such as a county's geography and meteorology may also contribute to nonattainment status, noncompliance based on DVs is the key determinant of nonattainment.[10] 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 to decompose 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 fund managers at the time of nonattainment designations.[11] Thus, we tailor the calculation

[10] See `https://www.epa.gov/ozone-designations/ozone-designations-guidance-and-data#B` for more details on other contributing factors. In our communications with the EPA, we were informed that DVs are the primary determinant of a county's nonattainment status, with the other factors being used to determine the geographic boundaries of the nonattainment area. After manually verifying each county's nonattainment designation in the Federal Register, we find that approximately 90% of all nonattainment designations are based on DVs and only 10% mention the influence of other factors. As we will show later in Section 4.2.1, counties with a DV in violation of the NAAQS threshold has a 65% higher probability of being designated nonattainment.

[11] 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.

of the DVs using time periods that mimics, as close as possible, the information available to fund managers at the time of nonattainment designations.[12]

3.5. *Variables*

3.5.1. *Outcome variable*

To explore portfolio responses, we follow Alekseev et al. (2022) and measure a given mutual fund m's *active* trading in stock s in quarter t as[13]

$$ActiveChanges_{m,s,t} = \frac{P_{s,t-1}Shares_{m,s,t}}{\sum_s P_{s,t-1}Shares_{m,s,t}} - \frac{P_{s,t-1}Shares_{m,s,t-1}}{\sum_s P_{s,t-1}Shares_{m,s,t-1}}, \tag{1}$$

where $P_{s,t-1}$ is the price for stock s at the end of quarter $t-1$ and $Shares_{m,s,t}$ is the number of shares of stock s held by fund m at the end of quarter t. The second fraction is effectively the weight of stock s in mutual fund m's portfolio at the end of quarter $t-1$, defined as the dollar holdings of the stock divided by the total dollar holdings of all stocks in the mutual fund's portfolio using quarter $t-1$ prices. The first fraction is the weight of stock s at the end of quarter t but calculated using quarter $t-1$ prices. Thus, *ActiveChanges* captures the change in portfolio allocation due to active trading as opposed to changes in value due to price movements during the quarter.[14]

3.5.2. *Explanatory variables*

Since a firm can own many plants located across multiple counties, we construct a firm-level measure of nonattainment exposure based on i) the geographic distribution of a firm's plants across counties; and ii) the amount of ozone emissions at each plant. Formally, we define

$$NA\ exposure_{s,t} = \ln\left(1 + \sum_j \left(ozone_{j,s,t-4} \cdot NA_{j,s,t}\right) / \#Plant_{s,t}\right), \tag{2}$$

where j denotes plant, s denotes stock, and t denotes quarter. $ozone_{j,s,t-4}$ is the total amount of ozone air emissions for plant j of stock s in quarter $t-4$; $NA_{j,s,t}$ is a dummy variable equal to one if plant j of stock s is located in a nonattainment county in quarter t, and zero

[12] 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 ozone concentration data from 2001 to 2003 in calculating DVs for nonattainment designations associated with the 8-Hour Ozone (1997) standard.

[13] We adjust for stock events such as stock splits, stock repurchases etc.

[14] We also consider an alternative variable, *PassiveChanges*, where the first fraction uses $P_{s,t}$ instead of $P_{s,t-1}$. By valuing current quarter holdings at current quarter prices takes price changes into account and would be a more suitable measure if funds constantly rebalance their portfolios. We verify that using *PassiveChanges* produces qualitatively similar results.

otherwise; and $\#Plant_{s,t}$ is the total number of polluting plants owned by stock s in quarter t.

A multi-plant firm that operates many heavy ozone-polluting plants in nonattainment counties will have a higher value of *NA exposure*, indicating that the firm is more exposed to nonattainment designations. Note that in the above definition, we lag plant ozone emissions by one year because the specific timing of the release of the TRI data implies that emissions data for a given year only becomes available the following year (Hsu et al., 2023). Thus, $ozone_{j,s,t-4}$ reflects the emissions data available to fund managers at the time of nonattainment designations. Furthermore, note that we use the *amount* of ozone emissions as opposed to ozone emission intensity (i.e., ozone emissions per unit of production) since EPA imposes emission limits in nonattainment counties based on the actual amount of ozone emissions.[15]

Since bump-ups and attainment redesignations are both conditional on nonattainment status, we measure a firm's exposure to bump-ups and attainment redesignations in a similar manner as follows:

$$Bump\ exposure_{s,t} = \ln\left(1 + \sum_{j}\left(ozone_{j,s,t-4} \cdot Bump_{j,s,t}\right)/\#NA\ plant_{s,t}\right), \tag{3}$$

$$Redesig\ exposure_{s,t} = \ln\left(1 + \sum_{j}\left(ozone_{j,s,t-4} \cdot Redesig_{j,s,t}\right)/\#NA\ plant_{s,t}\right), \tag{4}$$

where $Bump_{j,s,t}$ is a dummy variable equal to one if plant j of stock s is located in a nonattainment county experiencing a bump-up in quarter t, and zero otherwise; $Redesig_{j,s,t}$ is a dummy variable equal to one if plant j of stock s is located in a nonattainment county redesignated to attainment in quarter t, and zero otherwise; and $\#NA\ plant_{s,t}$ is the total number of nonattainment polluting plants owned by stock s in quarter t. A higher value of *Bump exposure* and *Redesig exposure* implies that the firm is more exposed to bump-ups and attainment redesignations, respectively.

3.5.3. Control variables

Following Alok et al. (2020), control variables for fund characteristics include fund size (*ln(Fund size)*), defined as the natural logarithm of one plus the sum of total net assets (TNA) of all fund classes; fund quarterly return (*Fund returns*), calculated as the weighted average of returns over the share classes, using individual share classes' total net assets as the weight; weighted average expense ratios (*Expense ratio*); weighted average turnover ratios (*Turnover ratio*); and fund flow in quarter t (*Net flow*), defined as $100 \times (TNA_t - (1 + Fund\ returns_t) \times TNA_{t-1})\,/\,TNA_{t-1}$.

[15] In robustness tests, we also use plant-level sales- and employee-weighted ozone emissions in alternative definitions of *NA exposure*.

Following Kang and Stulz (1997), control variables for firm characteristics that are potential determinants of fund holdings 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 percentage quarterly change in firm sales as compared to the same fiscal quarter of the prior year; price momentum (*Momentum*), defined as the cumulative 12-month return of a stock, excluding the immediate past month; and quarterly stock returns (*Stock returns*).

3.6. Descriptive statistics

After taking the intersection of various data sources, the final sample comprises 3,445,583 fund-stock-quarter observations between 1991 to 2019. Panels A and B of Table 2 present summary statistics on the fund and firm 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. On average, the weight of a stock in a mutual fund's portfolio is 1.014%. An average fund in our sample has a size of $169.55 million, an expense ratio of 0.012, a turnover ratio of 0.85, a fund flow of -0.069%, and a quarterly return of 0.80%.

The mean of *NA exposure* is non-zero, implying that the average firm in our sample is exposed to nonattainment designations. Comparing the mean of *Unexp. NA exposure* and *Antic. NA exposure* shows that the average firm is more exposed to unexpected nonattainment designations rather than anticipated nonattainment designations. Similarly, the average firm is more exposed to unexpected bump-ups and unexpected attainment redesignations. All of the firm-level regulatory exposure variables have sizable standard deviations, indicating that there is substantial variation in the exposure of firms to different regulatory shocks.

Table 1 reports county-level characteristics by state. Pennsylvania and California have the two highest number of nonattainment counties, followed by Michigan and Virginia. Most states have counties that were in nonattainment at least once during the sample period; only 11 states were never 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. The average length of time that counties have been in nonattainment ranges from zero to 28 years. There is also substantial variation in the county-level DVs across states.

4. Empirical strategy

4.1. Difference-in-differences

We examine funds' portfolio responses to three types of environmental regulation: nonattainment designations, bump-up classifications, and attainment redesignations. Our empirical model for nonattainment designations is a difference-in-differences specification. We focus on a five-quarter window centered on the nonattainment designation quarter. For instance, if the nonattainment designation occurs in quarter Q, then $Q-2$ and $Q-1$ are the pre-nonattainment designation quarters, while Q, $Q+1$, and $Q+2$ are the post-nonattainment designation quarters. The unit of observation in our analysis is a fund-firm-event quarter. Formally, our baseline specification is as follows:

$$\begin{aligned} ActiveChanges_{m,s,t} &= \beta_0 + \beta_1 NA\ exposure_{s,t} + \beta_2 Post\ NA_t + \beta_3 NA\ exposure_{s,t} \times Post\ NA_t \\ &+ X_{s,t-1} + X_{m,t-1} + \mu_m + \tau_s + \rho_t + \varepsilon_{m,s,t} \end{aligned} \tag{5}$$

for fund m, stock s, and quarter t. *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, and zero otherwise. $X_{s,t-1}$ and $X_{m,t-1}$ are vectors of lagged firm-level and fund-level control variables, respectively, measured at the end of quarter $t-1$.

We include fund fixed effects (μ_m) and stock fixed effects (τ_s) that absorb all time-invariant differences across funds and stocks, respectively. Finally, ρ_t are year-quarter fixed effects that control for aggregate macroeconomic shocks. We also estimate two variants of the baseline specification based on more stringent fixed effects. The first version includes fund $\times$ stock fixed effects, which ensures that the portfolio response to ozone pollution during nonattainment designations is identified after accounting for persistent preference differences by fund managers on ozone-polluting firms (Hong & Kostovetsky, 2012). The second version adds fund $\times$ year-quarter fixed effects, which controls for time-varying cross-fund factors.

The coefficient of interest is β_3, which captures the extent to which mutual funds adjust their portfolio holdings in response to nonattainment regulations. The rational hypothesis predicts that β_3 is negative, indicating that heavy ozone-polluting firms exposed to nonattainment designations are underweighted more in funds' portfolios. We modify our specification accordingly when examining portfolio response to the other events—bump-up classifications and attainment redesignations—while maintaining the basic setup. These regression specifications are explained in complete detail when we present the results.

4.2. Event anticipation

Since a county's monitored ozone pollution levels are observable, attentive fund managers may be able to anticipate a county's nonattainment status. To account for event anticipation, we decompose nonattainment designations into an anticipated component and an unexpected component based on county-level DVs. The intuition is that counties with a DV far above the NAAQS threshold are likely to be designated nonattainment, no matter what the threshold is revised to. Likewise, counties with a DV far below the threshold are likely to remain in attainment, independent of pending changes in the threshold. The question then becomes how far above or below the NAAQS threshold can one reasonably predict a county's designation status.

The idea underlying our approach is that nonattainment designations are a random outcome in an arbitrarily small interval around the NAAQS threshold; for example, whether a county is in compliance with a DV slightly below the NAAQS threshold or in violation with a DV slightly above the threshold is arguably random. Thus, using RDD to exploit the sharp increase in nonattainment probability when a county's DV moves from below to above the NAAQS threshold, we are able to estimate an optimal "bandwidth" centered on the NAAQS threshold that determines the region where ozone concentrations are as good as randomly assigned, and hence, unpredictable.

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

$$NA_{c,t+1} = \alpha + \beta Noncompliance_{c,t} + \phi f(R_{c,t}) + \varepsilon_{c,t+1} \tag{6}$$

for county c and year t. $NA_{c,t+1}$ is a dummy variable equal to one if county c is designated nonattainment in year $t+1$, and zero otherwise. $Noncompliance_{c,t}$ is a dummy variable equal to one if county c's DV is in violation of the NAAQS threshold in year t, and zero otherwise.

$R_{c,t}$ is the centered DV (i.e., the running variable in RDD parlance), defined as the difference between the DV of county c in year t and the NAAQS threshold. Negative (positive) values indicate that the county is in compliance with (violation of) the NAAQS threshold. We use local linear functions in the running variable with rectangular kernels as represented by $f(R_{c,t})$. Since treatment assignment is at the county-level, standard errors are clustered by county and bias-corrected as discussed in Calonico et al. (2014).

We conduct tests that support the identifying assumptions of the RDD specification in Section IA of the Internet Appendix. In short, we do not find any evidence that counties strategically manipulate their DVs to be right below the NAAQS threshold, nor do we find any statistically significant differences in preexisting firm characteristics in the narrow neighborhood around the threshold between those operating polluting plants in counties that are in violation of the NAAQS thresholds and those operating in counties that are in compliance.

4.2.1. Estimation results

We present the estimation results of Equation (6) in Table IA.3 of the Internet Appendix. The coefficient estimate on β captures the discontinuity at the NAAQS threshold and is equal to the difference in the probability of nonattainment between counties that marginally violate the NAAQS threshold and those that marginally comply with the threshold.[16] In column (1), we use the full sample of nonattainment designations based on revisions in the NAAQS threshold across all four ozone standards. Noncompliance based on DVs leads to an increase in the probability of nonattainment by roughly 65%, indicating that DVs are the main determinant of nonattainment status. Similar results are obtained when using the subsample of nonattainment designations based on revisions in the NAAQS threshold for each individual ozone standard separately.

Internet Appendix Table IA.3 also provides the estimates of the optimal bandwidth. The bandwidth estimate of 0.009 in column (1) implies that for the full sample of nonattainment designations, counties with DVs that are within 0.009 ppm of the NAAQS threshold have ozone concentration levels that are as good as randomized. Counties with DVs that exceed the threshold by more than 0.009 ppm are considered to be far "enough" *above* the threshold that they will most likely be designated nonattainment in the following year. Similarly, counties with DVs that are below the threshold by more than 0.009 ppm are considered to be far

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

"enough" *below* the threshold that they will most likely remain in attainment in the following year.

4.2.2. Unexpected and anticipated nonattainment designations

Figure 2 illustrates how we use the optimal bandwidth estimate of 0.009 to decompose nonattainment designations into an unexpected and anticipated component. The figure plots the probability of nonattainment against the centered DVs using the full sample of nonattainment designations based on revisions in the NAAQS threshold across all four ozone standards. Each dot in the figure represents the average of $NA_{c,t+1}$ using integrated mean squared error optimal bins following Calonico et al. (2014). As can be seen, the probability of nonattainment appears to be a continuous and smooth function of the centered DVs everywhere except at the NAAQS threshold, where there is a discontinuous jump upwards.

We define the region within the bounds of the optimal bandwidth as the unpredictable region. Within this region, changes in the probability of nonattainment are attributable to random fluctuations in the underlying DVs on either side of the threshold, and hence unpredictable. The region to the right of the right-endpoint of the optimal bandwidth is defined as the predicted nonattainment region. Similarly, the region on the left of the left-endpoint of the optimal bandwidth is defined as the predicted attainment region.[17]

To decompose nonattainment designations into an unexpected and anticipated component, we compare investors' predictions based on DVs prior to the designation and the actual realization of a county's designation status. We define anticipated nonattainment designations to be those counties that reside in the predicted nonattainment region and are designated nonattainment subsequently. Thus, anticipated nonattainment designations correspond to the counties where investors' predictions of nonattainment align with realizations. We define unexpected nonattainment designations to be those counties that either: i) reside in the unpredictable region and are designated nonattainment subsequently; or ii) reside in the predicted attainment region and are designated nonattainment subsequently. The first part captures the inherent unpredictability of nonattainment status due to random fluctuations in the DVs in the narrow window around the threshold, while the second part captures the cases where investors' predictions of nonattainment differ from realizations due to other unobservable

[17]Note that most counties in the predicted nonattainment region tend have a nonattainment probability of one, while some counties in the predicted attainment region may have small, but non-zero nonattainment probabilities. This observation is consistent with the fact that although counties with ozone concentrations that are considerably higher than the threshold will most certainly be designated nonattainment, those with ozone concentrations that are much lower than the threshold may still be designated nonattainment based on non-DV factors such as geography and meteorology.

non-DV factors contributing to the nonattainment designation.[18]

Using this decomposition, we find that out of a total of 1,286 nonattainment designation county-event-quarters, 935 are classified as unexpected nonattainment designations, while 351 are considered anticipated. Among the 935 unexpected nonattainment designations, 792 consists of counties that reside in the unpredictable region, while only 143 are in the predicted attainment region. Thus, the vast majority of all unexpected nonattainment designations are due to unpredictability in the underlying ozone concentrations, rather than other non-DV factors. This result reinforces the fact that noncompliance based on DVs is the key determinant of nonattainment.

We measure a firm's exposure to unexpected and anticipated nonattainment designations, respectively, as follows:

$$Unexp.\ NA\ exposure_{s,t} = \ln\left(1 + \sum_{j}\left(ozone_{j,s,t-4} \cdot Unexp.\ NA_{j,s,t}\right)/\#Plant_{s,t}\right), \quad (7)$$

$$Antic.\ NA\ exposure_{s,t} = \ln\left(1 + \sum_{j}\left(ozone_{j,s,t-4} \cdot Antic.\ NA_{j,s,t}\right)/\#Plant_{s,t}\right), \quad (8)$$

where $Unexp.\ NA_{j,s,t}$ ($Antic.\ NA_{j,s,t}$) is a dummy variable equal to one if plant j of stock s is located in an unexpected (anticipated) nonattainment county in quarter t, and zero otherwise. All other variables are defined as in Equation (2). A higher value of *Unexp. NA exposure* (*Antic. NA exposure*) indicates that the firm has a greater exposure to unexpected (anticipated) nonattainment designations.

5. Results

5.1. Portfolio response to nonattainment designations

5.1.1. Active changes in portfolio holdings

We begin our empirical analysis by examining active changes in portfolio holdings of ozone emitting firms in response to nonattainment designations. The rational hypothesis predicts that funds underweight heavy ozone-polluting firms exposed to nonattainment designations since the cash flows of these firms are negatively impacted by the nonattainment regulatory shock. We present the estimation results of Equation (5) in Table 3. In column (1), we present the results without control variables. Columns (2) and (3) separately include firm and fund

[18] These non-DV factors are also "unexpected" because they are unobservable from the investors' perspective. For example, a county may have a DV that is in compliance with the NAAQS threshold, but may still be designated nonattainment if winds or other geographical conditions causes it to contribute to the ozone levels of other neighboring counties.

control variables, respectively. Column (4) includes both sets of control variables. Regardless of the specification, the coefficients on *NA exposure* × *Post NA* are negative and statistically significant, indicating that funds actively rebalance their holdings by underweighting stocks that have high exposure to nonattainment designations.

Next, we utilize more stringent fixed effects. Column (5) of Table 3 uses fund × stock fixed effects, column (6) uses fund × year-quarter fixed effects, and column (7) includes both sets of fixed effects.[19] The results remain qualitatively unchanged across all three columns, indicating that our main findings continue to hold after controlling for unobservable, time-varying fund characteristics and differences in fund managers' preferences to hold ozone-polluting stocks. To interpret the economic magnitudes of the estimated coefficients, consider a median stock in a median fund's portfolio whose exposure to nonattainment increases by one standard deviation. Assuming there is no trading for any other stock in the fund's portfolio and no changes in the nonattainment exposure of all other stocks in the portfolio, then the one standard deviation increase in nonattainment exposure leads to a sizable 1.50% drop in the dollar value of holdings of the stock.[20]

5.1.2. Temporal dynamics in portfolio response

We now examine the temporal dynamics of active changes in portfolio holdings around nonattainment designations to see if there are any pre-trends in the data. The absence of pre-trends (differential response before nonattainment designations) in *ActiveChanges* is a necessary condition for the validity of our difference-in-differences setting. We estimate a dynamic version of Equation (5) by including a set of dummy variables that represent the quarters relative to the nonattainment designation event quarter, *Post NA(k)* where k ranges from -4 to $+4$, and their corresponding interaction terms with *NA exposure*. We extend the window from four quarters prior to four quarters after a nonattainment designation to better observe the presence of any pre-trends and to see how long funds take to actively rebalance their holdings. The quarter before the nonattainment designation is the omitted category.

Figure 3 reports the point estimates (solid line) and 95% confidence intervals (dashed lines) of the coefficients for the interaction terms *NA exposure* × *Post NA(k)*. There is no significant difference in the active changes of heavy ozone-polluting stocks exposed to nonattainment

[19] In columns (6) and (7), the fund control variables are absorbed by the fund × year-quarter fixed effects.

[20] The median size of a mutual fund portfolio in the pre-nonattainment period is \$176.38 million. The dollar value invested in the median stock with non-zero exposure to nonattainment designations is \$1.42 million. So, a one standard deviation increase in *NA exposure* combined with a difference-in-differences coefficient of -0.00286% translates into $0.00286\% \cdot 4.234 \cdot 176.38/1.42 \approx 1.50\%$ reduction in the dollar value of a stock holding.

designations compared to less-exposed stocks before the nonattainment designation. Then, starting in the event quarter, funds begin to underweight stocks with high exposures to nonattainment designations, which continues progressively until the fourth quarter post event.

5.1.3. Unexpected and anticipated nonattainment designations

In this section, we decompose portfolio responses to nonattainment designations into an unexpected and anticipated component. We expect funds to actively rebalance only in response to the unexpected component since any portfolio changes spurred by the anticipated component should have been incorporated before the nonattainment designation. To test this prediction, we replace *NA exposure* and its corresponding interaction terms in Equation (5) with *Unexp. NA exposure* and *Antic. NA exposure*.

The results are reported in Table 4. Across all specifications, only the coefficients on *Unexp. NA exposure* × *Post NA* are negative and statistically significant, while those on *Antic. NA exposure* × *Post NA* are statistically insignificant and considerably smaller in magnitude. These results indicate that funds rebalance their holdings by underweighting stocks with high exposures to *unexpected* nonattainment designations but do not adjust their holdings of stocks with exposures to *anticipated* nonattainment designations.

The insignificance of funds' portfolio response to the anticipated component of nonattainment designations provides additional support for the rational hypothesis. In particular, unexpected nonattainment designations are those where funds' predictions differ from realizations, hence, these unexpected nonattainment designations reveal new information on how firms' cash flows will covary with the nonattainment regulatory shock, which has not been priced by the market. Anticipated nonattainment designations, on the other hand, are those where funds' predictions of nonattainment status are in line with realizations and so there is relatively little new information on cash flows revealed from these shocks. Thus, any active changes in response to anticipated nonattainment designations should have been endogenized by fund portfolios before the actual designation event.

5.1.4. Heterogeneous portfolio responses to nonattainment designations

We now explore possible cross-sectional heterogeneity in active changes due to the heterogeneous application of nonattainment regulations. Specifically, we examine various firm characteristics that are predicted to impose additional regulatory costs during nonattainment designations, and hence, lead to a more negative shock to cash flows. We also examine fund characteristics that are predicted to increase fund managers' incentives to actively rebalance their holdings in response to nonattainment designations. Our empirical specification augments the decomposed version of Equation (5) with a variable Z that refers to a set of firm and fund characteristics measured in the quarter before the nonattainment designation and their corresponding interactions. Our focus is on the triple interaction terms *Unexp. NA exposure* × *Post NA* × Z and *Antic. NA exposure* × *Post NA* × Z that represent the differential effects of a particular characteristic on the active changes of stocks exposed to unexpected and anticipated nonattainment designations, respectively.

We begin by examining whether a firm owns an ozone operating permit. These operating permits are issued by the EPA and specifies the amount and type of pollutants that the polluting plants of a given firm is permitted to emit. Given a nonattainment designation, heavy ozone-polluting firms that do not own any ozone operating permits have a greater risk of violating nonattainment regulations (Walker, 2013), and hence, could potentially incur greater regulatory costs. In Figure 4, we define the variable *No ozone permit* to be a dummy variable equal to one if a given firm does not have an ozone operating permit, and zero otherwise.[21] We plot the point estimates and 95% confidence intervals of the coefficients for the unexpected (in black) and anticipated (in blue) components in the first two rows. In line with the predictions of the rational hypothesis, we find that heavy ozone-polluting firms without ozone operating permits that are exposed to unexpected nonattainment designations are underweighted more by funds, consistent with the fact that such firms experience a more negative shock to their cash flows. In contrast, the anticipated component is not statistically significant at any conventional significance levels.

Next, we consider the average distance of a firm's plants to the closest nonattainment monitor.[22] Given a nonattainment designation, firms that operate ozone emitting plants located close to nonattainment monitors are regulated more intensely than those located further away, since regulatory effort is localized in the areas surrounding nonattainment monitors (Auffhammer et al., 2009; Bento et al., 2015; Gibson, 2019). Thus, firms with plants that are located close to nonattainment monitors are subject to greater regulatory costs, leading to a more negative shock to their cash flows. In Figure 4, we define the variable *Close NA monitor* to be a dummy variable equal to one if the average distance between the polluting plants of a given firm to the closest nonattainment monitor is below the median, and zero otherwise. We find that firms operating ozone emitting plants closer to nonattainment

[21] We obtain plant-level permit data from EPA's Integrated Compliance Information System for Air (ICIS-Air) database

[22] A nonattainment monitor is defined to be a monitor that violates the NAAQS ozone standards.

monitors are underweighted more only for unexpected nonattainment designations.

Lastly, we distinguish between young and old plants. Becker and Henderson (2000) find that newer plants bear the brunt of nonattainment regulations because they are subject to costly LAER requirements, while older plants are grandfathered and escape regulation until they expand operations.[23] 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%. Following Becker and Henderson's (2001) definition, we define *Young plant* to be a dummy variable equal to one if the average plant age of a given firm is between zero and five years, and zero otherwise.[24] In Figure 4, we see that firms operating mostly young ozone emitting plants in unexpected nonattainment counties are underweighted more, consistent with these firms experiencing a greater negative shock to their cash flows.

In terms of fund characteristics, we examine a fund's concentration of stock holdings. Underdiversified funds may be particularly sensitive to temporary shocks stemming from nonattainment designations because of their higher idiosyncratic risks (Kacperczyk et al., 2005), which may lead to more underweighting of stocks exposed to nonattainment designations. We use two measures for fund portfolio diversification: the number of stocks held in the portfolio and the Herfindahl-Hirschman index (HHI), calculated based on the weights allocated to each stock in a given fund's portfolio. In Figure 4, *Low # stocks* is a dummy variable equal to one for funds with the number of stocks below the median, and zero otherwise, and *High HHI* is a dummy variable equal to one for funds with HHI concentration above the median, and zero otherwise. For both measures, we see that the underweighting of heavy ozone-polluting stocks exposed to unexpected nonattainment designations is more prevalent for more concentrated funds.

5.2. Portfolio response to bump-up classifications

We now explore active changes in response to bump-up classifications. Bump-ups increase the intensity of regulation in already nonattainment counties. Thus, heavy ozone-polluting

[23] Although younger plants may save on certain costs in terms of net present value since they do not need to renew their equipment as quickly as older plants, they face more "immediate" costs given a nonattainment designation. For example, older plants may already have RACT in place (thus saving on capital expenditures), while younger plants may need to implement RACT. Similarly, older plants may already have maintenance procedures in place to reduce emissions, while younger plants may not.

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

firms operating plants in nonattainment counties facing bump-ups experience even greater regulatory costs when compared to initial nonattainment designations. Under the rational hypothesis, we expect funds to underweight firms that are heavy polluters of ozone and operate a large fraction of plants in nonattainment counties experiencing bump-ups.

We estimate a difference-in-differences specification that is very similar to Equation (5), except we focus on a five-quarter window centered on the bump-up classification quarter:

$$ActiveChanges_{m,s,t} = \beta_0 + \beta_1 Bump\ exposure_{s,t} + \beta_2 Post\ bump_t + \beta_3 Bump\ exposure_{s,t} \times Post\ bump_t + X_{s,t-1} + X_{m,t-1} + \mu_m + \tau_s + \rho_t + \varepsilon_{m,s,t} \quad (9)$$

for fund m, stock s, and quarter t. *Post bump* is a dummy variable equal to one for the post-bump-up regulatory period, and zero otherwise. All other variables are defined previously. The coefficient of interest is β_3, which captures the extent to which mutual funds underweight heavy ozone-polluting firms operating plants in nonattainment counties that are exposed to bump-ups.

We present the estimation results of Equation (9) in Table 5. Columns (1) and (2) show that funds significantly underweight heavy ozone-polluting firms exposed to bump-ups. We then decompose bump-ups into an unexpected and anticipated component following the same procedure in Section 4.2.2. Attentive fund managers may anticipate a bump-up if they closely track the DVs over time, since nonattainment counties that do not improve their DVs to be below the NAAQS threshold by the attainment deadline set forth in the SIP are likely to be bumped up to a higher classification. Restricting the sample to only nonattainment counties and defining the dependent variable to be a dummy variable equal to one if a given county experiences a bump-up, and zero otherwise, we estimate a similar RDD specification to that of Equation (6) and obtain an optimal bandwidth estimate of 0.011. Unexpected bump-ups are defined to be those counties that either: i) reside in the narrow region defined by the optimal bandwidth and are bumped-up subsequently (i.e., unpredictability due to random fluctuations in the DVs); or ii) reside in the region to the left of the left-endpoint of the optimal bandwidth and are bumped-up subsequently (i.e., unobservable non-DV factors). Anticipated bump-ups are those counties that reside in the region to the right of the right-endpoint of the optimal bandwidth.[25]

In columns (3) and (4) of Table 5, we present the estimation results by replacing

[25]Out of a total of 330 bump-up event-quarters, 252 are classified as unexpected bump-ups, while 78 are considered anticipated.

Bump exposure and its corresponding interaction terms in Equation (9) with *Unexp. bump exposure* and *Antic. bump exposure.* The variables *Unexp. bump exposure* and *Antic. bump exposure* are constructed in a similar manner to *Bump exposure* as in Equation (3), except the dummy variable $Bump_{j,s,t}$ is replaced with $Unexp.\ bump_{j,s,t}$ or $Unexp.\ bump_{j,s,t}$, which are dummy variables equal to one if plant j of stock s is located in a nonattainment county experiencing an unexpected or anticipated bump-up in quarter t, respectively, and zero otherwise. Across both columns, only the coefficients on the interaction term of the unexpected component are negative and statistically significant, while those on the anticipated component are much smaller in magnitude and statistically insignificant. Our results are consistent with prior results using nonattainment designations and show that funds rebalance their holdings only in response to unexpected cash flow shocks.

5.3. Portfolio response to attainment redesignations

Redesignations to attainment represent an easing of regulation, which reduces the compliance costs of heavy ozone-polluting firms that operate in nonattainment counties (Becker, 2005). Given a decrease in regulatory stringency, heavy ozone-polluting firms operating in counties facing attainment redesignations experience a positive shock to their cash flows (Ramelli et al., 2021). Thus, under the rational hypothesis, we expect funds to adjust their portfolio holdings in the opposite direction compared to nonattainment designations by overweighting heavy ozone-polluting stocks exposed to attainment redesignations.

To examine active changes during attainment redesignations, we employ a similar empirical setup to that of previous sections, whereby we focus on a five-quarter window centered on the attainment redesignation quarter and estimate the following difference-in-differences specification:

$$ActiveChanges_{m,s,t} = \beta_0 + \beta_1 Redesig\ exposure_{s,t} + \beta_2 Post\ redesig_t + \beta_3 Redesig\ exposure_{s,t} \times Post\ redesig_t + X_{s,t-1} + X_{m,t-1} + \mu_m + \tau_s + \rho_t + \varepsilon_{m,s,t} \tag{10}$$

for fund m, stock s, and quarter t. *Post redesig* is a dummy variable equal to one for the post-attainment redesignation regulatory period, and zero otherwise. The coefficient of interest is β_3, which measures the extent to which mutual funds overweight heavy ozone-polluting firms exposed to attainment redesignations.

We present the estimation results of Equation (10) in Table 6. In columns (1) and (2), the coefficients on *Redesig exposure* × *Post redesig* are positive and statistically significant, indicating that funds overweight heavy ozone-polluting stocks exposed to attainment redesignations. Economically, a one standard deviation increase in the attainment redesignation exposure of the median stock in a median fund's portfolio leads to a 0.78% increase in the dollar value of holdings, assuming no trading and no changes in the attainment redesignation exposure for any other stock in the portfolio.[26]

We decompose portfolios' response to attainment redesignations into an unexpected and anticipated component in a similar fashion to the procedure outlined in Section 4.2.2. The only difference is that there is no need to use RDD to estimate an optimal bandwidth to determine predictability, since we can rely on EPA's issuance of a "clean data determination". In nonattainment counties where the DVs have improved to be considerably below the NAAQS threshold, the EPA will issue a clean data determination for these counties, indicating that the air quality has met the required standard. Thus, attentive fund managers who observe which counties receive a clean data determination may be able to predict attainment redesignations, since it signals that the DVs are far enough below the threshold to warrant an attainment redesignation. Similarly, counties that do not receive clean data determinations correspond to those where their DVs are either fluctuating too close around the NAAQS threshold to make a definitive clean data determination or too far above the threshold to make a determination at all. Thus, unexpected attainment redesignations are those counties that do not receive a clean data determination, but end up redesignated to attainment on the event date. Anticipated attainment redesignations are those counties that receive a clean data determination and do actually end up redesignated to attainment.[27]

Columns (3) and (4) of Table 6 reports the estimation results whereby *Redesig exposure* and its corresponding interaction terms in Equation (10) are replaced with *Unexp. redesig exposure* and *Antic. redesig exposure*. These two variables are constructed in the same way as *Redesig exposure* from Equation (4), except $Redesig_{j,s,t}$ is replaced with $Unexp.\ redesig_{j,s,t}$ or $Antic.\ redesig_{j,s,t}$, which are dummy variables equal to one if plant j of stock s is located in a nonattainment county experiencing an unexpected or anticipated redesignation in quarter t, respectively, and zero otherwise. The coefficients on *Unexp. redesig exposure* × *Post redesig* are positive and statistically significant, while those on *Antic. redesig exposure* × *Post redesig*

[26]The median size of a mutual fund portfolio in the pre-attainment redesignation period is $166.96 million. The dollar value invested in the median stock with non-zero exposure to attainment redesignations is $1.43 million. So, a one standard deviation increase in *Redesig exposure* combined with a difference-in-differences coefficient of 0.00167% translates into $0.00167\% \cdot 3.998 \cdot 166.96/1.43 \approx 0.78\%$ increase in the dollar value of a stock holding.

[27]Out of a total of 472 attainment redesignation event-quarters, 383 are classified as unexpected, while 89 are considered anticipated.

are considerably smaller in magnitude and statistically insignificant. This result indicates that funds only adjust portfolio holdings in response to the unexpected component of attainment redesignations, consistent with the interpretation that there is little uncertainty on how anticipated attainment redesignations will impact on firms' cash flows. Specifically, anticipated attainment redesignations are those where funds correctly predicted a cease in nonattainment regulations. For firms operating polluting plants in these counties, the real impact of the ease in regulatory costs has already been incorporated into their stock price valuations, implying that portfolio holdings would have already adjusted in response to this information before the actual attainment redesignation date.

We also explore possible heterogeneity in funds' active changes in response to attainment redesignations by conducting the same analysis as in Section 5.1.4. Since attainment redesignations represent a reversal in regulatory stringency, the same firm and fund characteristics that were associated with more *underweighting* in response to nonattainment designations should now lead to more *overweighting*. Figure 5 presents the coefficient estimates and 95% confidence intervals on the triple interaction terms *Unexp. redesig exposure* × *Post redesig* × *Z* (in black) and *Antic. redesig exposure* × *Post redesig* × *Z* (in blue). In line with the predictions of the rational hypothesis, the point estimates of the unexpected components in Figure 5 have the exact opposite sign to those in Figure 4, while the anticipated components are all statistically insignificant.

Given the strikingly opposite portfolio responses to nonattainment designations and attainment redesignations, one may wonder why funds do not endogenize the portfolio responses to these regulatory shocks by choosing an optimal level of holdings from the onset rather than rebalancing after nonattainment designations and subsequent attainment redesignations. The most obvious explanation is that we focus on unexpected shocks, which are unpredictable by nature. However, complicating the matter further 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 classification 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. Thus, given the uncertainty surrounding the net impact of these regulatory shocks on a firm's cash flows, it is hard for funds to endogenize the portfolio adjustments of such shocks from the onset.

6. Firm and fund performance in the post-nonattainment period

Our results so far indicate that funds underweight stocks that are most exposed to nonattainment designations and subsequent bump-up classifications, and overweight them during attainment redesignations. If the underweighting of these stocks is driven by portfolio rebalancing in response to expected changes in firm fundamentals due to negative cash flow shocks stemming from the costs of nonattainment regulation, then in the post-nonattainment period, we should observe: i) a drop in the performance and an increase in the regulatory compliance costs of heavy ozone-polluting stocks exposed to nonattainment designations; and ii) an improvement in the investment performance of funds that reduce their portfolio exposure to nonattainment designations.

6.1. Firms' operating performance

We analyze changes in measures of profitability (proxied by *ROA*), growth (*Sales growth*), and valuation (*Market to book*) over one, two, and three years following the nonattainment designation. Specifically, we estimate the following difference-in-differences specification at the firm-quarter level to evaluate whether stocks with greater exposures to nonattainment designations adversely impact their future operating performance:

$$\begin{aligned}\Delta Perf_{s,t} &= \beta_0 + \beta_1 Unexp.\ NA\ exposure_{s,t} + \beta_2 Antic.\ NA\ exposure_{s,t} + \beta_3 Post\ NA_t \\ &+ \beta_4 Unexp.\ NA\ exposure_{s,t} \times Post\ NA_t + \beta_5 Antic.\ NA\ exposure_{s,t} \times Post\ NA_t \\ &+ X_{s,t-1} + \text{F.E.} + \varepsilon_{s,t}\end{aligned} \tag{11}$$

for stock s and quarter t. We fix the pre-nonattainment regulatory period to be the two quarters before the designation, while the post-nonattainment regulatory period varies from one year, two years, and three years after the designation. The dependent variable measures the quarterly change in a given measure of operating performance. For example, $\Delta ROA_{s,t} = ROA_{s,t} - ROA_{s,t-1}$. *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, and zero otherwise. $X_{s,t-1}$ is a vector of lagged firm-level control variables. We include stock and year-quarter fixed effects, as well as industry fixed effects based on Fama and French's (1997) 48 industry classifications. The coefficients of interest are β_4 and β_5, which measure the post-nonattainment difference in quarterly changes in operating performance of stocks with high exposures to unexpected and anticipated nonattainment designations, respectively, relative to stocks with less exposures.

We present the results in Table 7. The dependent variable is ΔROA_t in columns (1) to (3),

Δ*Sales growth*$_t$ in columns (4) to (6), and Δ*Market to book*$_t$ in columns (7) to (9). Across all columns, the coefficients on *Unexp. NA exposure* × *Post NA* are all negative and statistically significant, indicating that heavy ozone-polluting firms exposed to unexpected nonattainment designations experience a decrease in quarterly changes in operating performance up to three years after the designation when compared to less-exposed firms. For example, a one standard deviation increase in *Unexp. NA exposure* decreases quarterly changes in *ROA* by 0.40 percentage points in the post-nonattainment period, corresponding to a decrease of 11.45% relative to the unconditional sample mean of *ROA*.

In contrast, the coefficients on *Antic. NA exposure* × *Post NA* are all statistically insignificant and economically small in magnitude, indicating that firms with exposure to anticipated nonattainment designations do not experience any deterioration in future operating performance. Taken together, these results suggest that only unexpected cash flow shocks manifest into lower operating performance in the post nonattainment regulatory period, consistent with our earlier findings that funds rebalance portfolios only in response to unexpected nonattainment designations.

6.2. Regulatory compliance costs

The rational hypothesis asserts that the negative shock to the cash flows of heavy ozone-polluting firms exposed to nonattainment designations is due to an increase in regulatory compliance costs. Ideally, we would want to use a firm's pollution abatement costs as a measure of their regulatory compliance costs. However, there is no available data directly on plant-level pollution abatement costs. Thus, following Xu and Kim (2022), we proxy for the potential compliance costs associated with nonattainment designations by examining facilities' *observable* pollution abatement efforts through source reduction activities and regulatory enforcement. The intuition is that facilities with more engagements in source reduction activities and regulatory enforcements presumably have higher compliance costs.

For facilities' pollution abatement efforts, we use data from EPA's Pollution Prevention (P2) database. 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 (collectively known as the total amount of source reduction) before being released into the environment. 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. The second most common abatement activity is "process modifications", which includes actions such as modifying equipment, layout, or piping.

We use three measures of regulatory enforcements based on data from EPA's ICIS-Air database, including high priority violations (HPV), Title V inspections, and full compliance evaluations. HPVs are serious plant violations that subject a facility to the threat of high fines, additional reporting, and intense regulatory oversight.[28] Title V inspections and compliance evaluations are essentially tests conducted for the purposes of determining and demonstrating a facility's compliance with CAA regulations. Failing these tests has potential negative consequences in that the facility could be labeled as a high priority violator. Lastly, we use three additional measures of regulatory enforcements based on data from EPA's Integrated Compliance Information System for Federal Civil Enforcement Case Data (ICIS FE&C). These variables include the number of formal judicial cases that the firm is involved in and the associated federal and total penalties imposed on the firm.[29]

Formally, we estimate the following difference-in-differences specification:

$$\begin{aligned} \textit{Comp cost}_{s,t} &= \beta_0 + \beta_1 \textit{Unexp. NA exposure}_{s,t} + \beta_2 \textit{Antic. NA exposure}_{s,t} + \beta_3 \textit{Post NA}_t \\ &+ \beta_4 \textit{Unexp. NA exposure}_{s,t} \times \textit{Post NA}_t + \beta_5 \textit{Antic. NA exposure}_{s,t} \times \textit{Post NA}_t \\ &+ X_{s,t-1} + \text{F.E.} + \varepsilon_{s,t} \end{aligned} \tag{12}$$

for stock s and year t. We focus on two years before to two years after the nonattainment designation because the real regulatory impact of nonattainment designations could take up to several years to fully materialize (Gibson, 2019). *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, and zero otherwise. We include firm-level control variables, as well as stock, year, and industry fixed effects. The dependent variables, *Comp cost*, measure a firm's regulatory compliance costs proxied by observable pollution abatement efforts and regulatory enforcement, and are defined when we present the results. The coefficients of interest are β_4 and β_5, which measure the differential regulatory compliance costs for the stocks with high exposure to unexpected and anticipated nonattainment designations, respectively, in the post-nonattainment period, when compared to those that are less exposed.

Table 8 presents the results. The dependent variables in columns (1) and (2) are a dummy variable equal to one if a given firm undertakes ozone-related source reduction activities and

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

[29]Formal judicial cases are those that pertain to violations of various environmental statutes. Cases can result in penalties at either the federal and/or local state level, which are fines for violating a statute

the natural logarithm of one plus the amount of ozone air emissions that undergo source reduction of a given firm, respectively. Both coefficients on *Unexp. NA exposure* × *Post NA* are positive and statistically significant, indicating that firms with greater exposure to unexpected nonattainment designations exert greater pollution abatement efforts in the post-nonattainment period.

In terms of regulatory enforcement, the dependent variables in columns (3) to (6) are the natural logarithm of one plus the number of ozone-related high priority violations, Title V inspections, full compliance evaluations, and formal judicial cases, respectively, of a given firm. Similarly, the dependent variables in columns (7) to (8) are the natural logarithm of one plus the dollar amount of ozone-related federal penalties and total penalties, respectively, of a given firm. All across columns, we find that stocks with greater exposures to unexpected nonattainment designations face more regulatory enforcement in the post-nonattainment years.

In line with the results in the previous section on operating performance, none of the coefficients on *Antic. NA exposure* × *Post NA* are statistically significant, suggesting that exposure to anticipated nonattainment designations do not have an impact on observable regulatory compliance costs. Overall, the evidence in this section is consistent with funds underweighting heavy ozone-polluting firms that are most exposed to unexpected nonattainment designations, since these firms experience the most increase in regulatory compliance costs.

6.3. Stock returns

We now examine the subsequent abnormal return performance of heavy ozone-polluting stocks exposed to nonattainment regulations. If the underweighting of these stocks is consistent with the rational hypothesis, then we would expect the most underweighted firms to underperform during the post-nonattainment period. However, if the underweighting is due to salience bias, then we should observe significant return reversals. To test this implication, we compare the stock return performance of the most underweighted stocks with those least underweighted conditional on their nonattainment exposure.

We follow a similar approach to Alok et al. (2020). Specifically, in each nonattainment designation quarter, we sort firms into high (low) nonattainment exposure based on whether their *Unexp. NA exposure* or *Antic. NA exposure* is above (below) the median. Then, we sort firms with high and low nonattainment exposure into tercile portfolios based on the average change in stock weights across all funds that hold the stock during the two quarters after the nonattainment designation relative to the two quarters before.

We compute equal-weighted DGTW-adjusted CARs (Daniel, Grinblatt, Titman, & Wermers, 1997) for each portfolio for one year before the event quarter (Year−1), one year after the event quarter (Year+1), two years after the event quarter (Year+2), and three years after the event quarter (Year+3). Table 9 shows the results. Panel A presents DGTW-adjusted returns for high nonattainment exposure firms, and Panel B reports results for low nonattainment exposure firms. Panel C reports the difference in returns between panels A and B. Tercile portfolio 1 is the most underweighted portfolio, whereas tercile portfolio 3 is the least underweighted portfolio. Portfolio $1-3$ represents a zero-investment long-short portfolio that is long tercile 1 and short tercile 3. Standard errors are computed based on Newey-West correction with a lag length of 3.

Panel A shows that the Year−1 CARs between the most and least underweighted portfolios are similar. The difference is only 1.3% based on *Unexp. NA exposure* and 3.9% based on *Antic. NA exposure*, and is statistically insignificant. It is the post-nonattainment CARs that we are most interested in. In the three years following *unexpected* nonattainment designations, we do not find any evidence of return reversals suggested by the salience hypothesis. Instead, we find that the most underweighted portfolio consistently underperforms the least underweighted. The CAR for the $1-3$ portfolio is negative across all horizons and the difference is statistically significant. The underperformance is also economically meaningful. For example, for the two year holding horizon, the CAR of -14% for the $1-3$ portfolio translates into a loss of approximately $322 million.[30] On the other hand, there are no differences in the post-nonattainment CARs for the most and least underweighted portfolios following *anticipated* nonattainment designations.

Panel B repeats our analysis for firms with low nonattainment exposure. There is no significant performance difference between the most and least underweighted portfolios prior to *unexpected* nonattainment designations. However, in contrast to Panel A, we do not find any evidence of underperformance for the most underweighted portfolio in the post-nonattainment years, as the CARs on the $1-3$ portfolio are all close to zero and statistically insignificant. There is no performance difference between tercile portfolios 1 and 3 following *anticipated* nonattainment designations either. Panel C shows the difference in returns. We find a greater underperformance associated with the $1-3$ portfolio consisting of firms with high exposure to unexpected nonattainment designations in the post-nonattainment years. The incremental underperformance is 10.9% for Year+1, 10.6% for Year+2, and 8.1% for

[30]The median market capitalization of firms belonging to tercile portfolio 1 (portfolio 3) is approximately $2.66 ($2.29) billion. Thus, the median loss for the $1-3$ portfolio over the two years after the unexpected nonattainment designation is 14.3% $\times$ $2.29 billion - 0.2% $\times$ $2.66 billion $\approx$ $322 million.

Year+3, with each difference-in-differences estimate being statistically significant. In summary, the findings in this section show that the most underweighted firms with high exposure to unexpected nonattainment designations exhibit worse abnormal return performance in the post-nonattainment years, consistent with the predictions of the rational hypothesis.

6.4. Funds' portfolio performance

Lastly, we examine whether the underweighting of heavy ozone-polluting stocks exposed to nonattainment designations translates into better investment performance for fund portfolios in the post-nonattainment period. Specifically, funds that reduce their portfolio exposure to nonattainment designations should experience an increase in the value of their rebalanced portfolio when the negative cash flows shocks due to higher regulatory costs materialize in the post-nonattainment period.

For each nonattainment designation, we sort funds into terciles based on the change in the average portfolio value-weighted *NA exposure* during the two quarters after the nonattainment designation relative to the two quarters before. Then we define the variable *Low vw-NA exposure* to be a dummy variable equal to one if a fund is in the lowest tercile, and zero otherwise. Thus, funds that have a *Low vw-NA exposure* value of one are those that reduce their portfolio exposure to nonattainment designations the most. We also define *Low Unexp. vw-NA exposure* and *Low Antic. vw-NA exposure* similarly, except they are based on the change in the average portfolio value-weighted *Unexp. NA exposure* and *Antic. NA exposure*, respectively. To examine portfolio performance, we follow Gibson et al. (2021) and focus on eight quarters before to eight quarters after the nonattainment designation and estimate a difference-in-differences specification by regressing eight quarter forward rolling portfolio-level performance measures on *Post NA*, *Low vw-NA exposure*, *Low Unexp. vw-NA exposure*, *Low Antic. vw-NA exposure*, and their interactions.

Table 10 presents the results. The dependent variables in columns (1) to (3) are the eight quarter forward rolling Sharpe ratio, while the dependent variables in columns (4) to (6) are the alpha from a Fama and French (1993) three factor model estimated using eight quarter forward rolling windows. All specifications include fund control variables and also value-weighted average characteristics of the portfolio's stock holdings. We use fund and year-quarter fixed effects. Columns (1) and (4) show that funds with the most reduction in portfolio exposure to nonattainment designations experience significantly higher Sharpe ratios and alpha in the post-nonattainment period. Economically, such funds experience a 21.33% (13.33%) increase in their Sharpe ratios (alpha) relative to the sample mean. Columns

(2) and (5) reveal that the outperformance is completely driven by reductions in exposures to *unexpected* nonattainment designations, while columns (3) and (6) indicate that reducing portfolio exposure to *anticipated* nonattainment designations does not significantly improve portfolio performance in the post-nonattainment period. This result is consistent with our prior findings that firm exposure to anticipated nonattainment designations do not negatively impact on future operating performance or stock returns, nor do they increase regulatory compliance costs.

7. Robustness

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 in Section IB of the Internet Appendix. Our main results on portfolio responses to nonattainment designations are robust to: 1) various windows around the nonattainment designations; 2) alternative outcome variables measuring portfolio response to mitigate concerns related to temporary drops in the stock price of polluting firms; 3) alternative measures of firm exposure to nonattainment designations; 4) placebo tests using non-regulated chemical emissions; 5) firms self-selecting into nonattainment counties; 6) controlling for the geographic distance between funds' headquarters and nonattainment plants; 7) conditioning on a fund's sustainability footprint (Azar, Duro, Kadach, & Ormazabal, 2021; Choi, Gao, Jiang, & Zhang, 2021; Gibson et al., 2021); 8) controlling for demand for ESG investment fund flows (Ceccarelli, Ramelli, & Wagner, 2023; Hartzmark & Sussman, 2019; Riedl & Smeets, 2017); and 9) the reallocation of production between attainment and nonattainment counties for multi-plant firms.

8. Conclusion

Environmental risks have received more focused attention from financial market participants over the past few years. In this study, we examine the response of mutual fund portfolios to environmental *regulatory* risks.

Using exogenous variation in local regulatory stringency driven by nonattainment designations, we find that funds underweight (overweight) those polluting stocks whose cash flows covary negatively (positively) with the regulatory shock. We validate our results using two related types of environmental regulatory events including bump-up classifications and attainment redesignations. Our results are consistent with active changes in portfolio holdings in response to expected changes in firm fundamentals due to negative cash flow shocks stemming from the costs of nonattainment regulation.

Examining firm performance in the post-nonattainment period, we find that heavy ozone-polluting firms exposed to nonattainment designations have worse operating performance and experience an increase in regulatory compliance costs. The most underweighted of such firms exhibit lower CARs relative to the least underweighted. Funds that reduce their portfolio exposure to nonattainment designations experience an increase in the value of their rebalanced portfolio.

The findings in this study demonstrate that environmental regulations have important implications for the allocation of capital of polluting firms in financial markets. Although shifting capital away from the biggest polluters exposed to stringent environmental regulations may increase the value of funds' portfolios, it may be detrimental to overall welfare as these are the firms that require funding for the transition to a greener economy. Thus, an exciting avenue for future research would be to evaluate the welfare and policy consequences of environmental regulation-driven capital allocations.

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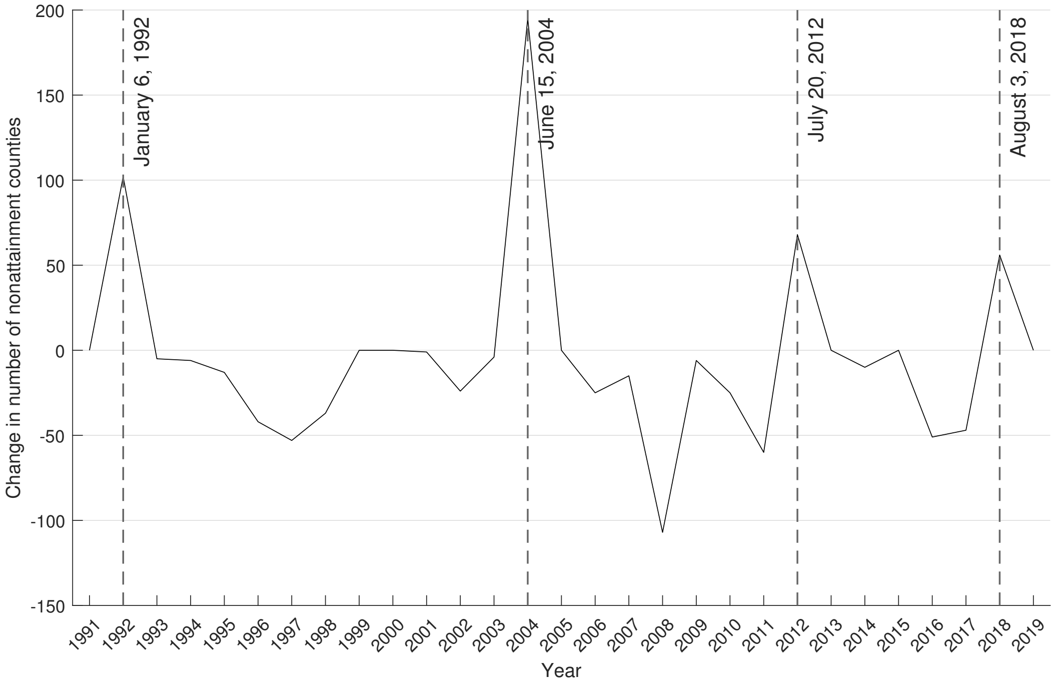
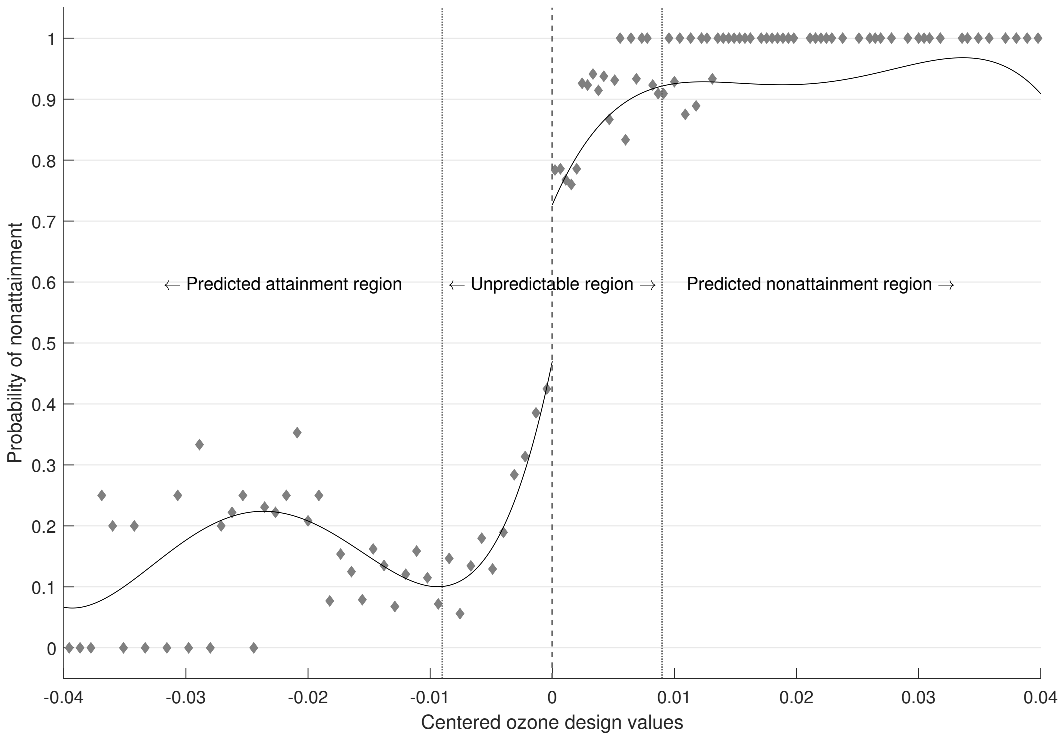
Figure 1
Policy changes in the NAAQS threshold and change in the number of nonattainment counties.



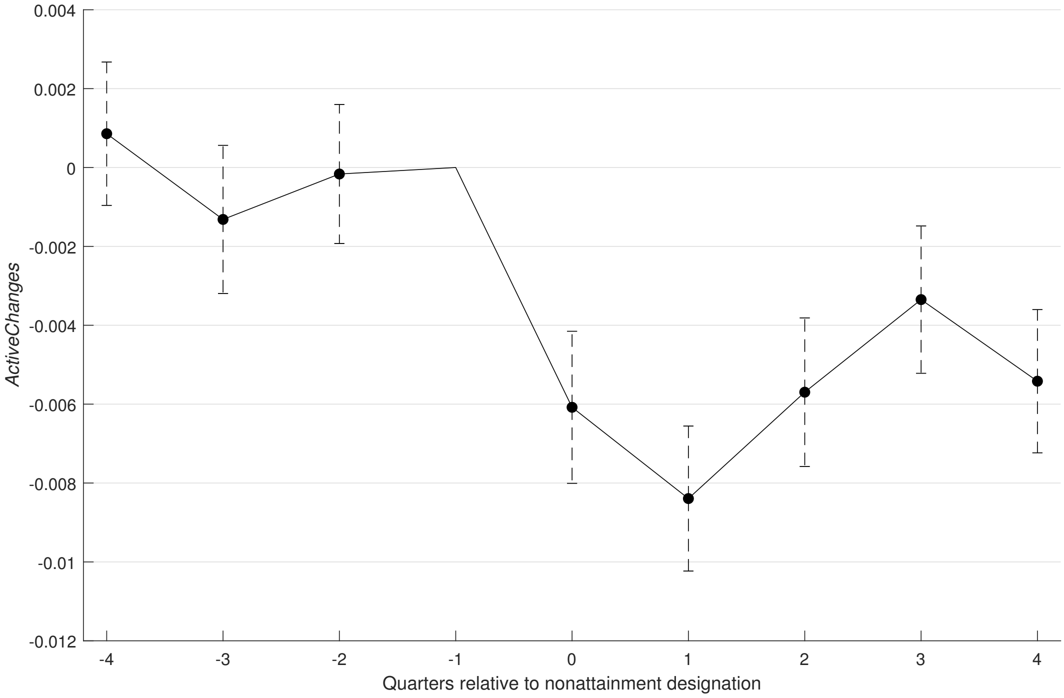
This figure shows the four discrete policy changes in the NAAQS threshold and the yearly change in the number of nonattainment counties during the sample period 1992 to 2019. In chronological order, the revisions to the NAAQS threshold include the 1-Hour Ozone (1979) standard effective on January 6, 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
Probability of nonattainment around ozone NAAQS thresholds.



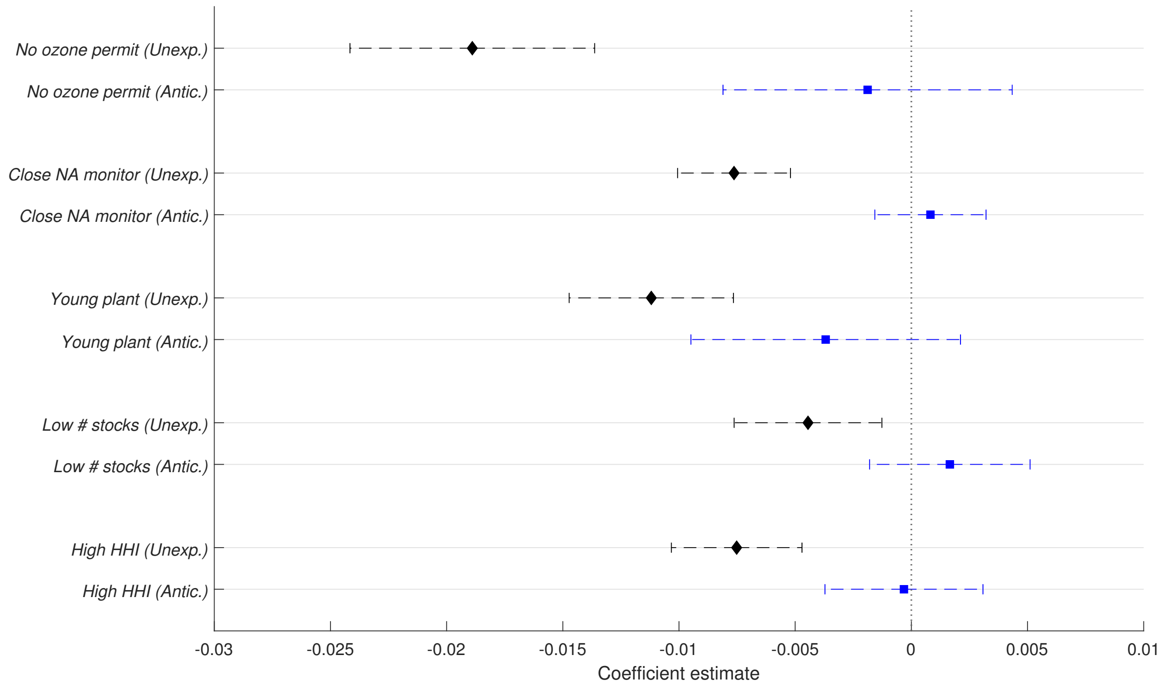
This figure presents the regression discontinuity relating centered DVs to the probability of nonattainment. The regression discontinuity is estimated from the local linear regression specification given in Equation (6) using the mean squared error optimal bandwidth with rectangular kernels following Calonico et al. (2014). We use the sample of nonattainment designations induced by revisions in the NAAQS threshold. The vertical axis shows the probability of nonattainment. The horizontal axis shows the centered DVs around zero by subtracting the NAAQS threshold from the DVs. The dashed vertical line at zero represents the NAAQS threshold for ozone nonattainment status. Observations on the right (left) of the line indicate that the county is in violation of (compliance with) the NAAQS threshold. Each dot in the figure represents the average of $NA_{c,t+1}$, defined as a dummy variable equal to one if county c is designated nonattainment in year $t+1$, using integrated mean squared error optimal bins following Calonico et al. (2014). The solid lines on either side of the NAAQS threshold is based on two separate regressions of $NA_{c,t+1}$ on local quartic polynomials in centered DVs using the rectangular kernel and mean squared error optimal bandwidth following Calonico et al. (2014). The unpredictable region refers to the narrow region surrounding the NAAQS threshold, which is bounded by the mean squared error optimal bandwidth following Calonico et al. (2014). The predicted nonattainment region refers to the region on the right of the right-endpoint of the optimal bandwidth. The predicted attainment region refers to the region on the left of the left-endpoint of the optimal bandwidth. For more details regarding the estimation of the optimal bandwidth, refer to Table IA.3 of the Internet Appendix.

Figure 3
Dynamics of portfolio response to nonattainment designations.



This figure shows the point estimates (solid line) and 95% confidence intervals (dashed lines) of the coefficients for the interaction term, $NA\ exposure_t \times Post\ NA(k)$, where k ranges from -4 to $+4$ quarters surrounding the nonattainment designation. The quarter before the nonattainment designation is the omitted category. The dependent variable, $ActiveChanges_{m,s,t}$, measures fund m's active trading in stock s in quarter t as defined in Equation (1). $NA\ exposure_t$ measures a firm's exposure to nonattainment designations as defined in Equation (2).

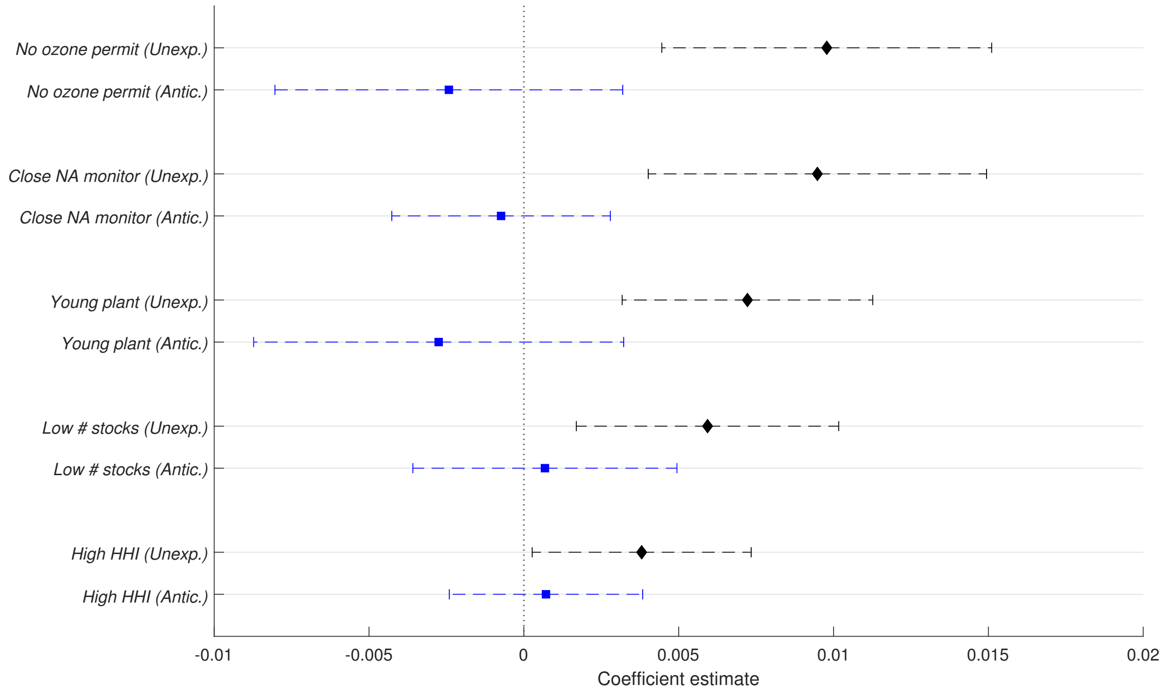
Figure 4
Heterogeneous portfolio responses to nonattainment designations.



This figure shows the point estimates and 95% confidence intervals of the coefficients for the triple interaction terms, *Unexp. NA exposure*$_t$ × *Post NA*$_t$ × *Z* (in black) and *Antic. NA exposure*$_t$ × *Post NA*$_t$ × *Z* (in blue), where *Z* refers to a set of firm and fund characteristics measured in the quarter before the nonattainment designation. We focus on two quarters before to two quarters after the nonattainment designation. The dependent variable, $ActiveChanges_{m,s,t}$, measures fund *m*'s active trading in stock *s* in quarter *t* as defined in Equation (1). *Unexp. NA exposure*$_t$ and *Antic. NA exposure*$_t$ measure a firm's exposure to unexpected and anticipated nonattainment designations as defined in Equations (7) and (8), respectively. *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, and zero otherwise. For each specification, the variable included in *Z* is listed on the vertical axis. *No ozone permit* is a dummy variable equal to one if a given firm does not have an ozone operating permit, and zero otherwise. *Close NA monitor* is a dummy variable equal to one if the average distance between the plants of a given firm to the closest nonattainment monitor is below the median, and zero otherwise. *Young plant* is a dummy variable equal to one if the average plant age of a given firm is between zero and five years, and zero otherwise. *Low # stocks* is a dummy variable equal to one for funds with the number of stocks below the median, and zero otherwise. *High HHI* is a dummy variable equal to one for funds with HHI concentration above the median, and zero otherwise.

Figure 5

Heterogeneous portfolio responses to attainment redesignations.



This figure shows the point estimates and 95% confidence intervals of the coefficients for the triple interaction terms, *Unexp. redesig exposure*$_t$ $\times$ *Post redesig*$_t$ $\times Z$ (in black) and *Antic. redesig exposure*$_t$ $\times$ *Post redesig*$_t$ $\times Z$ (in blue), where Z refers to a set of firm and fund characteristics measured in the quarter before the attainment redesignation. We focus on two quarters before to two quarters after the attainment redesignation. The dependent variable, $ActiveChanges_{m,s,t}$, measures fund m's active trading in stock s in quarter t as defined in Equation (1). *Unexp. redesig exposure*$_t$ and *Antic. redesig exposure*$_t$ measure a firm's exposure to unexpected and anticipated attainment redesignations, respectively. *Post redesig* is a dummy variable equal to one for the post-attainment redesignation regulatory period, and zero otherwise. For each specification, the variable included in Z is listed on the vertical axis. *No ozone permit* is a dummy variable equal to one if a given firm does not have an ozone operating permit, and zero otherwise. *Close NA monitor* is a dummy variable equal to one if the average distance between the plants of a given firm to the closest nonattainment monitor is below the median, and zero otherwise. *Young plant* is a dummy variable equal to one if the average plant age of a given firm is between zero and five years, and zero otherwise. *Low # stocks* is a dummy variable equal to one for funds with the number of stocks below the median, and zero otherwise. *High HHI* is a dummy variable equal to one for funds with HHI concentration above the median, and zero otherwise.

Table 1
Distribution of county characteristics by state.

State	# Counties nonattainment	# Counties bump-up	# Counties redesignated	# Counties total	Avg NA (years)	Std. dev. NA (years)	Avg DV (ppm)	Std. dev. DV (ppm)
Alaska	0	0	0	29	0.00	0.00	0.050	0.007
Alabama	2	0	2	67	0.42	2.40	0.075	0.018
Arkansas	1	1	1	75	0.12	1.04	0.074	0.018
Arizona	4	2	2	15	3.07	8.02	0.076	0.010
California	42	28	5	58	16.67	12.54	0.084	0.025
Colorado	9	9	7	64	2.78	7.11	0.075	0.012
Connecticut	8	8	0	8	28.00	0.00	0.093	0.027
District of Columbia	1	1	1	1	28.00	0.00	0.090	0.024
Delaware	3	0	0	3	26.33	2.89	0.086	0.022
Florida	7	0	7	67	0.34	1.02	0.072	0.015
Georgia	23	20	23	159	2.64	7.22	0.082	0.023
Hawaii	0	0	0	5	0.00	0.00	0.045	0.008
Iowa	0	0	0	99	0.00	0.00	0.069	0.011
Idaho	0	0	0	44	0.00	0.00	0.068	0.011
Illinois	12	11	12	102	3.03	8.49	0.077	0.015
Indiana	24	2	24	92	1.83	4.54	0.079	0.017
Kansas	2	0	2	105	0.02	0.14	0.072	0.014
Kentucky	16	0	16	120	1.27	4.44	0.078	0.017
Louisiana	17	5	17	64	2.75	6.53	0.081	0.019
Massachusetts	14	0	0	14	23.36	1.34	0.082	0.021
Maryland	14	11	7	24	15.25	13.64	0.087	0.023
Maine	12	0	11	16	8.44	6.38	0.073	0.019
Michigan	39	0	39	83	3.33	4.09	0.082	0.019
Minnesota	0	0	0	87	0.00	0.00	0.065	0.010
Missouri	8	5	8	115	1.19	5.49	0.078	0.017
Mississippi	1	0	1	82	0.04	0.33	0.077	0.018
Montana	0	0	0	56	0.00	0.00	0.056	0.004
North Carolina	23	0	23	100	1.56	3.60	0.079	0.019
North Dakota	0	0	0	53	0.00	0.00	0.060	0.006
Nebraska	0	0	0	93	0.00	0.00	0.063	0.011
New Hampshire	7	0	6	10	10.80	9.68	0.078	0.019
New Jersey	21	12	0	21	28.00	0.00	0.087	0.022
New Mexico	1	0	0	33	0.33	1.91	0.071	0.011
Nevada	2	1	1	17	1.41	4.05	0.073	0.012
New York	30	28	0	62	10.39	11.70	0.080	0.020
Ohio	34	0	34	88	4.48	6.74	0.083	0.019
Oklahoma	0	0	0	77	0.00	0.00	0.075	0.013
Oregon	5	0	3	36	1.19	3.45	0.065	0.011
Pennsylvania	49	7	32	67	13.03	9.70	0.082	0.020
Rhode Island	5	0	0	5	23.00	0.00	0.088	0.023
South Carolina	2	0	2	46	0.28	1.77	0.076	0.018
South Dakota	0	0	0	66	0.00	0.00	0.064	0.007
Tennessee	14	1	14	95	1.05	2.79	0.081	0.020
Texas	23	21	4	254	1.96	6.61	0.082	0.023
Utah	7	0	2	29	0.66	1.80	0.076	0.015
Virginia	37	10	36	133	3.42	7.42	0.079	0.021
Vermont	0	0	0	14	0.00	0.00	0.073	0.016
Washington	4	0	4	39	0.51	1.54	0.064	0.013
Wisconsin	11	2	11	72	2.89	7.26	0.077	0.017
West Virginia	10	0	10	55	0.84	1.89	0.077	0.017
Wyoming	3	0	0	23	0.91	2.41	0.065	0.009

This table reports the number of counties ever obtained a nonattainment designation, number of counties ever experienced a bump-up classification, number of counties ever obtained an attainment redesignation, total number of counties, average nonattainment period, standard deviation of nonattainment period, average DV, and standard deviation of DV. The sample period is from 1991 to 2019.

Table 2
Summary statistics: Mutual funds and firms.

Variables	Mean	Median	Std. dev.	P25	P75	Obs.
Panel A: Mutual fund variables						
w	1.014	0.667	1.145	0.202	1.425	3,445,583
ActiveChanges	-0.003	-0.002	0.631	-0.074	0.034	2,511,111
PassiveChanges	0.001	0.000	0.407	-0.072	0.080	2,514,556
Shares proportion	0.154	0.015	0.557	0.003	0.079	3,445,583
Exit	0.041	0.000	0.199	0.000	0.000	275,901
Expense ratio	0.012	0.012	0.006	0.010	0.015	143,274
Turnover ratio	0.845	0.620	1.120	0.340	1.050	139,325
ln(Fund size)	5.139	5.199	1.982	3.805	6.522	163,500
Net flow	-0.069	-0.007	7.697	-0.060	0.055	157,251
Fund returns	0.008	0.011	0.099	-0.006	0.026	158,276
Number of stocks	117.405	73.500	166.343	48.333	116.000	152,085
Concentration	0.020	0.017	0.015	0.012	0.024	152,085
Sharpe ratio	0.483	0.447	0.821	0.185	0.751	137,398
Alpha FF3	0.015	0.011	0.036	-0.003	0.026	137,399
Panel B: Firm variables						
NA exposure	4.455	4.389	4.234	0.000	8.469	1,615
Unexp. NA exposure	3.276	0.000	4.006	0.000	7.251	1,615
Antic. NA exposure	2.121	0.000	3.603	0.000	4.013	1,615
Bump exposure	3.038	0.075	3.790	0.000	6.710	831
Unexp. bump exposure	1.996	0.000	3.347	0.000	3.481	831
Antic. bump exposure	1.174	0.000	2.811	0.000	0.000	831
Redesig exposure	3.175	0.061	3.998	0.000	6.755	1,329
Unexp. redesig exposure	2.440	0.000	3.842	0.000	4.938	1,329
Antic. redesig exposure	0.740	0.000	2.196	0.000	0.000	1,329
ln(Size)	7.260	7.285	2.127	5.908	8.651	60,482
ln(BM)	0.513	0.522	0.152	0.411	0.619	60,328
ROA	0.035	0.034	0.028	0.023	0.046	57,562
Leverage	0.263	0.216	0.212	0.101	0.381	58,923
Sales growth	0.038	0.018	1.012	-0.048	0.087	62,197
Momentum	1.164	1.105	0.540	0.898	1.329	59,327
Stock returns	0.040	0.030	0.229	-0.074	0.136	59,327
No ozone permit	0.228	0.000	0.419	0.000	1.000	12,353
NA monitor distance (km)	220.996	167.653	196.624	80.228	306.177	12,353
Young plant	0.170	0.000	0.175	0.000	0.000	12,353
SR activity	0.346	0.000	0.476	0.000	1.000	11,991
SR amount	8.078	10.053	6.051	0.000	12.849	11,991
#High priority violation	0.136	0.000	0.401	0.000	0.000	11,991
#Title V inspection	0.537	0.000	0.923	0.000	0.693	11,991
#Compliance evaluation	0.648	0.000	0.839	0.000	1.099	11,991
#Formal case	0.037	0.000	0.194	0.000	0.000	11,991
Federal penalty	0.348	0.000	1.996	0.000	0.000	11,991
Total penalty	0.424	0.000	2.325	0.000	0.000	11,991

Panel A reports summary statistics for fund-level variables. Panel B reports summary statistics for firm-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 1991 to 2019.

Table 3
Active changes in portfolio holdings in response to nonattainment designations.

Dep. variable: *ActiveChanges*	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$NA\ exposure_t$	-0.002**	-0.000	-0.002**	-0.001	-0.001	-0.001	-0.003**
	(-2.41)	(-0.54)	(-2.40)	(-0.73)	(-0.73)	(-1.44)	(-2.44)
$Post\ NA_t$	0.031***	0.029***	0.031***	0.031***	0.003	0.030***	0.002
	(8.92)	(8.31)	(8.71)	(8.22)	(0.80)	(8.37)	(0.57)
$NA\ exposure_t \times Post\ NA_t$	-0.003***	-0.003***	-0.003***	-0.003***	-0.003***	-0.003***	-0.003***
	(-5.53)	(-4.68)	(-5.44)	(-4.83)	(-4.68)	(-4.79)	(-4.64)
$ln(Size)_{t-1}$		-0.029***		-0.027***	-0.042***	-0.029***	-0.033***
		(-9.06)		(-7.96)	(-5.86)	(-9.01)	(-4.45)
$ln(BM)_{t-1}$		0.084***		0.099***	0.128**	0.100***	0.183***
		(3.55)		(3.87)	(2.26)	(4.28)	(3.39)
ROA_{t-1}		0.201*		0.316**	0.114	0.190	0.029
		(1.72)		(2.55)	(0.51)	(1.63)	(0.13)
$Leverage_{t-1}$		0.044***		0.041***	0.068**	0.040***	0.077***
		(2.97)		(2.59)	(2.13)	(2.75)	(2.63)
$Sales\ growth_{t-1}$		-0.030***		-0.032***	-0.053***	-0.029***	-0.065***
		(-3.53)		(-3.48)	(-2.86)	(-3.34)	(-3.62)
$Momentum_{t-1}$		0.004		0.006	0.002	0.004	0.007
		(0.97)		(1.46)	(0.26)	(0.94)	(0.82)
$Stock\ returns_t$		0.068***		0.076***	0.048**	0.070***	0.025
		(6.30)		(6.52)	(2.18)	(6.50)	(1.15)
$Expense\ ratio_{t-1}$			0.141	0.137	1.601		
			(0.16)	(0.15)	(1.09)		
$Turnover\ ratio_{t-1}$			-0.001	-0.003	0.007		
			(-0.18)	(-0.38)	(0.81)		
$ln(Fund\ size)_{t-1}$			0.004**	0.004**	0.009**		
			(2.24)	(2.16)	(2.42)		
$Net\ flow_{t-1}$			-0.021	-0.019	0.003		
			(-1.28)	(-1.11)	(0.11)		
$Fund\ returns_{t-1}$			0.088	-0.172	-1.035***		
			(0.40)	(-0.75)	(-2.70)		
Fund × Stock F.E.	No	No	No	No	Yes	No	Yes
Fund × Year-Quarter F.E.	No	No	No	No	No	Yes	Yes
Fund F.E.	Yes	Yes	Yes	Yes	No	No	No
Stock F.E.	Yes	Yes	Yes	Yes	No	Yes	No
Year-Quarter F.E.	Yes	Yes	Yes	Yes	Yes	No	No
Observations	206,940	194,806	177,681	167,113	157,327	194,762	183,602
Adj R^2	0.03	0.04	0.04	0.04	0.20	0.06	0.22

This table reports the regression estimates from Equation (5) at the fund-firm-quarter level. We focus on two quarters before to two quarters after the nonattainment designation. The dependent variable, $ActiveChanges_{m,s,t}$, measures fund m's active trading in stock s in quarter t as defined in Equation (1). $NA\ exposure_t$ measures a firm's exposure to nonattainment designations as defined in Equation (2). *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, and zero otherwise. For all specifications, standard errors are robust to heteroskedasticity and clustered at the fund-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
Active changes in portfolio holdings in response to unexpected and anticipated nonattainment designations.

Dep. variable: *ActiveChanges*	(1)	(2)	(3)	(4)
$Unexp.\ NA\ exposure_t$	0.001	0.000	0.000	-0.002
	(0.84)	(0.10)	(0.20)	(-1.61)
$Antic.\ NA\ exposure_t$	0.003***	0.005***	0.002***	0.003*
	(3.54)	(3.43)	(3.41)	(1.90)
$Post\ NA_t$	0.024***	-0.004	0.024***	-0.003
	(6.99)	(-0.95)	(7.53)	(-0.83)
$Unexp.\ NA\ exposure_t \times Post\ NA_t$	-0.006***	-0.006***	-0.006***	-0.006***
	(-10.47)	(-10.46)	(-10.99)	(-10.91)
$Antic.\ NA\ exposure_t \times Post\ NA_t$	0.001	0.001	0.001	0.001
	(1.31)	(1.45)	(1.43)	(1.42)
Stock controls	Yes	Yes	Yes	Yes
Fund controls	Yes	Yes	No	No
Fund × Stock F.E.	No	Yes	No	Yes
Fund × Year-Quarter F.E.	No	No	Yes	Yes
Fund F.E.	Yes	No	No	No
Stock F.E.	Yes	No	Yes	No
Year-Quarter F.E.	Yes	Yes	No	No
Observations	167,113	157,327	194,762	183,602
Adj R^2	0.04	0.21	0.06	0.22

This table reports portfolio responses to nonattainment designations when decomposed into an unexpected and anticipated component. We focus on two quarters before to two quarters after the nonattainment designation. The dependent variable, $ActiveChanges_{m,s,t}$, measures fund m's active trading in stock s in quarter t as defined in Equation (1). $Unexp.\ NA\ exposure_t$ and $Antic.\ NA\ exposure_t$ measure a firm's exposure to unexpected and anticipated nonattainment designations as defined in Equations (7) and (8), respectively. *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, and zero otherwise. For all specifications, standard errors are robust to heteroskedasticity and clustered at the fund-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
Active changes in portfolio holdings in response to bump-up classifications.

Dep. variable: *ActiveChanges*	(1)	(2)	(3)	(4)
Bump exposure$_t$	-0.001*		-0.000	
	(-1.70)		(-0.71)	
Unexp. bump exposure$_t$		0.000		0.000
		(0.31)		(1.25)
Antic. bump exposure$_t$		-0.004***		-0.006***
		(-5.69)		(-3.90)
Post bump$_t$	-0.042***	-0.045***	-0.042***	-0.046***
	(-13.87)	(-14.89)	(-14.98)	(-16.07)
Bump exposure$_t$ × *Post bump$_t$*	-0.002***		-0.002***	
	(-3.43)		(-3.72)	
Unexp. bump exposure$_t$ × *Post bump$_t$*		-0.002***		-0.002***
		(-2.79)		(-2.99)
Antic. bump exposure$_t$ × *Post bump$_t$*		0.001		0.001
		(0.83)		(0.87)
Stock controls	Yes	Yes	Yes	Yes
Fund controls	Yes	No	Yes	No
Fund × Stock F.E.	No	Yes	No	Yes
Fund × Year-Quarter F.E.	No	Yes	No	Yes
Fund F.E.	Yes	No	Yes	No
Stock F.E.	Yes	No	Yes	No
Year-Quarter F.E.	Yes	No	Yes	No
Observations	123,330	123,330	123,330	123,330
Adj R^2	0.03	0.03	0.13	0.13

This table examines the active changes in portfolio holdings in response to bump-up classifications. We focus on two quarters before to two quarters after the bump-up classification. The dependent variable, $ActiveChanges_{m,s,t}$, measures fund m's active trading in stock s in quarter t as defined in Equation (1). *Bump exposure$_t$* measures a firm's exposure to bump-up classifications as defined in Equation (3). *Unexp. bump exposure$_t$* and *Antic. bump exposure$_t$* measure a firm's exposure to unexpected and anticipated bump-up classifications, respectively. *Post bump* is a dummy variable equal to one for the post-bump-up regulatory period, and zero otherwise. For all specifications, standard errors are robust to heteroskedasticity and clustered at the fund-level; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Table 6
Active changes in portfolio holdings in response to attainment redesignations.

Dep. variable: *ActiveChanges*	(1)	(2)	(3)	(4)
Redesig exposure$_t$	-0.002***		-0.000	
	(-3.49)		(-0.96)	
Unexp. redesig exposure$_t$		-0.002*		-0.003**
		(-1.79)		(-2.08)
Antic. redesig exposure$_t$		-0.002		0.002**
		(-1.62)		(1.98)
Post redesig$_t$	-0.021***	-0.019***	-0.021***	-0.017***
	(-7.72)	(-7.79)	(-7.89)	(-7.71)
Redesig exposure$_t$ × *Post redesig*$_t$	0.002**		0.002***	
	(2.46)		(3.03)	
Unexp. redesig exposure$_t$ × *Post redesig*$_t$		0.006***		0.006***
		(3.94)		(3.89)
Antic. redesig exposure$_t$ × *Post redesig*$_t$		0.001		0.001
		(0.38)		(0.41)
Stock controls	Yes	Yes	Yes	Yes
Fund controls	Yes	No	Yes	No
Fund × Stock F.E.	No	Yes	No	Yes
Fund × Year-Quarter F.E.	No	Yes	No	Yes
Fund F.E.	Yes	No	Yes	No
Stock F.E.	Yes	No	Yes	No
Year-Quarter F.E.	Yes	No	Yes	No
Observations	110,700	110,700	110,700	110,700
Adj R^2	0.04	0.04	0.17	0.17

This table examines the active changes in portfolio holdings in response to attainment redesignations. We focus on two quarters before to two quarters after the attainment redesignation. The dependent variable, $ActiveChanges_{m,s,t}$, measures fund m's active trading in stock s in quarter t as defined in Equation (1). *Redesig exposure*$_t$ measures a firm's exposure to attainment redesignations as defined in Equation (4). *Unexp. redesig exposure*$_t$ and *Antic. redesig exposure*$_t$ measure a firm's exposure to unexpected and anticipated attainment redesignations, respectively. *Post redesig* is a dummy variable equal to one for the post-attainment redesignation regulatory period, and zero otherwise. For all specifications, standard errors are robust to heteroskedasticity and clustered at the fund-level; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Table 7
Impact of nonattainment designations on firms' operating performance.

Dep. variable:	ΔROA_t			$\Delta Sales\ growth_t$			$\Delta Market\ to\ book_t$		
Post regulatory period:	1 Yr.	2 Yrs.	3 Yrs.	1 Yr.	2 Yrs.	3 Yrs.	1 Yr.	2 Yrs.	3 Yrs.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Unexp. NA exposure$_t$	-0.000	-0.000	-0.000	-0.000	0.001	0.000	0.001	0.001	0.001
	(-0.99)	(-0.46)	(-1.53)	(-0.40)	(0.77)	(0.71)	(0.93)	(0.33)	(0.71)
Antic. NA exposure$_t$	0.000**	0.000***	0.000**	0.001	0.002*	0.002*	0.001	0.001	0.000
	(2.49)	(2.77)	(2.11)	(1.61)	(1.82)	(1.65)	(0.85)	(0.68)	(0.20)
Post NA$_t$	-0.001	0.000	-0.001	0.004	0.005	0.002	-0.002	-0.002	-0.009
	(-1.41)	(0.50)	(-1.30)	(0.96)	(1.16)	(0.44)	(-0.19)	(-0.16)	(-0.63)
Unexp. NA exposure$_t$ × Post NA$_t$	-0.001**	-0.001***	-0.001**	-0.002***	-0.002***	-0.002**	-0.004**	-0.004**	-0.003**
	(-2.22)	(2.63)	(-2.37)	(-2.80)	(-2.58)	(-2.45)	(-2.20)	(-2.17)	(-2.16)
Antic. NA exposure$_t$ × Post NA$_t$	0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001
	(1.65)	(0.49)	(1.41)	(-0.17)	(-0.79)	(-0.64)	(-0.16)	(-0.29)	(-0.41)
Stock controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Stock F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-Quarter F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8,243	9,632	12,277	8,413	9,965	12,747	8,397	9,938	12,713
Adj R^2	0.03	0.02	0.01	0.02	0.01	0.04	0.05	0.04	0.04

This table reports the regression estimates from Equation (11) at the firm-quarter level. The pre-nonattainment regulatory period is the two quarters before the designation, while the post-nonattainment regulatory period varies from one year, two years, and three years after the designation. The dependent variable is ΔROA_t in columns (1) to (3), $\Delta Sales\ growth_t$ in columns (4) to (6), and $\Delta Market\ to\ book_t$ in columns (7) to (9). *Unexp. NA exposure$_t$* and *Antic. NA exposure$_t$* measure a firm's exposure to unexpected and anticipated nonattainment designations as defined in Equations (7) and (8), respectively. *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, 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 8

Impact of nonattainment designations on firms' observable regulatory compliance costs.

Dep. variable:	SR activity	SR amount	#High priority violation	#Title V inspection	#Compliance evaluation	#Formal case	Federal penalty	Total penalty
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Unexp. NA $exposure_t$	0.017***	0.265***	0.005	-0.025*	0.018***	-0.002	-0.006	-0.007
	(3.93)	(6.29)	(1.37)	(-1.94)	(3.00)	(-1.11)	(-0.23)	(-0.25)
Antic. NA $exposure_t$	0.006	0.224***	0.007**	-0.009	0.010	0.004	0.046*	0.058**
	(1.13)	(3.95)	(2.14)	(-0.77)	(1.06)	(1.65)	(1.93)	(2.08)
Post NA_t	-0.044***	0.039	-0.032***	0.054***	0.000	0.001	0.019	0.037
	(-3.42)	(0.35)	(-3.34)	(5.86)	(0.03)	(0.19)	(0.35)	(0.60)
Unexp. NA $exposure_t \times$ *Post* NA_t	0.019***	0.047***	0.007***	0.008***	0.004**	0.002*	0.042**	0.046**
	(5.96)	(2.59)	(2.82)	(2.68)	(2.26)	(1.68)	(2.17)	(2.02)
Antic. NA $exposure_t \times$ *Post* NA_t	-0.001	0.017	0.002	-0.002	-0.001	0.000	-0.019	-0.025
	(-0.22)	(0.97)	(1.34)	(-1.30)	(-0.66)	(0.07)	(-1.20)	(-1.29)
Stock controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Stock F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-Quarter F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,539	5,539	5,539	5,539	5,539	5,539	5,539	5,539
Adj R^2	0.40	0.82	0.45	0.82	0.79	0.14	0.16	0.16

This table reports the regression estimates from Equation (12) at the firm-year level. We focus on two years before to two years after the nonattainment designation. The dependent variable in: i) column (1) is a dummy variable equal to one if a given firm undertakes ozone-related source reduction activities; ii) column (2) is the natural logarithm of one plus the amount of ozone air emissions that undergo source reduction of a given firm; iii) columns (3) to (6) is the natural logarithm of one plus the number of ozone-related high priority violations, Title V inspections, full compliance evaluations, and formal judicial cases, respectively, of a given firm; and iv) columns (7) to (8) is the natural logarithm of one plus the dollar amount of ozone-related federal penalties and total penalties, respectively, of a given firm. *Unexp. NA* $exposure_t$ and *Antic. NA* $exposure_t$ measure a firm's exposure to unexpected and anticipated nonattainment designations as defined in Equations (7) and (8), respectively. *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, 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 9
Firm exposure to nonattainment designations and cumulative stock returns.

Panel A: High nonattainment exposure								
	High *Unexp. NA exposure*				High *Antic. NA exposure*			
Tercile	Year−1	Year+1	Year+2	Year+3	Year−1	Year+1	Year+2	Year+3
1	0.019	-0.008	0.002	0.048	0.039	0.007	0.010	0.109**
	(1.22)	(-0.37)	(0.08)	(1.23)	(1.43)	(0.28)	(0.32)	(2.46)
2	-0.066**	0.005	0.023	0.049	-0.034	0.016	0.093***	0.074*
	(-2.60)	(0.26)	(0.77)	(1.37)	(-1.29)	(0.66)	(2.89)	(1.92)
3	0.006	0.078***	0.143***	0.177***	-0.000	0.027	0.071**	0.111***
	(0.40)	(4.40)	(5.24)	(5.55)	(-0.01)	(1.12)	(2.19)	(3.45)
1 − 3	0.013	-0.085***	-0.140***	-0.129***	0.039	-0.020	-0.061	-0.001
	(0.58)	(-3.31)	(-3.83)	(-2.64)	(1.19)	(-0.55)	(-1.32)	(-0.02)
Panel B: Low nonattainment exposure								
	Low *Unexp. NA exposure*				Low *Antic. NA exposure*			
Tercile	Year−1	Year+1	Year+2	Year+3	Year−1	Year+1	Year+2	Year+3
1	0.047***	0.036***	0.031	0.051	0.047***	0.014	0.024	0.060*
	(2.76)	(2.64)	(1.04)	(1.60)	(2.94)	(0.88)	(0.93)	(1.96)
2	-0.044**	0.063**	0.066**	0.085**	-0.045***	0.036**	0.072***	0.086**
	(-2.35)	(2.50)	(2.22)	(2.17)	(-3.20)	(2.43)	(2.89)	(2.41)
3	0.013	0.011	0.066***	0.098***	0.009	0.036***	0.067***	0.082**
	(0.82)	(0.71)	(2.75)	(3.19)	(0.56)	(2.66)	(3.03)	(2.56)
1 − 3	0.033	0.024	-0.035	-0.047	0.038*	-0.022	-0.043	-0.022
	(1.44)	(1.23)	(-0.96)	(-1.13)	(1.71)	(-1.02)	(-1.24)	(-0.50)
Panel C: Difference between high and low nonattainment exposure								
	(High - Low) *Unexp. NA exposure*				(High - Low) *Antic. NA exposure*			
Tercile	Year−1	Year+1	Year+2	Year+3	Year−1	Year+1	Year+2	Year+3
1	-0.027	-0.043*	-0.029	-0.003	-0.008	-0.007	-0.014	0.049
	(-1.18)	(-1.74)	(-0.71)	(-0.06)	(-0.24)	(-0.22)	(-0.34)	(0.92)
2	-0.022	-0.058**	-0.042	-0.036	0.011	-0.019	0.021	-0.012
	(-0.70)	(-1.98)	(-1.02)	(-0.77)	(0.38)	(-0.65)	(0.52)	(-0.22)
3	-0.007	0.067***	0.077**	0.078*	-0.009	-0.009	0.004	0.029
	(-0.30)	(2.81)	(2.14)	(1.81)	(-0.39)	(-0.30)	(0.10)	(0.63)
1 − 3	-0.021	-0.109***	-0.106**	-0.081***	0.001	0.002	-0.018	0.021
	(-0.64)	(-3.17)	(-1.97)	(3.23)	(0.03)	(0.04)	(-0.32)	(0.30)

This table reports equal-weighted portfolio DGTW-adjusted cumulative abnormal returns. In each nonattainment designation quarter, we sort firms into high (low) nonattainment exposure based on whether their *Unexp. NA exposure* or *Antic. NA exposure* is above (below) the median. In Panel A (Panel B), we sort firms with high (low) nonattainment exposure into tercile portfolios based on the average change in stock weights across all funds that hold the stock during the two quarters after the nonattainment designation relative to the two quarters before. We then compute equal-weighted DGTW-adjusted cumulative abnormal returns for each portfolio for one year before the event quarter (Year−1), one year after the event quarter (Year+1), two years after the event quarter (Year+2), and three years after the event quarter (Year+3). Tercile portfolio 1 is the most underweighted portfolio, whereas tercile portfolio 3 is the least underweighted portfolio. Portfolio 1 − 3 represents a zero-investment long-short portfolio that is long tercile 1 and short tercile 3. Panel C shows the difference in returns between panels A and B. Standard errors are computed based on Newey-West correction with a lag length of 3; t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

Table 10

Fund exposure to nonattainment designations and portfolio performance.

Dep. variable:	Sharpe ratio			Alpha FF3		
	(1)	(2)	(3)	(4)	(5)	(6)
Low vw-NA exposure$_t$	-0.049***			-0.002**		
	(-2.68)			(-2.06)		
Low Unexp. vw-NA exposure$_t$		-0.029			-0.001	
		(-1.46)			(-0.67)	
Low Antic. vw-NA exposure$_t$			-0.058**			-0.002**
			(-2.29)			(-2.25)
Post NA$_t$	-0.071***	-0.075***	-0.057***	-0.001**	-0.001**	-0.001*
	(-8.39)	(-8.62)	(-3.55)	(-2.02)	(-2.09)	(-1.85)
Low vw-NA exposure$_t$ × *Post NA*$_t$	0.103***			0.002**		
	(6.73)			(2.52)		
Low Unexp. vw-NA exposure$_t$ × *Post NA*$_t$		0.112***			0.002***	
		(7.18)			(2.63)	
Low Antic. vw-NA exposure$_t$ × *Post NA*$_t$			0.019			0.000
			(1.04)			(0.84)
Value-weighted stock controls	Yes	Yes	Yes	Yes	Yes	Yes
Fund controls	Yes	Yes	Yes	Yes	Yes	Yes
Fund F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Year-Quarter F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	32,521	32,521	32,521	32,521	32,521	32,521
Adj R^2	0.24	0.27	0.10	0.37	0.40	0.36

This table examines the impact of funds' exposure to nonattainment designations on their portfolio performance. We focus on two years before to two years after the nonattainment designation. The dependent variable in columns (1) to (3) is the eight quarter forward rolling Sharpe ratio. The dependent variable in columns (4) to (6) is the alpha from a Fama and French (1993) three factor model estimated using eight quarter forward rolling windows. For each nonattainment designation, we sort funds into terciles based on the change in the average portfolio value-weighted *NA exposure* during the two quarters after the nonattainment designation relative to the two quarters before. *Low vw-NA exposure* is a dummy variable equal to one if a fund is in the lowest tercile, and zero otherwise. *Low Unexp. vw-NA exposure* and *Low Antic. vw-NA exposure* are defined similarly, except they are based on the change in the average portfolio value-weighted *Unexp. NA exposure* and *Antic. NA exposure*, respectively. *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, and zero otherwise. For all specifications, standard errors are robust to heteroskedasticity and clustered at the fund-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
Mutual fund variables		
w	The weight (percentage points) of a given stock in a given mutual fund's portfolio at the end of quarter, where the weight is calculated as the dollar holdings of a stock divided by the total dollar holdings of all stocks in the mutual fund's portfolio.	Thomson Reuters mutual fund holdings (s12); CRSP
ActiveChanges	Following Alekseev et al. (2022), for a given mutual fund m, we measure its *active* trading in stock s in quarter t, denoted $ActiveChanges_{m,s,t}$, as $$\frac{P_{s,t-1} Shares_{m,s,t}}{\sum_s P_{s,t-1} Shares_{m,s,t}} - \frac{P_{s,t-1} Shares_{m,s,t-1}}{\sum_s P_{s,t-1} Shares_{m,s,t-1}},$$ where $P_{s,t-1}$ is the price for stock s at the end of quarter $t-1$ and $Shares_{m,s,t}$ is the number of shares of stock s held by fund m at the end of quarter t.	Thomson Reuters mutual fund holdings (s12); CRSP
PassiveChanges	Following Alekseev et al. (2022), for a given mutual fund m, we measure its *passive* trading in stock s in quarter t, denoted $PassiveChanges_{m,s,t}$, as $$\frac{P_{s,t} Shares_{m,s,t}}{\sum_s P_{s,t} Shares_{m,s,t}} - \frac{P_{s,t-1} Shares_{m,s,t-1}}{\sum_s P_{s,t-1} Shares_{m,s,t-1}},$$ where $P_{s,t}$ is the price for stock s at the end of quarter t and $Shares_{m,s,t}$ is the number of shares of stock s held by fund m at the end of quarter t.	Thomson Reuters mutual fund holdings (s12); CRSP
Shares proportion	The ratio of total number of shares of a given stock in a given mutual fund's portfolio to the total number of shares outstanding (in percentage points).	Thomson Reuters mutual fund holdings (s12); CRSP
Exit	A dummy variable equal to one if a given fund's portfolio completely divests a given stock in the post-nonattainment period, and zero otherwise.	Thomson Reuters mutual fund holdings (s12)
Expense ratio	Fund expense ratio as reported in the CRSP Mutual Funds database. For funds with multiple share classes, the expense ratio is the weighted average using individual share classes' total net assets as the weight.	CRSP Mutual Funds
Turnover ratio	Fund turnover ratio as reported in the CRSP Mutual Funds database. For funds with multiple share classes, the turnover ratio is the weighted average using individual share classes' total net assets as the weight.	CRSP Mutual Funds
ln(Fund size)	The natural logarithm of one plus the sum of total net assets (TNA) of all fund classes.	CRSP Mutual Funds
Fund returns	The average net (after-expense) monthly return over a quarter. For funds with multiple share classes, fund returns are computed as the weighted average using individual share classes' total net assets as the weight.	CRSP Mutual Funds
Net flow	Net fund flows during quarter t is calculated as $100 \times (TNA_t - (1 + \textit{Fund returns}_t) \times TNA_{t-1}) / TNA_{t-1}$.	CRSP Mutual Funds
Number of stocks	The number of stocks held in a given fund's portfolio.	Thomson Reuters mutual fund holdings (s12)
Concentration	The Herfindahl-Hirschman index (HHI) calculated based on the weights allocated to each stock in a given fund's portfolio.	Thomson Reuters mutual fund holdings (s12); CRSP
Sharpe ratio	A given fund portfolio's eight quarter forward rolling Sharpe ratio.	Thomson Reuters mutual fund holdings (s12); CRSP
Alpha FF3	A given fund portfolio's alpha calculated from a Fama and French (1993) three factor model estimated using eight quarter forward rolling windows.	Thomson Reuters mutual fund holdings (s12); CRSP

Table A.1 continued

Variable	Definitions	Data source
Firm variables		
NA exposure	For a given stock s, we measure its exposure to nonattainment designations in quarter t, denoted $NA\ exposure_{s,t}$, as $$\ln\left(1+\sum_j \left(ozone_{j,s,t-4}\cdot NA_{j,s,t}\right)/\#Plant_{s,t}\right),$$ where $ozone_{j,s,t-4}$ is the total amount of ozone air emissions for plant j of stock s in quarter $t-4$, $NA_{j,s,t}$ is a dummy variable equal to one if plant j of stock s is located in a nonattainment county in quarter t, and zero otherwise, and $\#Plant_{s,t}$ is the total number of polluting plants owned by stock s in quarter t.	TRI; Federal Register
Unexp. NA exposure	The same expression as *NA exposure* except $NA_{j,s,t}$ is replaced with $Unexp.\ NA_{j,s,t}$, which is a dummy variable equal to one if plant j of stock s is located in an *unexpected* nonattainment county in quarter t, and zero otherwise.	TRI; Federal Register; AQS
Antic. NA exposure	The same expression as *NA exposure* except $NA_{j,s,t}$ is replaced with $Antic.\ NA_{j,s,t}$, which is a dummy variable equal to one if plant j of stock s is located in an *anticipated* nonattainment county in quarter t, and zero otherwise.	TRI; Federal Register; AQS
Bump exposure	For a given stock s, we measure its exposure to bump-up classifications in quarter t, denoted $Bump\ exposure_{s,t}$, as $$\ln\left(1+\sum_j \left(ozone_{j,s,t-4}\cdot Bump_{j,s,t}\right)/\#NA\ plant_{s,t}\right),$$ where $ozone_{j,s,t-4}$ is the total amount of ozone air emissions for plant j of stock s in quarter $t-4$, $Bump_{j,s,t}$ is a dummy variable equal to one if plant j of stock s is located in a nonattainment county experiencing a bump-up in quarter t, and zero otherwise, and $\#NA\ plant_{s,t}$ is the total number of nonattainment polluting plants owned by stock s in quarter t.	TRI; Federal Register
Unexp. bump exposure	The same expression as *Bump exposure* except $Bump_{j,s,t}$ is replaced with $Unexp.\ bump_{j,s,t}$, which is a dummy variable equal to one if plant j of stock s is located in a nonattainment county experiencing an *unexpected* bump-up in quarter t, and zero otherwise.	TRI; Federal Register; AQS
Antic. bump exposure	The same expression as *Bump exposure* except $Bump_{j,s,t}$ is replaced with $Antic.\ bump_{j,s,t}$, which is a dummy variable equal to one if plant j of stock s is located in a nonattainment county experiencing an *anticipated* bump-up in quarter t, and zero otherwise.	TRI; Federal Register; AQS
Redesig exposure	For a given stock s, we measure its exposure to attainment redesignations in quarter t, denoted $Redesig\ exposure_{s,t}$, as $$\ln\left(1+\sum_j \left(ozone_{j,s,t-4}\cdot Redesig_{j,s,t}\right)/\#NA\ plant_{s,t}\right),$$ where $ozone_{j,s,t-4}$ is the total amount of ozone air emissions for plant j of stock s in quarter $t-4$, $Redesig_{j,s,t}$ is a dummy variable equal to one if plant j of stock s is located in a nonattainment county redesignated to attainment in quarter t, and zero otherwise, and $\#NA\ plant_{s,t}$ is the total number of nonattainment polluting plants owned by stock s in quarter t.	TRI; Federal Register
Unexp. redesig exposure	The same expression as *Redesig exposure* except $Redesig_{j,s,t}$ is replaced with $Unexp.\ redesig_{j,s,t}$, which is a dummy variable equal to one if plant j of stock s is located in a nonattainment county experiencing an *unexpected* redesignation in quarter t, and zero otherwise.	TRI; Federal Register; AQS
Antic. redesig exposure	The same expression as *Redesig exposure* except $Redesig_{j,s,t}$ is replaced with $Antic.\ redesig_{j,s,t}$, which is a dummy variable equal to one if plant j of stock s is located in a nonattainment county experiencing an *anticipated* redesignation in quarter t, and zero otherwise.	TRI; Federal Register; AQS

Table A.1 continued

Variable	Definitions	Data source
ln(Size)	The natural logarithm of market value of assets.	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	Percentage quarterly change in firm sales.	Compustat
Momentum	Cumulative 12-month return of a stock, excluding the immediate past month.	CRSP
Stock returns	Firm-level quarterly stock returns.	CRSP
No ozone permit	A dummy variable equal to one if a given firm does not have an ozone operating permit, and zero otherwise.	ICIS-Air
NA monitor distance	The average distance (in km) between the plants of a given firm to the closest nonattainment monitor.	TRI; AQS
Young plant	A dummy variable equal to one if the average plant age of a given firm is between zero and five years, and zero otherwise.	NETS
SR activity	A dummy variable equal to one if a given firm undertakes ozone-related source reduction activities, and zero otherwise.	TRI P2
SR amount	The natural logarithm of one plus the amount of ozone air emissions that undergo source reduction of a given firm.	TRI
#*High priority violation*	The natural logarithm of one plus the number of ozone-related high priority violations of a given firm.	ICIS-Air
#*Title V inspection*	The natural logarithm of one plus the number of ozone-related Title V inspections of a given firm.	ICIS-Air
#*Compliance evaluation*	The natural logarithm of one plus the number of ozone-related full compliance evaluations of a given firm.	ICIS-Air
#*Formal case*	The natural logarithm of one plus the number of ozone-related formal judicial cases of a given firm.	FE&C
Federal penalty	The natural logarithm of one plus the dollar amount of ozone-related federal penalties of a given firm.	FE&C
Total penalty	The natural logarithm of one plus the dollar amount of ozone-related total penalties of a given firm.	FE&C

Internet Appendix For Online Publication Only

Appendix IA. RDD identifying assumptions

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

IA.1. Continuity in the distribution of design values

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

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

Internet Appendix Figure IA.2 plots the local density of centered DVs, estimated separately on either side of the NAAQS threshold with the corresponding 95% confidence interval bounds, calculated using the plug-in estimator proposed by Cattaneo, Jansson, and Ma (2020). Observations on the left (right) of the vertical dashed line indicate that the county is in compliance with (violation of) the NAAQS threshold. If counties were manipulating their DVs to strategically avoid nonattainment designations, one would expect to see a bunching of counties just below the NAAQS thresholds. As shown in the figure, there is no evidence for a discontinuous jump around the threshold. Using the density break test following Cattaneo et al. (2020),[31] we fail to reject the null hypothesis that counties are unable to manipulate their pollution levels in order to be right below the NAAQS threshold (p-value = 0.712).

IA.2. Preexisting differences

The second testable implication of the randomness assumption is that firms operating plants in counties whose DVs are immediately below or above the NAAQS threshold should be very similar on the basis of ex ante characteristics. In other words, if a county's designation status is as good as randomized, it should be orthogonal to firm characteristics prior to the designation.

In Internet Appendix Table IA.4, we examine whether there are any preexisting differences observable firm characteristics between firms that operate polluting plants in counties that are in violation of the NAAQS thresholds and those operating in counties that are in compliance. In addition to the main control variables on firm characteristics, we also include the following variables on financial constraints (*KZ*), defined as the Kaplan-Zingales index; cash ratio (*Cash*), calculated as cash divided by total assets; 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*);[32] 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*).[33] The data used to construct *Source reduction* and *Production ratio* are obtained from the EPA's Pollution Prevention (P2) database

In column (1) of Internet Appendix Table IA.4, we examine these characteristics in the year preceding the designation ($t-1$). In column (2), we examine the change in these characteristics between years $t-2$ and $t-1$. Both columns report the differences using a narrow window around the NAAQS threshold by computing the mean squared error optimal bandwidth following Calonico et al. (2014). As can be seen in both columns, there are no systematic or statistically significant differences in firm characteristics in the optimal neighborhood around the threshold, which lends support to our identification strategy.

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

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

[33] This variable measures the change in output associated with the release of a chemical in a given year. 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 $\frac{\#\text{Molds cleaned}_t}{\#\text{Molds cleaned}_{t-1}}$.

Appendix IB. Additional robustness tests

IB.1. Alternative pre- and post-nonattainment periods

To ensure our results are not driven by a particular window around nonattainment designations, we perform tests with alternative windows around the nonattainment designation quarter. We work with the following windows around the nonattainment designation quarter: $[-1, +1]$, $[-1, +2]$, $[-1, +3]$, $[-2, +1]$, $[-2, +3]$, and $[-3, +3]$. The coefficients on *NA exposure* $\times$ *Post NA* and *Unexp. NA exposure* $\times$ *Post NA* remain negative and statistically significant (unreported).

IB.2. Alternative measures of portfolio response

We use a variety of different dependent variables to measure portfolio response. First, we consider scenarios where the fund completely divests its holdings of a given stock in response to nonattainment designations. Specifically, we define the dummy variable *Exit* to be equal to one if a given fund's portfolio holds a given stock in the pre-nonattainment designation quarters, but divests it in the post-nonattainment designation quarters, and zero otherwise. In Internet Appendix Table IA.5, we regress *Exit* on *NA exposure* in column (1) and on *Unexp. NA exposure* and *Antic. NA exposure* in column (2). We find that funds are more likely to completely divest their holdings of stocks with high exposure to nonattainment designations, with the result completely driven by exposure to the unexpected component.

We also use two other alternative dependent variables in estimating Equation (5): *Shares proportion*, defined as the ratio of total number of shares of a given stock in a given mutual fund's portfolio to the total number of shares outstanding (in percentage points); and *PassiveChanges*, defined as the same as in Equation (1) except the first fraction uses $P_{s,t}$ instead of $P_{s,t-1}$. Columns (3) and (4) of Internet Appendix Table IA.5 present the results using *Shares proportion* as the dependent variable. We find that funds tend to sell more shares of stocks with high exposure to unexpected nonattainment designations. Columns (5) and (6) use *PassiveChanges* and obtain qualitatively similar results.

IB.3. Alternative measures of firm exposure to nonattainment designations

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. Given our focus on air emissions, we follow Gamper-Rabindran (2006) and use the inhalation toxicity weight. *Unexp. TW NA exposure* and *Antic. TW NA exposure* are defined in a similar fashion to Equations (7) and (8), respectively, except we use toxicity-weighted ozone emissions. We replicate the analyses involving active changes in response to nonattainment designations in column (1) of Internet Appendix Table IA.6 using *Unexp. TW NA exposure* and *Antic. TW NA exposure*, and find robust results.

To mitigate the concern of reporting errors in the TRI data, we consider only core ozone chemicals. Core chemical groups exclude any chemicals that were added to or removed from the TRI list during our sample period. The idea is that using core chemical groups ensures that there were consistent reporting requirements for chemicals in the analysis across all reporting years. In addition, routine inspections and audits should work more effectively in ensuring accurate reporting for the core chemical groups. *Unexp. Core NA exposure* and *Antic. Core NA exposure* measure a firm's exposure to unexpected and anticipated nonattainment designations using core chemical ozone emissions, respectively. Column (2) of Internet Appendix Table IA.6 shows that our results hold in this robustness check.

One potential concern in our main analysis is that *NA exposure* may not reflect the relative importance of a firm's different polluting plants. For example, it may be more costly if polluting plants that generate the majority of sales for a given firm are located in nonattainment counties. As robustness checks, we use plant-level sales and employee data from NETS to construct the variables *Unexp. Sales NA exposure*, *Antic. Sales NA exposure*, *Unexp. Emp NA exposure*, and *Antic. Emp NA exposure*. The former (latter) two variables measure a firm's exposure to unexpected and anticipated nonattainment designations where each plant's ozone emissions are sales-weighted (employee-weighted), respectively. Columns (3) and (4) of Internet Appendix Table IA.6 show that our main results remain intact when using these variables to measure nonattainment designation exposure.

IB.4. Placebo tests

Since nonattainment designations regulate a facility's onsite ozone emissions, funds should not actively rebalance holdings based on a polluting firm's offsite ozone emissions. To test this, we construct the variables *Unexp. Offsite NA exposure* and *Antic. Offsite NA exposure*, which measure a firm's exposure to unexpected and anticipated nonattainment designations using offsite ozone emissions, respectively. The coefficients on the interaction terms involving these two variables are both statistically insignificant in column (1) of Internet Appendix Table IA.7, which lends support to the placebo test.

Similarly, since other pollutants such as particulate matter are not regulated under ozone NAAQS, firms that are polluters of particulate matter in ozone nonattainment counties should not be affected by nonattainment designations. Consequently, funds should not actively rebalance holdings based on a firm's particulate matter emissions. We define the variables *Unexp. PM NA exposure* and *Antic. PM NA exposure* to be a firm's exposure to unexpected and anticipated nonattainment designations using onsite particular matter emissions, respectively. Column (2) of Internet Appendix Table IA.7 shows that fund holdings do not respond to heavy polluters of particulate matter in ozone nonattainment counties.

IB.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 the latest pollution abatement technology may expect an implementation of mandatory pollution requirement that increases the cost of its local competitors, and hence, choose to continue operations in nonattainment counties. If this is the case, then firms' exposure to nonattainment designations may be self-selected. 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 noncompliance 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 noncompliance based on prior year DVs positively predicts subsequent 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 $HC_{s,t}$ using county-event year level IMR as follows:

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

for firm s, county c, and year t. The variable $\#Plant_{s,c,t}$ is the number of polluting plants that firm s operates in county c in year t. Then, we include the variable $HC_{s,t}$ in our estimation of Equation (5). The results are presented in columns (2) and (3) of Internet Appendix Table IA.8. The findings are qualitatively unchanged from Tables 3 and 4. 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.

IB.6. Distance between funds' headquarters and nonattainment plants

Alok et al. (2020) argue that a key identifying assumption of the salience hypothesis is that portfolio responses are stronger for funds located close to firms' operating plants. To test whether our results depend on geographic distance, we calculate the distance (in miles) between the fund's headquarters and the nearest nonattainment plant of a given firm based on ZIP codes. Following Alok et al. (2020), we define *Close fund* to be a dummy variable equal to one if the distance between the fund's headquarters and the closest nonattainment plant of a given firm is less than 100 miles, and zero otherwise. For robustness, we also use alternative cutoff distances of 150, 200, and 250 miles. Then, we augment our regressions by including the triple interaction terms *Unexp. NA exposure* × *Post NA* × *Close fund* and *Antic. NA exposure* × *Post NA* × *Close fund*. The results are presented in Internet Appendix

Table IA.9. None of the coefficients on the triple interaction terms are significant, while those on the double interaction term *Unexp. NA exposure* × *Post NA* remain negative and statistically significant. These results imply that our main findings are not driven by funds located close to nonattainment plants, providing evidence against the salience hypothesis.

IB.7. Funds' sustainability

Studies have shown that funds that are more environmentally conscious ("sustainable funds") may attempt to engage with portfolio firms on environmental issues such as pollution (Azar et al., 2021; Choi et al., 2021; Gibson et al., 2021). Thus, it could be possible that our results are driven by more sustainable funds divesting from ozone-polluting firms to exert pressure on firms' management to reduce their emissions. We argue, however, that such a scenario is unlikely to impact on our results since emission reductions due to nonattainment regulations are binding for polluting firms, which diminish funds' incentives to engage. Nonetheless, we conduct a robustness check, whereby we estimate Equation (5), but condition on a fund's pre-nonattainment historical sustainability footprint. The idea is that funds that historically hold greener portfolios may be more likely to divest from ozone-polluting firms.

We use two measures of funds' sustainability footprint. First, following Gibson et al. (2021), we define *vw-Env score* as a fund's portfolio holding value-weighted *Environment score* (difference between the average strength and concern environment scores from MSCI KLD for a given firm) in the quarter prior to the nonattainment designation. A higher value of *vw-Env score* implies that the fund's portfolio is more environmentally sustainable. We present the results in Internet Appendix Table IA.10. In the first column, the coefficient on *Unexp. NA exposure* × *Post NA* remains negative and statistically significant, while that on the triple interaction term *Unexp. NA exposure* × *Post NA* × *vw-Env score* is statistically insignificant, implying that there are no differences in the degree of underweighting of heavy ozone-polluting firms exposed to nonattainment designations between more sustainable funds and less sustainable funds.

Since firms have incentives to window dress and engage in greenwashing, we also use a news-based measure of ESG incidents from RepRisk that allows for an objective assessment of a firm's reputational risk exposure (Houston & Shan, 2022; Li & Wu, 2020). Specifically, we measure a firm's reputational risk exposure by using RepRisk's Reputational Risk Index (RRI). The RRI is a score that ranges from 0 to 100, where a higher value denotes a higher ESG incident rate. The RRI of a firm increases whenever it experiences a new ESG incident. We use RepRisk's "Peak RRI" score, which is the two-year maximum value of the RRI capturing the long-term ESG incident history of a firm. In the second column of Internet Appendix Table IA.10, we use the variable *vw-RRI*, which is a fund's portfolio holding value-weighted peak RRI score in the quarter prior to the nonattainment designation. Again, the results remain qualitatively unchanged.

IB.8. Demand for ESG fund flows

We examine the possibility that the underweighting of stocks exposed to nonattainment designations is driven by funds competing for ESG investment flows (Ceccarelli et al., 2023; Hartzmark & Sussman, 2019; Riedl & Smeets, 2017). Specifically, nonattainment designations may induce fund managers to shift their holdings toward firms with less exposure in order to attract ESG-conscious investors. Since ESG investment flows is based on investors' perceptions of a fund portfolio's overall "greenness", we check whether funds that reduce their portfolio exposure to nonattainment designations experience greater investment flows in the subsequent quarters.

Our specification is the same difference-in-differences regression described in Section 6.4, except the dependent variable is a fund's net flow in quarter t. If funds compete for ESG investment flows, then we expect the coefficient on *Low vw-NA exposure* × *Post NA* to be positive and statistically significant. However, as shown in column (1) of Internet Appendix Table IA.11, the coefficient on *Low vw-NA exposure* × *Post NA* is statistically insignificant, indicating that demand for ESG investment flows does not appear to be driving our results. Similarly, in columns (2) and (3), we replace *Low vw-NA exposure* with *Low Unexp. vw-NA exposure* and *Low Antic. vw-NA exposure*, respectively. Again, neither interaction terms have a statistically significant impact on fund flows.

IB.9. Reallocation of production

Lastly, we test for the possibility that in response to nonattainment designations, multi-plant firms may reallocate production (and hence, 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 test this, we restrict the sample to only plants in attainment counties that emit ozone prior to the nonattainment designation. Then, we construct the dummy variable *Other NA* to be equal to one if a given plant belongs to a firm that operates one or more plants located in nonattainment counties that emits ozone in the year prior to the nonattainment designation, and zero otherwise. We estimate the following difference-in-differences specification at the plant-year level:

$$\begin{aligned} &\textit{ln(Ozone)}_{j,t} = \beta_0 + \beta_1 \textit{Other NA}_{j,t} + \beta_2 \textit{Post NA}_t + \beta_3 \textit{Other NA}_{j,t} \\ &\times \textit{Post NA}_t + \text{F.E.} + \varepsilon_{j,t} \end{aligned} \tag{IB.2}$$

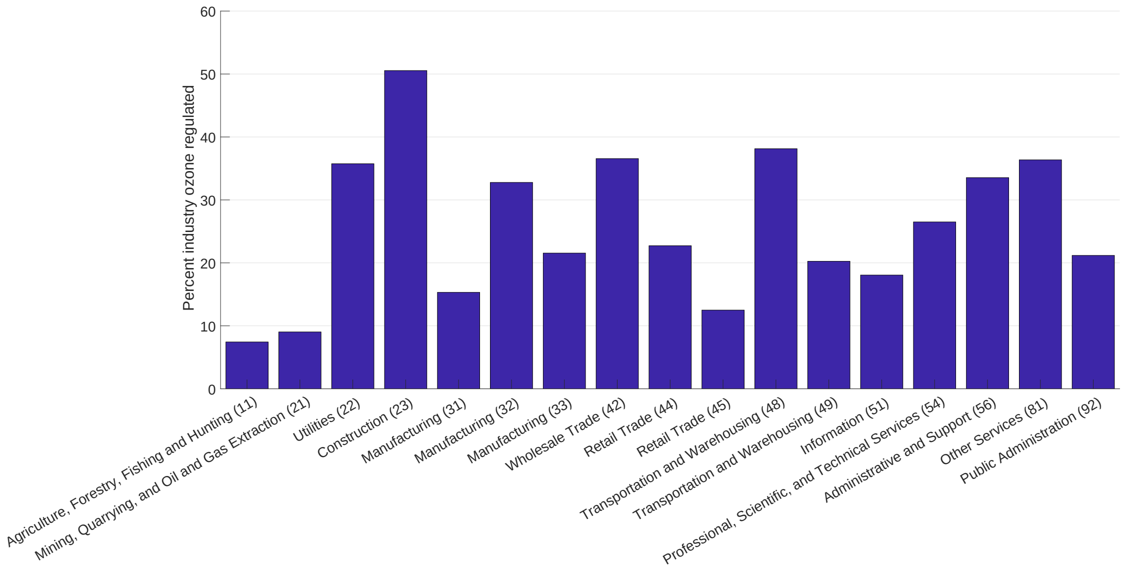
for plant j and year t. We focus on two years before to two years after the nonattainment designation. The dependent variable is the natural logarithm of one plus the total amount of ozone air emissions for a given plant. If multi-plant firms reallocate emissions to ozone plants in attainment counties in response to nonattainment designations, then we would expect a positive and statistically significant β_3.

Column (1) of Internet Appendix Table IA.12 shows that there is virtually no intrafirm reallocation of ozone emissions from nonattainment counties to attainment counties for multi-plant firms. In column (2), we replace *Other NA* with *Other Unexp. NA* and *Other Antic. NA*, which are dummy variables equal to one if a given plant belongs to a firm that operates one or more plants located in unexpected and anticipated nonattainment counties, respectively, that emits ozone in the year prior to the nonattainment designation, and zero otherwise. Again, we find no evidence of intrafirm reallocation of ozone emissions. In the remaining columns, we use alternative dependent variables such as a given plant's ozone production ratio, number of employees, and the dollar amount of sales. The results remain qualitatively unchanged.

Our results are consistent with the results of Cui and Ji (2016), who also do not find any significant evidence of intrafirm ozone emissions leakage for multi-plant firms operating in nonattainment and attainment counties. A plausible reason why there are no intrafirm reallocation of emissions could be due to the fact that the majority of nonattainment designations are unexpected.[34] Given that firms need time to make the necessary investments to shift production, it may be difficult for firms to strategically time their investments to expand into attainment counties. Additionally, the benefits from the less stringent regulations in attainment counties may be offset by the costs of sacrificing local supply chains and local customers in nonattainment counties, which may make reallocation less appealing.

[34]Recall from Section 4.2.2 that there are 935 unexpected nonattainment designations compared to 351 anticipated nonattainment designations.

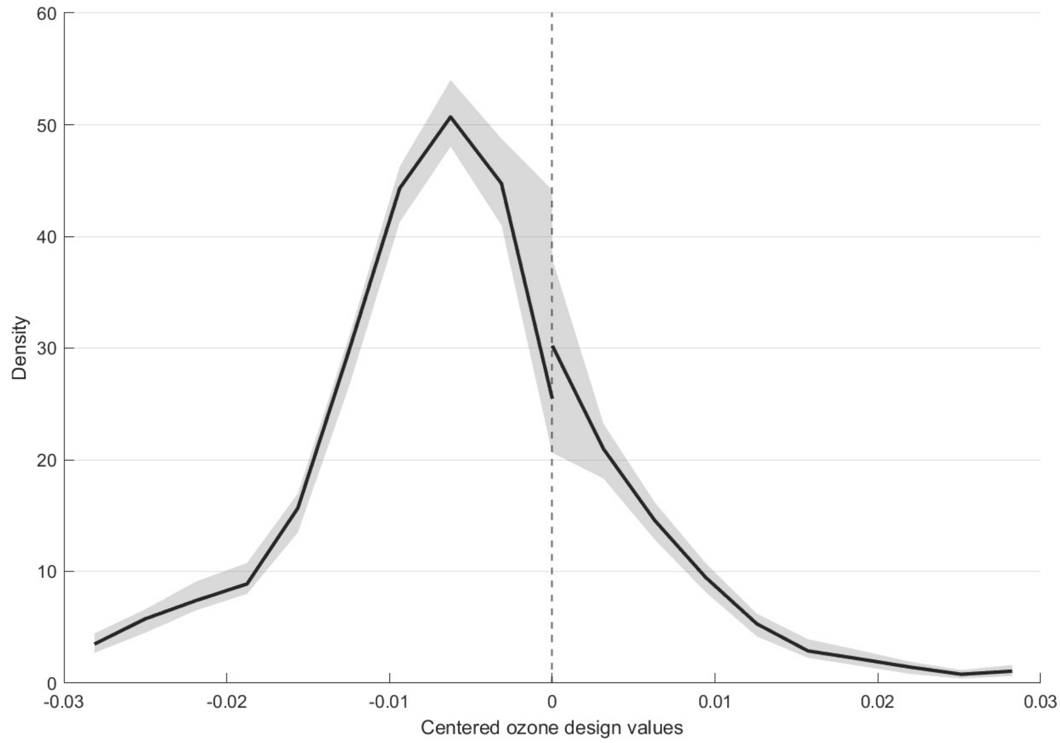
Figure IA.1
Fraction of ozone plants by industry in nonattainment counties.



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

Density break test around NAAQS thresholds.



This figure presents the density of observations by the distance to the ozone NAAQS threshold. The horizontal axis shows the centered DVs around zero by subtracting the NAAQS threshold from the DVs. The dashed vertical line at zero represents the NAAQS threshold for ozone nonattainment status. Observations on the right (left) of the line indicate that the county is in violation of (compliance with) the NAAQS threshold. The solid black lines represent the local density on either side of the NAAQS threshold and the shaded gray area corresponds to the 95% confidence interval bounds, calculated using the plug-in estimator proposed by Cattaneo et al. (2020). We fail to reject the null hypothesis that there is no break in density around the threshold, with a *p*-value of 0.712.

Table IA.1
Ozone NAAQS.

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

This table provides basic descriptions of the ozone NAAQS used in our study. Standard refers to the name of the ozone NAAQS. Effective date is the date on which the standard is effectively implemented as stated in the Federal Register. Averaging time is the sampling frequency of the ozone concentration used to calculate DVs. Threshold refers to the DV value which if exceeded, then the county is considered to be in nonattainment. This value is measured in parts per million (ppm). Form is the rule used to compute the DVs for the relevant ozone standard. The 1-Hour Ozone (1979) standard was proposed in 1979 and implemented effective January 6, 1992. The 8-Hour Ozone (1997) was proposed in 1997 and implemented effective June 15, 2004. The 8-Hour Ozone (2008) was proposed in 2008 and implemented effective July 20, 2012. The 8-Hour Ozone (2015) was proposed in 2015 and implemented effective August 3, 2018. 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
Noncompliant design values and probability of nonattainment.

	Full sample	1-Hour Ozone (1979)	8-Hour Ozone (1997)	8-Hour Ozone (2008)	8-Hour Ozone (2015)
Dep. variable: $NA_{c,t+1}$	(1)	(2)	(3)	(4)	(5)
$Noncompliance_{c,t}$	0.651***	0.597***	0.604***	0.781***	0.718***
	(17.14)	(4.03)	(8.86)	(9.03)	(8.02)
Kernel	Rec.	Rec.	Rec.	Rec.	Rec.
Bandwidth type	Opt.	Opt.	Opt.	Opt.	Opt.
Bandwidth estimate	0.009	0.009	0.008	0.005	0.005
Covariates	Yes	Yes	Yes	Yes	Yes
Observations	1,493	133	378	243	326

This table presents the probability of nonattainment designation when a given county's DV is in violation of the NAAQS threshold. We estimate the local linear regression specification given in Equation (6) using the mean squared error optimal bandwidth with rectangular kernels following Calonico et al. (2014). Column (1) uses the full sample of nonattainment designations based on revisions in the NAAQS threshold for all four ozone standards. Columns (2) to (5) use the subsample of nonattainment designations based on revisions in the NAAQS threshold for the 1-Hour Ozone (1979), 8-Hour Ozone (1997), 8-Hour Ozone (2008), and 8-Hour Ozone (2015) standards, respectively. $NA_{c,t+1}$ is a dummy variable equal to one if county c is designated nonattainment in year $t+1$, and zero otherwise. $Noncompliance_{c,t}$ is a dummy variable equal to one if county c's DV is in violation of the NAAQS threshold in year t, and zero otherwise. County-level covariates include the natural logarithm of one plus the employment levels in a given county, a given county's NO_x emissions to employment ratio, the change in a given county's employment levels, and a dummy variable equal to one if the county is located in a MSA. For all specifications, standard errors are clustered by county and bias-corrected following Calonico et al. (2014); t-statistics are reported in the parenthesis. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Variable definitions are presented in Table A.1 in Appendix A.

Table IA.4
Preexisting differences in firm characteristics.

	Year $(t-1)$	Δ from year $(t-2)$ to $(t-1)$
	(1)	(2)
ln(Size)	0.156	-0.034
	(0.176)	(0.047)
ln(BM)	-0.012	0.000
	(0.011)	(0.009)
ROA	-0.001	-0.001
	(0.001)	(0.001)
Leverage	-0.017	0.007
	(0.012)	(0.010)
Sales growth	-0.059	0.017
	(0.083)	(0.018)
KZ	-0.090	0.254
	(0.219)	(0.313)
Cash	0.010	0.000
	(0.008)	(0.003)
Momentum	0.005	0.011
	(0.059)	(0.078)
Stock returns	0.011	-0.051
	(0.053)	(0.086)
Core chemical	-0.032	0.001
	(0.034)	(0.012)
Permit	0.002	-0.001
	(0.059)	(0.002)
Source reduction	0.007	-0.010
	(0.018)	(0.020)
Production ratio	-0.018	0.036
	(0.037)	(0.054)
Sample:	Opt.	Opt.

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

Table IA.5

Alternative measures of portfolio response to nonattainment designations.

Dep. variable:	*Exit*		*Shares proportion*		*PassiveChanges*	
	(1)	(2)	(3)	(4)	(5)	(6)
NA exposure$_t$	0.001***		0.004**		-0.006*	
	(2.58)		(2.29)		(-1.86)	
Unexp. NA exposure$_t$		0.001**		0.004***		-0.004
		(2.21)		(2.57)		(-1.15)
Antic. NA exposure$_t$		-0.000		0.002		-0.009***
		(-0.86)		(1.57)		(-2.62)
Post NA$_t$			0.002	0.002	-0.006	-0.024***
			(1.59)	(1.62)	(-1.06)	(-3.66)
NA exposure$_t$ × *Post NA$_t$*			-0.0005**		-0.003***	
			(-2.44)		(-2.94)	
Unexp. NA exposure$_t$ × *Post NA$_t$*				-0.0005***		-0.004***
				(-2.66)		(-2.96)
Antic. NA exposure$_t$ × *Post NA$_t$*				-0.0001		-0.000
				(-0.77)		(-0.29)
Stock controls	Yes	Yes	Yes	Yes	Yes	Yes
Fund × Stock F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Fund × Year-Quarter F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	142,900	142,900	234,029	234,029	183,602	183,602
Adj R^2	0.02	0.02	0.94	0.93	0.04	0.06

This table examines portfolio responses to nonattainment designations using alternative dependent variables. We focus on two quarters before to two quarters after the nonattainment designation. The dependent variable in columns (1) and (2) is a dummy variable equal to one if a given fund's portfolio completely divests a given stock in the post-nonattainment period, and zero otherwise. The dependent variable in columns (3) and (4) is the ratio of total number of shares of a given stock in a given mutual fund's portfolio to the total number of shares outstanding (in percentage points). The dependent variable in columns (5) and (6) measures the passive changes of a given stock in a given quarter for a given fund's portfolio. *NA exposure$_t$* measures a firm's exposure to nonattainment designations as defined in Equation (2). *Unexp. NA exposure$_t$* and *Antic. NA exposure$_t$* measure a firm's exposure to unexpected and anticipated nonattainment designations as defined in Equations (7) and (8), respectively. *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, and zero otherwise. For all specifications, standard errors are robust to heteroskedasticity and clustered at the fund-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

Alternative measures of firm exposure to nonattainment designations.

Dep. variable: *ActiveChanges*	(1)	(2)	(3)	(4)
Unexp. TW NA exposure$_t$ × *Post NA*$_t$	-0.001***			
	(-2.74)			
Antic. TW NA exposure$_t$ × *Post NA*$_t$	0.000			
	(0.95)			
Unexp. Core NA exposure$_t$ × *Post NA*$_t$		-0.006***		
		(-10.53)		
Antic. Core NA exposure$_t$ × *Post NA*$_t$		0.001		
		(1.48)		
Unexp. Sales NA exposure$_t$ × *Post NA*$_t$			-0.009***	
			(-11.88)	
Antic. Sales NA exposure$_t$ × *Post NA*$_t$			0.002	
			(1.43)	
Unexp. Emp NA exposure$_t$ × *Post NA*$_t$				-0.009***
				(-11.93)
Antic. Emp NA exposure$_t$ × *Post NA*$_t$				0.002
				(1.39)
Stock controls	Yes	Yes	Yes	Yes
Fund × Stock F.E.	Yes	Yes	Yes	Yes
Fund × Year-Quarter F.E.	Yes	Yes	Yes	Yes
Observations	183,602	183,602	178,690	178,690
Adj R^2	0.22	0.22	0.22	0.22

This table examines portfolio responses to nonattainment designations using alternative measures of firm exposure to nonattainment designations. We focus on two quarters before to two quarters after the nonattainment designation. The dependent variable, $ActiveChanges_{m,s,t}$, measures fund m's active trading in stock s in quarter t as defined in Equation (1). *Unexp. TW NA exposure*$_t$ and *Antic. TW NA exposure*$_t$ measure a firm's exposure to unexpected and anticipated nonattainment designations using toxicity-weighted ozone emissions, respectively. *Unexp. Core NA exposure*$_t$ and *Antic. Core NA exposure*$_t$ measure a firm's exposure to unexpected and anticipated nonattainment designations using core chemical ozone emissions, respectively. *Unexp. Sales NA exposure*$_t$ and *Antic. Sales NA exposure*$_t$ measure a firm's exposure to unexpected and anticipated nonattainment designations where each plant's ozone emissions are sales-weighted, respectively. *Unexp. Emp NA exposure*$_t$ and *Antic. Emp NA exposure*$_t$ measure a firm's exposure to unexpected and anticipated nonattainment designations where each plant's ozone emissions are employee-weighted, respectively. *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, and zero otherwise. For all specifications, standard errors are robust to heteroskedasticity and clustered at the fund-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

Placebo tests of portfolio response to nonattainment designations.

Dep. variable: *ActiveChanges*	(1)	(2)
Unexp. Offsite NA exposure$_t$ × *Post NA*$_t$	0.000	
	(0.49)	
Antic. Offsite NA exposure$_t$ × *Post NA*$_t$	-0.000	
	(-0.01)	
Unexp. PM NA exposure$_t$ × *Post NA*$_t$		-0.001
		(-1.21)
Antic. PM NA exposure$_t$ × *Post NA*$_t$		0.002
		(1.44)
Stock controls	Yes	Yes
Fund × Stock F.E.	Yes	Yes
Fund × Year-Quarter F.E.	Yes	Yes
Observations	200,801	200,801
Adj R^2	0.21	0.22

This table reports the results of placebo tests on the portfolio response to nonattainment designations. We focus on two quarters before to two quarters after the nonattainment designation. The dependent variable, $ActiveChanges_{m,s,t}$, measures fund m's active trading in stock s in quarter t as defined in Equation (1). *Unexp. Offsite NA exposure*$_t$ and *Antic. Offsite NA exposure*$_t$ measure a firm's exposure to unexpected and anticipated nonattainment designations using offsite ozone emissions, respectively. *Unexp. PM NA exposure*$_t$ and *Antic. PM NA exposure*$_t$ measure a firm's exposure to unexpected and anticipated nonattainment designations using onsite particular matter emissions, respectively. *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, and zero otherwise. For all specifications, standard errors are robust to heteroskedasticity and clustered at the fund-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

Active changes in portfolio holdings in response to nonattainment designations using Heckman correction.

	First stage		Second stage	
Dep. variable: NA_t	(1)	Dep. variable: *ActiveChanges*	(2)	(3)
$\mathit{Noncompliance}_{t-1}$	0.753***	$\mathit{NA\ exposure}_t$	-0.003**	
	(10.81)		(-2.48)	
$\mathit{ln(County\ emp)}_{t-1}$	0.823***	$\mathit{Unexp.\ NA\ exposure}_t$		-0.002
	(3.40)			(-1.61)
$\mathit{Nox\text{-}county\ emp\ ratio}_{t-1}$	0.153**	$\mathit{Antic.\ NA\ exposure}_t$		0.003*
	(2.02)			(1.85)
$\Delta \mathit{County\ emp}_{t-1}$	0.002	$\mathit{Post\ NA}_t$	0.003	-0.003
	(0.26)		(0.67)	(-0.77)
MSA	3.397***	$\mathit{NA\ exposure}_t \times \mathit{Post\ NA}_t$	-0.003***	
	(21.30)		(-4.77)	
		$\mathit{Unexp.\ NA\ exposure}_t \times \mathit{Post\ NA}_t$		-0.006***
Year F.E.	Yes			(-10.83)
County F.E.	Yes	$\mathit{Antic.\ NA\ exposure}_t \times \mathit{Post\ NA}_t$		0.000
Observations	16,707			(1.30)
Adj R^2	0.27	*HC*	0.044	0.019
			(1.23)	(0.57)
		Stock controls	Yes	Yes
		Fund × Stock F.E.	Yes	Yes
		Fund × Year-Quarter F.E.	Yes	Yes
		Observations	182,440	182,440
		Adj R^2	0.22	0.22

This table reports the two-stage Heckman correction results when estimating the portfolio response to nonattainment designations. 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, and zero otherwise. The explanatory variables are $\mathit{Noncompliance}_{t-1}$, which is a dummy variable equal to one if a given county's DV is in violation of the NAAQS threshold in year $t-1$, and zero otherwise; $\mathit{ln(County\ emp)}_{t-1}$, defined as the natural logarithm of one plus the employment levels in a given county; $\mathit{NOx\text{-}county\ emp\ ratio}_{t-1}$, defined as a given county's NO_x emissions to employment ratio; $\Delta \mathit{County\ emp}_{t-1}$, 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 (3) present the second-stage results where a Heckman correction variable, *HC*, is included in all regressions. We focus on two quarters before to two quarters after the nonattainment designation. The dependent variable, $\mathit{ActiveChanges}_{m,s,t}$, measures fund m's active trading in stock s in quarter t as defined in Equation (1). $\mathit{NA\ exposure}_t$ measures a firm's exposure to nonattainment designations as defined in Equation (2). $\mathit{Unexp.\ NA\ exposure}_t$ and $\mathit{Antic.\ NA\ exposure}_t$ measure a firm's exposure to unexpected and anticipated nonattainment designations as defined in Equations (7) and (8), respectively. *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, and zero otherwise. For all specifications, standard errors are robust to heteroskedasticity and clustered at the fund-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

Active changes in portfolio holdings in response to nonattainment designations conditional on the distance between funds' headquarters and nonattainment plants.

	Distance (miles)			
	100	150	200	250
Dep. variable: *ActiveChanges*	(1)	(2)	(3)	(4)
Unexp. NA exposure$_t$ × *Post NA*$_t$	-0.006***	-0.006***	-0.006***	-0.006***
	(-10.74)	(-10.64)	(-10.57)	(-10.63)
Antic. NA exposure$_t$ × *Post NA*$_t$	0.001	0.001	0.001	0.001
	(1.47)	(1.45)	(1.59)	(1.54)
Unexp. NA exposure$_t$ × *Post NA*$_t$ × *Close fund*	-0.002	-0.001	-0.001	0.002
	(-0.72)	(-0.24)	(-0.43)	(0.81)
Antic. NA exposure$_t$ × *Post NA*$_t$ × *Close fund*	-0.004	-0.001	-0.001	-0.001
	(-1.24)	(-0.37)	(-0.27)	(-0.31)
Stock controls	Yes	Yes	Yes	Yes
Fund × Stock F.E.	Yes	Yes	Yes	Yes
Fund × Year-Quarter F.E.	Yes	Yes	Yes	Yes
Observations	183,602	183,602	183,602	183,602
Adj R^2	0.22	0.22	0.22	0.22

This table examines portfolio response to nonattainment designations conditional on the distance between funds' headquarters and nonattainment plants. We focus on two quarters before to two quarters after the nonattainment designation. The dependent variable, $ActiveChanges_{m,s,t}$, measures fund m's active trading in stock s in quarter t as defined in Equation (1). *Close fund* is a dummy variable equal to one if the distance between the fund's headquarters and the closest nonattainment plant of a given firm is less than i) 100 miles in column (1); ii) 150 miles in column (2); iii) 200 miles in column (3); and iv) 250 miles in column (4), and zero otherwise. *Unexp. NA exposure*$_t$ and *Antic. NA exposure*$_t$ measure a firm's exposure to unexpected and anticipated nonattainment designations as defined in Equations (7) and (8), respectively. *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, and zero otherwise. For all specifications, standard errors are robust to heteroskedasticity and clustered at the fund-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.10

Active changes in portfolio holdings in response to nonattainment designations conditional on funds' portfolio sustainability footprint.

Dep. variable: *ActiveChanges*	(1)	(2)
Unexp. NA exposure$_t$ × *Post NA*$_t$	-0.007***	-0.005***
	(-4.51)	(-3.07)
Antic. NA exposure$_t$ × *Post NA*$_t$	0.000	-0.001
	(0.27)	(-0.37)
Unexp. NA exposure$_t$ × *Post NA*$_t$ × *vw-Env score*$_{t-1}$	-0.001	
	(-0.09)	
Antic. NA exposure$_t$ × *Post NA*$_t$ × *vw-Env score*$_{t-1}$	0.003	
	(0.54)	
Unexp. NA exposure$_t$ × *Post NA*$_t$ × *vw-RRI*$_{t-1}$		-0.000
		(-0.51)
Antic. NA exposure$_t$ × *Post NA*$_t$ × *vw-RRI*$_{t-1}$		0.000
		(1.15)
Stock controls	Yes	Yes
Fund × Stock F.E.	Yes	Yes
Fund × Year-Quarter F.E.	Yes	Yes
Observations	166,737	133,328
Adj R^2	0.21	0.22

This table examines portfolio response to nonattainment designations conditional on funds' portfolio sustainability footprint. We focus on two quarters before to two quarters after the nonattainment designation. The dependent variable, $ActiveChanges_{m,s,t}$, measures fund m's active trading in stock s in quarter t as defined in Equation (1). *vw-Env score* is a given mutual fund's portfolio holding value-weighted difference between the average strength and concern environment scores for a given firm. *vw-RRI*, which is a fund's portfolio holding value-weighted peak RRI score. *Unexp. NA exposure*$_t$ and *Antic. NA exposure*$_t$ measure a firm's exposure to unexpected and anticipated nonattainment designations as defined in Equations (7) and (8), respectively. *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, and zero otherwise. For all specifications, standard errors are robust to heteroskedasticity and clustered at the fund-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

Impact of portfolio exposure to nonattainment designations on fund flows.

Dep. variable: *Net flow*	(1)	(2)	(3)
Low vw-NA exposure$_t$	0.005		
	(0.60)		
Low Unexp. vw-NA exposure$_t$		0.013*	
		(1.73)	
Low Antic. vw-NA exposure$_t$			0.002
			(0.35)
Post NA$_t$	0.001	0.001	-0.000
	(0.19)	(0.21)	(-0.04)
Low vw-NA exposure$_t$ × *Post NA*$_t$	-0.009		
	(-1.26)		
Low Unexp. vw-NA exposure$_t$ × *Post NA*$_t$		-0.009	
		(-1.37)	
Low Antic. vw-NA exposure$_t$ × *Post NA*$_t$			-0.005
			(-0.73)
Value-weighted stock controls	Yes	Yes	Yes
Fund controls	Yes	Yes	Yes
Fund F.E.	Yes	Yes	Yes
Year-Quarter F.E.	Yes	Yes	Yes
Observations	32,482	32,482	32,482
Adj R^2	0.07	0.07	0.07

This table examines the impact of funds' exposure to nonattainment designations on their fund flows. We focus on two years before to two years after the nonattainment designation. The dependent variable is mutual fund flows in quarter t. For each nonattainment designation, we sort funds into terciles based on the change in the average portfolio value-weighted *NA exposure* during the two quarters after the nonattainment designation relative to the two quarters before. *Low vw-NA exposure* is a dummy variable equal to one if a fund is in the lowest tercile, and zero otherwise. *Low Unexp. vw-NA exposure* and *Low Antic. vw-NA exposure* are defined similarly, except they are based on the change in the average portfolio value-weighted *Unexp. NA exposure* and *Antic. NA exposure*, respectively. *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, and zero otherwise. For all specifications, standard errors are robust to heteroskedasticity and clustered at the fund-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.12

Impact of nonattainment designations on the reallocation of production.

Dep. variable:	*ln(Ozone)*		*Production ratio*		*ln(Employee)*		*ln(Sales)*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Other NA_t	0.020		0.007		0.033		0.051	
	(0.09)		(0.21)		(0.35)		(0.49)	
Other Unexp. NA_t		-0.124		-0.006		0.025		0.065
		(-0.57)		(-0.20)		(0.28)		(0.62)
Other Antic. NA_t		0.767***		0.036		0.095		0.052
		(3.83)		(1.24)		(1.00)		(0.51)
Other NA_t × *Post* NA_t	-0.014		0.019		0.017		0.005	
	(-0.14)		(1.11)		(0.71)		(0.17)	
Other Unexp. NA_t × *Post* NA_t		0.029		0.020		0.035		0.026
		(0.34)		(1.28)		(1.42)		(0.90)
Other Antic. NA_t × *Post* NA_t		-0.134		-0.009		-0.033		-0.031
		(-1.42)		(-0.48)		(-1.27)		(-1.00)
Plant F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County × Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17,784	17,784	14,312	14,312	12,391	12,391	12,391	12,391
Adj R^2	0.85	0.85	0.13	0.13	0.93	0.93	0.93	0.93

This table reports the regression estimates from Equation (IB.2) at the plant-year level. We focus on two years before to two years after the nonattainment designation. The dependent variable in columns (1) and (2) is the natural logarithm of one plus the total amount of ozone air emissions for a given plant. The dependent variable in columns (3) and (4) is a given plant's ozone production ratio. The dependent variable in columns (5) and (6) ((7) and (8)) is the natural logarithm of one plus the number of employees (dollar amount of sales) for a given plant. *Other NA* 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 that emits ozone in the year prior to the nonattainment designation, and zero otherwise. *Other Unexp. NA* (*Other Antic. NA*) is a dummy variable equal to one if a given plant belongs to a firm that operates one or more plants located in unexpected (anticipated) nonattainment counties that emits ozone in the year prior to the nonattainment designation, and zero otherwise. *Post NA* is a dummy variable equal to one for the post-nonattainment regulatory period, 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.