The Sunshine Effect: Why Facility-Level GHG Transparency Regulation Has Spillover Effects on Firm-Level Emission Reductions*

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Abstract

This study draws the causal inference of facility-level GHG transparency on firm-wide emissions by analyzing firms that voluntarily disclosed their emissions before and after the regulation. Using a difference-in-differences design and leveraging the staggered implementation of the initial facility-level disclosure mandate, I find that firms reduce their overall emissions in response to increased granular transparency. The standardized regulation functions as a "sunshine mechanism," exposing true corporate climate impact and previous underreporting, which prompts stakeholder engagement and negative feedback, thereby incentivizing firms to adopt more socially responsible practices. Consistent with the growing influence of climate change on corporate decision-making, I find that facility-level regulation significantly increases firm-level climate change concerns and negative regulatory sentiment during earnings conference calls. This heightened awareness translates into greater development of low-carbon patents. Overall, my findings suggest that facility-level GHG transparency regulation has spillover effects on firm-wide decision-making, driving broader organizational changes beyond the regulated facilities.

Keywords: Transparency Regulation, Disclosure level, Greenhouse Gas Emissions, Sunshine Effects, Feedback Effect, Stakeholder Engagement

JEL Codes: D72, M40, Q54, Q56

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"*Sunshine is the best disinfectant*". - Justice Louis D. Brandeis 1913.

1 Introduction

Regulators are increasingly implementing disaggregated greenhouse gas (GHG) transparency regulations to strengthen market discipline at the facility level, where a facility encompasses any physical site, such as manufacturing plants, power stations, refineries, and other industrial operations. A major milestone in this effort was the 2010 launch of the U.S. Environmental Protection Agency's (EPA) Greenhouse Gas Reporting Program (GHGRP). The GHGRP establishes a standardized framework for facility-level emissions calculations[1] and mandates public disclosure for facilities exceeding a specified emissions threshold. To ensure data accuracy and reliability, the EPA enforces stringent monitoring,[2] verification,[3] and enforcement measures.[4] Since 2012, the agency has publicly released annual emissions data—including total emissions and ownership details—for over 8,000 facilities through its online database. By providing objective and comprehensive emissions data, the GHGRP serves as a vital resource for policymakers, investors, environmental organizations, and the public, facilitating more informed decision-making and supporting national GHG management efforts. While this granular transparency regulation does not mandate emissions reductions, it carries significant implications for publicly traded firms with regulated facilities. Unlike firms without such facilities, these companies must meet annual reporting requirements, exposing them to increased regulatory scrutiny and stakeholder evaluation, which may influence their environmental strategies and risk management decisions.

Previous studies (Yang et al. (2021), Tomar (2022)) show that facilities subject to the GHGRP—or firms' aggregated facility-level emissions under the program—tend to reduce emissions more than control facilities. However, within GHGRP firms, Bartram et al. (2022)

[1] https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98?toc=1
[2] https://www.epa.gov/sites/default/files/2017-12/documents/ghgrp_bamm_factsheet.pdf
[3] https://www.epa.gov/sites/default/files/2017-12/documents/ghgrp_verification_factsheet.pdf
[4] https://www.epa.gov/enforcement/enforcement-greenhouse-gas-reporting-program-hfc-importers

highlight an unintended consequence of California's cap-and-trade policy: financially constrained firms exposed to the regulation increase emissions at their non-California facilities by 14% more than firms without California operations. Despite these findings, the literature lacks direct evidence on the firm-wide impact of facility-level transparency regulation. Since facilities represent only a subset of larger organizations, and many firms operate globally, it remains unclear how localized U.S. facility-level GHG transparency influences broader firm-wide emissions strategies. This paper fills that gap by examining whether facility-level transparency regulation creates spillover effects that shape firm-wide decision-making beyond directly regulated facilities. The key question is not just whether these spillover effects exist, but also how they materialize.

To address causal inference questions, researchers must carefully narrow the scope of their samples, even at the cost of reduced statistical power and external validity (Leuz & Wysocki (2016)). In this study, I focus on firms that voluntarily disclosed their firm-level GHG emissions (e.g., Matsumura et al. (2014), Griffin et al. (2017)) both before and after the introduction of the GHGRP, examining differential impacts on firm-level emissions changes in firms with and without regulated facilities. To strengthen the internal validity of causal inferences about the impact of increased facility-level GHG transparency on firm-level emissions, I focus on firms that voluntarily disclose their emissions rather than relying on vendor-estimated data for several key reasons. First, vendor-estimated emissions often diverge significantly from firm-disclosed emissions, raising concerns about estimation errors due to proprietary methods that rely heavily on firm fundamentals (Aswani et al. (2023)). Second, because vendor-estimated data is commercialized, there is often a significant delay in investor access to this information (Zhang (2024)), making it challenging to identify contemporaneous capital market effects on firm behavior. Third, Zhang (2024) finds a perfect correlation between log-transformed vendor-estimated emissions and firm sales, complicating the distinction between emissions reductions due to actual changes in emissions versus changes in firm sales. In fact, Bauckloh et al. (2023) document an apparent contradiction

using vendor-estimated data: while firms affected by the GHGRP do not exhibit greater reductions in their "raw emissions" compared to control firms, they do demonstrate more significant reductions when measured by the "emissions-to-sales ratio."

Climate change is increasingly shaping business practices (Sautner et al. (2023)). Through regulatory oversight—including standardized GHG calculation, monitoring, verification, and enforcement—mandatory facility-level GHG disclosure functions as a "sunshine mechanism." This mechanism objectively reveals the true extent of firms' climate impact, which was previously obscured at the firm level, by providing a more accurate and comprehensive quantification of facility-level emissions and identifying publicly traded companies that own emitting facilities. Such granular transparency heightens stakeholder awareness and increases corporate visibility among investors, regulators, and the public, compelling firms to anticipate potential negative feedback and political costs associated with the mandatory disclosure of their emissions' true negative externalities (Watts & Zimmerman (1978, 1990)). Consistent with stakeholder theory (Freeman (1984)), which posits that a firm's success depends on its responsiveness to stakeholder interests, the anticipation of negative relational consequences incentivizes firms to adopt more inclusive and socially responsible decision-making. I term this transparency-driven behavioral shift the "sunshine effect," wherein firms proactively adopt sustainable practices to mitigate adverse societal reactions to mandatory disclosures that objectively reveal the true extent of their climate impact—previously unavailable at the firm level.

I employ a generalized difference-in-differences (DID) design to assess the impact of the facility-level GHG emissions disclosure mandate on firm-level emissions. Leveraging the staggered implementation of the mandate, which took effect on January 1, 2010, firms are evaluated based on the year they first acquired regulated facilities. The design compares firm-years of newly regulated firms to a control group consisting of firms already subject to the mandate or not yet exposed. By incorporating firm-fixed effects to account for time-invariant differences between treated and control firms, and industry-year fixed effects to

address time-varying industry-level shocks, I estimate the average treatment effect of the granular transparency mandate. Consequently, any alternative explanation for the results would need to coincide with the timing of firms' initial exposure to the facility-level GHG emissions mandate. The findings indicate that firms subject to the GHGRP reduce their firm-level GHG emissions by 8 to 11% more than unregulated firms in the years following the program's implementation. These results underscore the mandate's effectiveness in driving broader environmental accountability beyond facility-level compliance.

However, alternative explanations for the observed reduction in firm-level emissions must be addressed. One possibility is that the reductions stem from changes in reporting methodologies—such as adopting new emissions factors, revising measurement standards, or narrowing the scope of reported emissions—rather than reflecting actual operational improvements. These adjustments could reduce reported emissions without signifying genuine environmental progress. Another explanation is that the reductions are primarily localized to facility-level emissions cuts, as documented in prior research. While improvements like energy efficiency upgrades or optimized production processes may result from the transparency requirements at the facility level, they do not necessarily reflect a broader organizational commitment to reducing emissions or integrating sustainability into the firm's overall strategy. I predict that the effectiveness of facility-level transparency regulation in driving firm-level behavioral change depends on how the granular regulation elevates climate change concerns across the organization. Crucially, these heightened climate change concerns must lead to tangible, comprehensive adjustments in emissions practices that reflect a broader integration of sustainability into the firm's overall strategy, rather than being confined to localized regulatory compliance efforts.

One way to evaluate whether facility-level regulation influences firm-wide behavior is to analyze how the facility-level regulation shifts organizational priorities and public messaging, particularly in forums where management engages with key stakeholders. Earnings conference calls provide a unique platform for management to discuss the firm's perfor-

mance, strategy, and critical issues, including environmental, social, and governance (ESG) factors like climate change. These calls offer real-time insights into how management frames climate-related risks and opportunities, revealing the extent to which climate concerns permeate the organization and influence strategic decisions. Consistent with the premise that facility-level regulation drives firm-wide behavior change, I find that the disaggregated-level regulation significantly increases firm-level climate change concerns and negative regulatory sentiment compared to non-GHGRP firms, as measured by the share of conversation in earnings call transcripts devoted to the topic (Sautner et al. (2023)). Furthermore, I find that these heightened climate concerns indeed lead to tangible changes in emissions practices at the firm level. Specifically, firms subject to facility-level regulation develop more green innovations than non-GHGRP firms in the years following the program's implementation. Using data from the United States Patent and Trademark Office (USPTO) linked to public firms' patent records (Kogan et al. (2017)), I find that GHGRP firms produce 11 more low-carbon patents per firm than non-GHGRP firms, with low-carbon patents classified based on the Cooperative Patent Classification (CPC) Y02 class (Sautner et al. (2023), Cohen et al. (2024)).

The primary driver of the transparency-induced behavioral shift is regulatory oversight, which objectively reveals firms' true climate impact. Standardized regulation functions as a sunshine mechanism, exposing actual corporate climate performance and past underreporting, prompting stakeholder scrutiny and negative feedback. In response, firms are incentivized to adopt more socially responsible practices to mitigate adverse societal reactions to mandatory disclosures that reveal the full extent of their climate impact—previously unavailable at the firm level. To empirically illustrate the negative feedback firms face due to increased granular transparency, I examine contemporaneous market reactions to mandatory facility-level GHG disclosures. The sunshine mechanism is particularly evident when standardized facility-level emissions data expose discrepancies with previously reported voluntary firm-level emissions for the same calendar year. The EPA's role in standardizing GHG

calculation methods, monitoring facility-level emissions, and enforcing verification processes enhances objectivity and reliability compared to voluntary disclosures. Since facility-level emissions represent only a portion of a firm's total emissions, investors ex-ante expect mandatory disclosures to align with or fall below previously reported firm-level figures for the same reporting year. However, when facility-level data reveal underreporting, investors perceive prior voluntary disclosures as misleading, triggering adverse market reactions. Consistent with the role of facility-level regulation as a sunshine mechanism, I find that the revelation of underreporting leads to an average market reaction of -0.49%, corresponding to an estimated market value loss of approximately $49 million.

Furthermore, I examine stakeholder responses by analyzing changes in third-party environmental ratings following the introduction of facility-level GHG disclosure regulation. These independent evaluations capture the perceptions of a broad range of stakeholders, including investors, consumers, and environmental advocacy groups, regarding firms' sustainability practices. By providing granular, standardized emissions data, facility-level disclosures enhance transparency, enabling stakeholders to scrutinize corporate environmental performance more rigorously. This heightened transparency exposes previously overlooked corporate shortcomings—such as inconsistencies, reporting gaps, or deliberate misreporting—activating the sunshine mechanism, which objectively reveals firms' true climate impact. As a result, third-party evaluators reassess firms' environmental credibility. When voluntary emissions disclosures conflict with mandatory facility-level data or when emissions exceed stakeholder expectations, firms often experience declines in ESG ratings, reflecting negative stakeholder sentiment. Using MSCI ESG ratings—a widely recognized benchmark in accounting and finance research—I find that firms subject to GHGRP regulations receive significantly lower environmental ratings than their non-regulated peers, despite voluntarily disclosing value-relevant environmental information before and after the regulation, specifically their firm-level GHG emissions. This evidence underscores that mandatory facility-level disclosures not only trigger immediate market reactions but also heighten stakeholder pres-

sures, particularly for firms under increased regulatory scrutiny.

The primary contribution of this paper is to provide evidence and a rationale for how and why facility-level GHG transparency regulation generates spillover effects at the organizational level, shaping firm-wide decision-making beyond regulated facilities. This addresses a gap in the literature on the real effects of U.S. facility-level GHG transparency regulation (Yang et al. (2021), Tomar (2022), Bartram et al. (2022), Bauckloh et al. (2023)), where direct evidence on firm-wide emissions reductions is lacking. This extends the literature on disclosure policies and resource allocation (e.g., Kanodia & Sapra (2016), Leuz & Wysocki (2016), Roychowdhury et al. (2019)) by demonstrating that disaggregated GHG disclosure—a subset of organizational reporting—significantly influences firm-level resource allocation, particularly by fostering green innovation. Although the transparency regulation applies at the facility level, its standardized framework objectively reveals firms' true climate impact, which was previously unavailable at the firm level. This heightened granular transparency increases firm-level climate concerns, intensifies negative regulatory sentiment expressed during earnings conference calls, and amplifies direct negative feedback from societal stakeholders. More broadly, this study also contributes to the literature on CSR-related reporting (e.g., Chen et al. (2018), Christensen et al. (2017), Johnson (2020), Rauter (2020)) and feedback effects in financial markets (Subrahmanyam & Titman (2001), Goldstein et al. (2013), Bond et al. (2012)). By examining how facility-level GHG mandates interact with stakeholder reactions—such as investor responses to underreporting and third-party ESG evaluations—this paper offers new insights into the implications of CSR reporting and feedback effects in capital markets.

Second, this study contributes to the literature on the real effects of mandatory firm-level GHG transparency regulation in the United Kingdom (UK). For instance, Downar et al. (2021) analyzed emissions data aggregated from the facility-level European Union's Emissions Trading System (ETS) at the firm level, comparing pre- and post-regulation periods. Their findings reveal that the UK's firm-level GHG transparency regulation led to

significantly greater reductions in aggregated ETS emissions among UK firms compared to their EU counterparts. Jouvenot & Krueger (2019) leveraged vendor-estimated firm-level emissions data available before and after the regulation, showing that UK firms achieved more substantial emissions reductions relative to firms in other EU countries. Similarly, Grewal (2024) examined CDP data from voluntary disclosers and found that the UK's firm-level GHG transparency regulation significantly reduced both total firm-level emissions and emissions intensity. These results are intuitive, as facility-level emissions (ETS emissions) are a subset of total firm emissions, and firm-level GHG transparency regulation is likely to influence either this subset or the organization as a whole. While these studies primarily focus on how increased firm-level GHG transparency impacts facility emissions or overall firm-level reductions, this paper reverses the perspective by examining how increased facility-level GHG transparency drives broader firm-wide emissions reductions. In doing so, it extends the literature on mandatory reporting programs by exploring the multi-level effects of transparency regulations.

Finally, this paper provides valuable policy insights for regulators seeking to enhance market discipline through disclosure regulations (see Leuz & Wysocki (2016) for a comprehensive review). While the U.S. Securities and Exchange Commission's (SEC) recent rule mandating the disclosure of Scope 1 and Scope 2 GHG emissions represents a significant step forward in climate-related transparency (US SEC (2024)), its reliance on firm-specific calculation methodologies undermines comparability both across firms and within the same firm over time. Although firms are required to disclose their methodologies, assumptions, and data sources, the lack of standardization hampers stakeholders' ability to effectively assess environmental performance. In contrast, the Environmental Protection Agency's Greenhouse Gas Reporting Program provides standardized and verified facility-level GHG disclosures, ensuring consistency and comparability. This paper demonstrates that the reliability and comparability established through the GHGRP's regulatory framework activate the "sunshine mechanism," effectively uncovering specific negative externalities

and instances of underreporting. By equipping stakeholders with objective and standardized data—unlike voluntary disclosures, which often reflect discretionary reporting practices—the GHGRP enables stakeholders to deliver informed feedback, hold firms accountable, and drive meaningful organizational change. As Justice Louis D. Brandeis famously remarked, "Sunshine is the best disinfectant." This study underscores that transparency fosters market discipline only when supported by consistent and comparable data, allowing stakeholders to objectively evaluate environmental performance and provide impactful feedback. Without tangible negative feedback enabled by standardized transparency, firms lack incentives to align with societal expectations.

The remainder of the paper is organized as follows: Section 2 provides a detailed discussion of the institutional context and formulates the hypotheses. Section 3 describes the sample selection process and the data sources utilized in the analysis. Section 4 outlines the empirical methodology and presents the key results. Finally, Section 5 concludes and highlights its broader policy implications.

2 Institutional Background and Hypothesis Development

2.1 Greenhouse Gas Reporting Program by the EPA

In response to growing concerns about greenhouse gas emissions, the Consolidated Appropriations Act of 2008[5] allocated funding to the U.S. Environmental Protection Agency (EPA) to develop a rule mandating the reporting of greenhouse gas emissions across all sectors of the U.S. economy under the Clean Air Act.[6] This initiative led to the creation of the Greenhouse Gas Reporting Program (GHGRP), which took effect on January 1, 2010. The

[5]https://www.govinfo.gov/content/pkg/PLAW-110publ161/pdf/PLAW-110publ161.pdf
[6]https://www.epa.gov/clean-air-act-overview/clean-air-act-text

Table 1: Timeline of important Greenhouse Gas Reporting Program events

Calendar Time	Event
January 1, 2010	Greenhouse Gas Reporting Program was implemented, requiring facilities to measure and report their facility-level emissions to the EPA.
January 11, 2012	Facility-level GHG information for calendar year 2010 was first released to the public.
February 22, 2012	After revision, facility-level GHG information for calendar year 2010 was released again to the public.
February 5, 2013	Facility-level GHG information for calendar year 2011 released to the public.
October 23, 2013	Facility-level GHG information for calendar year 2012 released to the public.
September 30, 2014	Facility-level GHG information for calendar year 2013 released to the public.
October 5, 2015	Facility-level GHG information for calendar year 2014 released to the public.

GHGRP standardizes the calculation of facility-level GHG emissions[7] and mandates the submission of emissions data to the EPA for facilities emitting above specified thresholds, primarily set at 25,000 metric tons of CO2e. These thresholds may vary depending on the facility's source category, such as power plants, refineries, or manufacturing facilities.

To ensure data accuracy, the EPA enforces rigorous monitoring,[8] verification,[9] and enforcement processes.[10] Starting in 2012, annual emissions data for over 8,000 facilities, including total emissions and ownership information, is publicly disseminated through the EPA's Facility Level Information on Greenhouse Gases Tool (FLIGHT) website, promoting transparency and enabling more informed decision-making among societal stakeholders. For a detailed timeline of key events related to the Greenhouse Gas Reporting Program during the sample period, please refer to Table 1. While the GHGRP does not mandate emissions reductions, it has significant implications for publicly traded firms with regulated facilities, as these firms must comply with annual reporting requirements that do not apply to firms without regulated facilities.

[7] https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98?toc=1
[8] https://www.epa.gov/sites/default/files/2017-12/documents/ghgrp_bamm_factsheet.pdf
[9] https://www.epa.gov/sites/default/files/2017-12/documents/ghgrp_verification_factsheet.pdf
[10] https://www.epa.gov/enforcement/enforcement-greenhouse-gas-reporting-program-hfc-importers

2.2 Voluntary Firm-Level GHG Emission Reporting Before and After GHGRP Implementation

Prior to the introduction of the GHGRP, firms increasingly responded to societal pressure by voluntarily disclosing their firm-level GHG emissions. This pressure extended beyond shareholder concerns, involving various stakeholders—including regulators, investors, consumers, and society at large—who are impacted by the externalities associated with corporate GHG emissions. Non-profit organizations, such as the CDP (formerly the Carbon Disclosure Project), have played a key role in promoting voluntary emissions disclosure. CDP encourages major global corporations to publicly share detailed information about their emissions through dedicated surveys.[11] By 2010, 59% of S&P 500 companies in the U.S. had voluntarily disclosed their firm-level emissions data to CDP (the CDP (2010)).

In addition to CDP surveys, some firms disclosed their emissions through various channels, including annual reports, sustainability reports, ESG data sheets, and their official corporate websites. Most of these disclosures primarily focused on Scope 1 emissions (direct emissions). To address causal inference questions, researchers must carefully narrow the scope of their samples, even at the expense of reduced statistical power and external validity (Leuz & Wysocki (2016)). In this study, I focus on firms that voluntarily disclosed their firm-level GHG emissions (e.g., Matsumura et al. (2014), Griffin et al. (2017)) both before and after the introduction of the program, examining the differential impacts on firm-level emissions changes in firms with and without regulated facilities.

2.3 Hypothesis Development

The increasing adoption of facility-level greenhouse gas (GHG) transparency regulation, such as the U.S. Environmental Protection Agency's (EPA) Greenhouse Gas Reporting Program (GHGRP), has profound implications for corporate environmental behavior beyond

[11] https://www.cdp.net/en/info/about-us/what-I-do

the directly regulated facilities. While prior research has predominantly focused on the localized impacts of such regulations—specifically, emissions reductions at facilities subject to direct reporting requirements—less attention has been paid to the broader organizational spillover effects. This study aims to fill this gap by examining whether and how facility-level transparency regulations influence firm-wide climate awareness and the adoption of more sustainable operational practices.

The first hypothesis builds on the growing body of literature identifying climate change as a critical driver of corporate decision-making (Sautner et al. (2023)). The GHGRP mandates facility-level GHG emissions disclosure, which entails standardized measurement, monitoring, verification, and public reporting. This regulatory oversight functions as a "sunshine mechanism"—a concept rooted in the idea that transparency can induce behavioral change by exposing previously obscured or underestimated environmental impacts. Facility-level reporting provides a more comprehensive and accurate assessment of a firm's carbon footprint, highlighting emissions that were previously aggregated or selectively disclosed at the firm level. By making such detailed emissions data publicly accessible, the regulation enhances external stakeholder scrutiny, increasing corporate visibility among investors, regulators, and the broader public. This heightened transparency has direct consequences for corporate behavior. Under stakeholder theory (Freeman (1984)), firms respond to the interests and concerns of various external constituencies, including investors, customers, and regulators, to maintain legitimacy and avoid reputational damage. The anticipation of negative stakeholder reactions—ranging from activist pressure and consumer backlash to regulatory scrutiny and capital market penalties—creates strong incentives for firms to engage in proactive environmental strategies. The GHGRP's disclosures make it easier for investors and policymakers to identify firms with high-carbon footprints, potentially exposing them to negative media coverage, higher capital costs, or even regulatory interventions. Consequently, firms may adopt sustainability initiatives, such as internal carbon reduction targets, supply chain decarbonization, or investment in cleaner technologies, in an effort to mitigate potential neg-

ative consequences arising from enhanced transparency. I refer to this transparency-induced behavioral shift as the "sunshine effect"—where firms voluntarily adopt more sustainable practices in response to the increased visibility of their environmental impact.

However, the extent to which facility-level GHG transparency translates into firm-wide emissions reductions remains an open question. Several factors introduce ambiguity into the expected outcome. First, the GHGRP's disclosure requirements apply to individual facilities rather than entire corporate entities, while many firms operate across multiple jurisdictions, including countries with varying environmental regulations. This raises the question of whether transparency at the facility level in the U.S. is sufficient to drive meaningful, firm-wide sustainability initiatives, especially for multinational firms with significant operations outside the program's regulatory scope. Second, unlike financial disclosures mandated by the Securities and Exchange Commission (SEC), which are subject to formal auditing and integrated into regulatory filings such as 10-K reports, GHGRP disclosures occur through informal reporting channels. Prior research suggests that investors and other market participants may perceive environmental disclosures outside formal financial statements as less material or credible (e.g., Christensen et al. (2017)). If investors discount the importance of GHGRP disclosures, the regulatory pressure on firms to respond with substantive emissions reductions may be weaker than expected.

Given these competing forces—on one hand, the potential for transparency-induced behavioral change, and on the other, the possible limitations of localized and informal disclosures—the net impact of GHGRP on firm-wide emissions remains an empirical question. To test the extent to which facility-level transparency induces broader firm-level environmental improvements, I propose the following hypothesis:

H1: Firms subject to facility-level GHG transparency regulation reduce their overall firm-level GHG emissions more than firms without regulated facilities, following years of program implementation.

Changes in reported firm-level GHG emissions must be carefully examined to differenti-

ate substantive reductions from methodological shifts or localized compliance efforts. One potential concern is that reported emissions may decrease not due to actual reductions in carbon output, but as a result of modifications in reporting methodologies. Firms have considerable discretion in their reporting practices, and adjustments in emissions factors, measurement techniques, or disclosure frameworks can significantly alter reported figures without reflecting meaningful operational improvements. For example, firms may adopt more lenient measurement standards, reclassify certain emission sources, or adjust organizational boundaries in ways that exclude specific facilities or subsidiaries from the reported total. Such methodological changes create the appearance of lower emissions while leaving the firm's actual environmental footprint largely unchanged.

A second possibility is that emissions reductions occur primarily at regulated facilities in response to compliance pressures rather than as part of a broader, firm-wide sustainability initiative. Prior research indicates that firms often take a targeted, compliance-driven approach when facing environmental regulations, implementing energy efficiency measures or modifying production processes at specific facilities to meet mandated standards. While these localized actions lead to emissions reductions at the facility level, they do not necessarily indicate an overarching corporate strategy aimed at achieving sustainability across the firm. Instead, they may reflect a reactive response to regulatory oversight, where firms meet minimum compliance requirements without fundamentally altering their overall emissions trajectory or long-term climate strategy.

To determine whether emissions reductions reflect genuine firm-wide changes rather than mere reporting adjustments or localized compliance efforts, it is crucial to examine mechanisms that extend beyond individual facility-level actions. While facility-level transparency regulations such as the U.S. EPA' GHGRP apply at the facility level, their impact may extend more broadly by increasing firm-wide climate awareness and influencing corporate decision-making. This broader influence stems from the enhanced visibility and scrutiny that facility-level disclosures bring to a firm's overall carbon footprint. Prior to the imple-

mentation of granular reporting requirements, a firm's emissions profile could be obscured through aggregation, selective disclosure, or lack of standardized measurement. However, facility-level disclosures provide a more objective, detailed, and publicly accessible representation of a firm's emissions impact. As a result, stakeholders—including investors, analysts, regulators, and the public—gain more precise insights into climate-related risks, increasing the pressure on firms to address carbon management at the organizational level rather than merely at the facility level.

One key channel through which this heightened climate awareness manifests is corporate communications, particularly earnings conference calls. These calls serve as a critical venue where management articulates the firm's strategic priorities and responses to external developments, including regulatory changes and investor concerns. As facility-level transparency brings firms' climate impact into sharper focus, stakeholders are likely to raise more questions regarding firms' climate strategies, regulatory risks, and preparedness for potential policy shifts such as carbon taxes or emissions caps. Consequently, firms facing heightened scrutiny may respond by engaging in more extensive climate-related discussions in their earnings calls, signaling a firm-wide recognition of climate risks and an increased commitment to managing them.

Moreover, intensified stakeholder scrutiny may heighten negative regulatory sentiment, as investors, analysts, and policymakers critically assess firms' environmental performance and their readiness for an evolving regulatory landscape. Firms with high facility-level emissions may face increased skepticism from market participants, who question their ability to adapt to tightening carbon regulations. This regulatory pressure, coupled with greater public awareness, can push firms to adopt more proactive environmental strategies, extending beyond compliance-driven facility-level adjustments to broader firm-wide climate initiatives.

H2: Even though transparency applies at the facility level, firms subject to granular GHG transparency regulation experience a simultaneous increase in firm-level climate change concerns and negative regulatory sentiment in earnings conference calls compared to firms

without regulated facilities.

Crucially, if facility-level transparency regulation enhances firm-wide climate awareness, this heightened attention must translate into meaningful, organization-wide changes rather than remain confined to regulated facilities. A genuine commitment to sustainability requires integrating climate considerations into a firm's core business strategy, extending beyond compliance-driven facility-level adjustments to proactive initiatives that reshape corporate operations, investments, and innovation priorities. This transformation involves adopting new technologies, optimizing processes, and developing business models aimed at reducing emissions across all operational domains.A key indicator of such a strategic shift is an increased emphasis on low-carbon innovation, particularly the development of low-carbon patents. Innovation in green technologies reflects a firm's forward-looking approach to sustainability, demonstrating not only compliance with regulatory requirements but also a strategic effort to align with long-term market trends and stakeholder expectations. By investing in low-carbon technologies, firms can enhance their competitive position, capitalize on emerging opportunities in the transition to a low-carbon economy, and reduce exposure to future regulatory and reputational risks. The development of green technology patents provides a concrete and measurable indicator of a firm's commitment to sustainability. Unlike voluntary sustainability disclosures or short-term emissions reductions, which may be influenced by compliance pressures or reporting adjustments, patents represent substantive investments in research and development (R&D) with long-term strategic implications. Prioritizing low-carbon patents signals the proactive integration of sustainability into corporate innovation strategy, reflecting a shift toward embedding climate considerations into business decisions rather than treating them as peripheral regulatory obligations. This perspective is supported by prior research suggesting that regulatory pressures can serve as catalysts for innovation, particularly when transparency mechanisms increase external scrutiny and internal awareness of climate-related risks. Firms facing heightened stakeholder expectations may seek to demonstrate leadership in sustainability by directing R&D resources toward

green technology development. Additionally, as investors and policymakers place greater emphasis on corporate environmental performance, firms that invest in low-carbon innovation may benefit from improved market valuations, enhanced access to capital, and stronger stakeholder relationships.

H3: Firms subject to facility-level GHG transparency regulation develop more low-carbon patents compared to firms without regulated facilities in the years following program implementation.

The primary driver of the transparency-induced behavioral shift is regulatory oversight, which objectively reveals firms' true climate impact. Standardized facility-level disclosure functions as a sunshine mechanism, exposing actual corporate environmental performance and previously hidden underreporting. This transparency heightens stakeholder scrutiny and amplifies negative feedback from investors, regulators, and the public. In response, firms face strong incentives to adopt more socially responsible practices to mitigate adverse societal reactions and relational damage stemming from mandatory disclosures that objectively reveal the full extent of their emissions—data that was previously unavailable at the firm level. To evaluate the market consequences of facility-level GHG transparency, it is crucial to assess investor reactions to discrepancies between firms' voluntarily reported emissions and their objectively measured facility-level emissions. The sunshine mechanism operates through standardized facility-level reporting, which can uncover inconsistencies in prior voluntary disclosures. The U.S. Environmental Protection Agency's (EPA) regulatory framework—mandating standardized GHG calculations, facility-level monitoring, and independent verification—ensures a more objective and reliable emissions measure than voluntary corporate reporting. As a result, investors expect total firm-level emissions to align with or be lower than the sum of facility-level emissions within the same reporting year. However, when facility-level disclosures reveal that a firm has underreported its emissions in its voluntary corporate filings, this discrepancy serves as a negative signal of misrepresentation, raising investor concerns about governance quality, environmental risk exposure, and

potential regulatory repercussions. Investors interpret such inconsistencies as indications of weak internal controls, opportunistic disclosure strategies, or environmental negligence. These concerns contribute to negative market sentiment, eroding investor confidence in the firm's credibility and long-term sustainability strategy. Consequently, firms that previously underreported their emissions face significant stock price penalties when facility-level disclosures contradict their voluntary reports, emphasizing the critical role of transparency in enforcing corporate accountability and shaping investor perceptions.

H4: Revelation of firms that underreport their firm-level GHG emissions relative to objective facility-level data leads to negative stock price reactions, leading to a decline in market value.

The fifth hypothesis examines the broader reputational impact of facility-level GHG transparency regulation, particularly as reflected in third-party Environmental, Social, and Governance (ESG) ratings. ESG ratings serve as an indirect yet influential measure of stakeholder perception, capturing assessments from investors, regulators, and the public. These ratings are widely used by institutional investors, policymakers, and sustainability-focused funds to evaluate a firm's environmental performance and long-term risk exposure. A key consideration is whether the introduction of facility-level reporting materially affects ESG ratings for firms that had already been voluntarily disclosing firm-level emissions before and after the regulation. A baseline expectation might be that the additional transparency has minimal impact, given that firms had already made their carbon disclosures available to the market. Prior research suggests that voluntary environmental disclosure conveys value-relevant information to investors and stakeholders (e.g., Matsumura et al. (2014), Griffin et al. (2017)), implying that firms were already being evaluated based on their self-reported emissions. If ESG ratings are primarily based on firms' voluntary disclosures, then the facility-level regulation should not significantly alter these assessments. However, facility-level GHG disclosures introduce a standardized and independently verified emissions dataset, which enhances transparency and intensifies external scrutiny of corporate environmental

performance. Unlike voluntary disclosures, which often lack uniformity and may be influenced by strategic reporting incentives, facility-level data provides a more objective and disaggregated view of a firm's actual carbon footprint. This additional granularity enables third-party evaluators to detect inconsistencies, selective reporting, or potential misrepresentations, activating the sunshine mechanism, which exposes firms' true climate impact more accurately than prior self-reported firm-level disclosures.From a broader stakeholder perspective, this increased transparency has significant reputational implications. Discrepancies between voluntary firm-level reports and newly revealed facility-level data—or emissions levels that exceed stakeholder expectations—can lead to ESG rating downgrades, signaling increased reputational risk. Even for firms engaged in voluntary disclosure, the introduction of a standardized reporting framework heightens external scrutiny, as environmental rating agencies revise their assessments to reflect newly available facility-level information. This underscores how transparency mechanisms influence not only financial market outcomes but also broader corporate sustainability evaluations. The shift toward more granular and standardized GHG reporting may reveal previously hidden risks, prompt ESG rating agencies to reassess firms' climate performance, and ultimately reinforce negative stakeholder perceptions for firms with unexpectedly high emissions or inconsistencies in their voluntary disclosures.

H5: Firms subject to facility-level GHG transparency regulation contemporaneously receive lower environmental ratings compared to firms without regulated facilities.

3 Sample and Data

3.1 Data

The data used in this study is sourced from multiple databases. The sample comprises U.S. publicly listed firms that voluntarily disclosed their GHG emissions both before and after the implementation of the GHGRP policy. Firm-level GHG emissions data, voluntarily

reported[12] by the firms, is sourced from Refinitiv Eikon, a leading platform for financial professionals. This data was collected in April 2022. Firm characteristic data are obtained from Compustat, and stock market data are sourced from CRSP. To ensure data quality, only firms with complete information in the Compustat-CRSP merged database are included. Analyst coverage data are retrieved from the I/B/E/S database, and institutional holdings data are sourced from the Thomson Reuters 13F database.

Annual facility-level GHG emissions data, including production quantities and ownership details, is obtained from the EPA's FLIGHT database.[13] To match each facility ID with Compustat identifiers (GVKEY), I compare the legal names of facility parent entities with the names of publicly traded companies using a Levenshtein distance algorithm (Levenshtein (1966)) and manually correct mismatches. In rare cases where a single facility is owned by multiple parent firms, emissions are allocated based on each entity's ownership percentage.

The main panel dataset is constructed by merging fiscal year firm characteristics with calendar year facility-level GHG information. This process generates the main policy variable of interest, GHGRP, a binary indicator set to 1 starting in the year a firm first becomes subject to the GHGRP's implementation and in all subsequent years, and 0 otherwise. The starting year for each firm is staggered, reflecting the timing of the firm's initial exposure to the mandate.

To assess firm-level climate change concerns, I leverage the dataset developed by Sautner et al. (2023), which develops an innovative machine learning-based approach to quantify firm-level climate change exposure using earnings call transcripts. This dataset identifies climate-related keywords and calculates the frequency of discussions on climate topics, encompassing physical risks, regulatory shocks, and opportunities.

To analyze firm-level green innovations, I use patent data sourced from the United States

[12]Refinitiv Eikon provides firm-level emissions data through a hierarchical process, prioritizing the most accurate source. The primary category, "Reported," uses self-reported CO2 emissions from companies, halting the process at this step if available. If not, emissions are estimated using a CO2-specific model, energy metrics, or, as a last resort, a median-based approach. For this study, only "Reported" emissions data is used to ensure accuracy and reliability.

[13]https://ghgdata.epa.gov/ghgp/main.do

Patent and Trademark Office (USPTO), linked to public firms' patent records (Kogan et al. (2017)). Following previous literature (Sautner et al. (2023), Cohen et al. (2024)), low-carbon patents are identified using the Cooperative Patent Classification (CPC) Y02 class, which captures technologies with environmental benefits. This dataset allows for an assessment of how facility-level transparency regulations influence innovation in sustainable technologies.

For the event study analysis, daily stock data is sourced from CRSP, while factor data is obtained from Ken French's website.

Finally, environmental ratings data is sourced from MSCI ESG ratings, specifically focusing on the Environment Pillar, which evaluates dimensions such as carbon emissions, climate change vulnerability, raw material sourcing, and waste management. The MSCI dataset provides an independent assessment of firms' environmental performance and is widely recognized in accounting and finance research.

In total, the sample comprises 1,890 firm-year observations for 379 unique firms, covering the period from fiscal year 2007 to 2014. To mitigate the influence of outliers, all continuous control variables are winsorized at the 1st and 99th percentiles.

3.2 Descriptive Statistics

Table 2 presents the summary statistics for the key variables. ln(FirmE), representing the natural logarithm of voluntarily disclosed firm-level GHG emissions, has a mean of 13.60 and a standard deviation of 2.28, indicating moderate variability around the average value. The primary policy variable, GHGRP, is a binary indicator with a mean of 0.29, signifying that approximately 29% of the firms in the sample are subject to the GHGRP. ln(FacilityE), which captures the total aggregated facility-level emissions at the firm level, exhibits a mean of 4.15 and a substantially larger standard deviation of 6.66, reflecting significant heterogeneity in emissions across firms.

Table 3 presents the Pearson correlation matrix. Firm-level emissions exhibit strong positive correlations with facility-level emissions, firm size, and capital intensity—factors

Table 2: Summary Statistics

	Obs	Mean	STD	Median
ln(FirmE)	1890	13.60	2.28	13.48
GHGRP	1890	0.29	0.45	0.00
ln(FacilityE)	1890	4.15	6.66	0.00
ClimateConcerns	1890	1.58	3.17	0.41
NegRegSenti	1890	-0.22	1.06	0.00
LowCarbonPatents	1890	9.14	37.76	0.00
EnvironmentScore	1730	5.20	1.81	5.21
Size	1890	9.60	1.31	9.51
BM	1890	0.54	0.43	0.42
AI	1890	0.56	0.39	0.49
Leverage	1890	0.25	0.15	0.24
Cash	1890	0.13	0.13	0.09
ROA	1890	0.14	0.08	0.14
Dividend	1890	0.02	0.02	0.02
IO	1890	0.77	0.15	0.79
Analysts	1890	2.79	0.49	2.89

This table provides descriptive statistics for the key variables used in the analysis. ln(FirmE) represents the natural logarithm of voluntarily disclosed firm-level GHG emissions, measured in metric tons of carbon dioxide equivalent (CO2e), capturing the scale of firm-reported emissions. The main policy variable of interest, GHGRP, is a binary indicator set to 1 starting in the year a firm becomes subject to the GHGRP's implementation and remains 1 in all subsequent years, distinguishing treated firms from non-treated firms. ln(FacilityE) represents the natural logarithm of a firm's total aggregated facility-level emissions, measured in metric tons of CO2e, offering a detailed and granular perspective on emissions data. The variables ClimateConcerns and NegRegSenti capture firm-level measures of overall climate change concerns and negative regulatory sentiment, respectively. These measures are based on the proportion of earnings call transcripts focused on these topics, as described by Sautner et al. (2023), and are scaled by multiplying by constant number. LowCarbonPatents reflects the number of firm-level low-carbon patents classified using the Cooperative Patent Classification (CPC) Y02 class, which identifies technologies with environmental benefits (Sautner et al. (2023), Cohen et al. (2024)). EnvironmentScore represents the MSCI Environment Pillar Score assigned to firms, assessing their environmental performance across dimensions such as carbon emissions and natural resource management. SIZE captures firm size and is measured as the natural logarithm of total market capitalization as of December. BM represents the book-to-market ratio, calculated as book equity divided by the market value of common equity at the end of December, reflecting valuation characteristics. AI is measured as the ratio of property, plant, and equipment to total assets, indicating the capital intensity of the firm. Leverage reflects financial risk and is calculated as the sum of long-term and short-term debt divided by total assets. Cash measures liquidity as the proportion of cash holdings to total assets. ROA represents return on assets, a measure of profitability. Dividend reflects the dividend payout ratio, calculated as the sum of common and preferred dividends divided by total assets. IO indicates the proportion of shares owned by institutional investors, while Analysts captures market attention as the natural logarithm of one plus the number of analysts following the firm during the year.

that reflect a firm's operational scale and industry classification. Furthermore, the positive correlation with climate concerns suggests that higher-emission firms are more actively engaged in climate-related discussions, likely as part of their environmental communication and strategic positioning. The control variables do not display strong correlations.

Table 3: Pearson Correlation Matrix

#	Variables	ln(FirmE)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	GHGRP	**0.45**	1	**0.97**	**0.26**	**-0.10**	**0.16**	**-0.14**	**0.22**	**0.16**	**0.35**	**0.17**	**-0.24**	**-0.11**	**0.05**	**-0.14**	-0.0
3	ln(FacilityE)	**0.52**	**0.97**	1	**0.34**	**-0.15**	**0.13**	**-0.18**	**0.24**	**0.20**	**0.41**	**0.17**	**-0.27**	**-0.13**	0.03	**-0.15**	-0.0
4	ClimateConcerns	**0.44**	**0.26**	**0.34**	1	**-0.45**	**-0.05**	**-0.13**	**0.06**	**0.33**	**0.36**	**0.20**	**-0.27**	**-0.22**	**-0.09**	**-0.21**	**-0.1**
5	NegRegSenti	**-0.23**	**-0.10**	**-0.15**	**-0.45**	1	0.03	**0.06**	**-0.05**	**-0.15**	**-0.16**	**-0.06**	**0.11**	**0.09**	**0.05**	**0.10**	**0.0**
6	LowCarbonPatents	**0.08**	**0.16**	**0.13**	**-0.05**	0.03	1	**0.16**	**0.26**	**-0.11**	**-0.08**	**-0.05**	**0.11**	**0.06**	**0.05**	**-0.16**	**0.1**
7	EnvironmentScore	**-0.14**	**-0.14**	**-0.18**	**-0.13**	**0.06**	**0.16**	1	**0.17**	**-0.17**	**-0.24**	**-0.06**	**0.20**	**0.09**	0.04	-0.04	**0.1**
8	Size	**0.48**	**0.22**	**0.24**	**0.06**	**-0.05**	**0.26**	**0.17**	1	**0.26**	0.02	**0.08**	**-0.18**	**-0.17**	-0.00	**-0.30**	**0.3**
9	BM	**0.23**	**0.16**	**0.20**	**0.33**	**-0.15**	**-0.11**	**-0.17**	**0.26**	1	**0.20**	**0.05**	**-0.27**	**-0.51**	**-0.32**	**-0.05**	**-0.1**
10	AI	**0.70**	**0.35**	**0.41**	**0.36**	**-0.16**	**-0.08**	**-0.24**	0.02	**0.20**	1	**0.24**	**-0.44**	**0.07**	0.03	**-0.21**	**-0.1**
11	Leverage	**0.29**	**0.17**	**0.17**	**0.20**	**-0.06**	**-0.05**	**-0.06**	**0.08**	**0.05**	**0.24**	1	**-0.34**	**-0.19**	0.04	**-0.11**	**-0.2**
12	Cash	**-0.48**	**-0.24**	**-0.27**	**-0.27**	**0.11**	**0.11**	**0.20**	**-0.18**	**-0.27**	**-0.44**	**-0.34**	1	**0.17**	0.01	**0.19**	**0.2**
13	ROA	**-0.05**	**-0.11**	**-0.13**	**-0.22**	**0.09**	**0.06**	**0.09**	**-0.17**	**-0.51**	**0.07**	**-0.19**	**0.17**	1	**0.42**	**-0.05**	**0.2**
14	Dividend	**0.05**	**0.05**	0.03	**-0.09**	**0.05**	**0.05**	0.04	-0.00	**-0.32**	0.03	0.04	0.01	**0.42**	1	**-0.26**	0.02
15	IO	**-0.34**	**-0.14**	**-0.15**	**-0.21**	**0.10**	**-0.16**	-0.04	**-0.30**	**-0.05**	**-0.21**	**-0.11**	**0.19**	**-0.05**	**-0.26**	1	-0.0
16	Analysts	-0.04	-0.01	-0.02	**-0.19**	**0.08**	**0.19**	**0.19**	**0.38**	**-0.19**	**-0.14**	**-0.20**	**0.23**	**0.22**	0.02	-0.00	1

This table presents the Pearson correlation matrix among key variables. Correlation coefficients that are significant at the 5% level are highlighted in bold. For variable definitions, refer to Table 2.

4 Empirical Analysis

4.1 H1: Impact of Facility-Level GHG Transparency Regulation on Firm-Level Emissions

4.1.1 Empirical Design

Following Bertrand & Mullainathan (2003), I employ a generalized difference-in-differences (DID) research design to assess the impact of the granular disclosure mandate on firm-level emissions. This methodology leverages the staggered implementation of the facility-level GHG emissions disclosure mandate, which came into effect on January 1, 2010. A firm's initial exposure to the mandate is determined by the year it first owns regulated facilities. In the analysis, I compare firm-years when a firm first becomes subject to the mandate with other firm-years, including a control group comprising firms already regulated and those not yet exposed in a given year. To ensure robustness, the model incorporates common firm characteristics, firm-fixed effects to account for time-invariant differences between treated and control firms, and industry-year fixed effects to capture time-varying industry-level shocks. This setup enables estimation of the average treatment effect on firms encountering the GHGRP for the first time in a specific year. Consequently, any alternative explanations for the observed effects would need to align temporally with the timing of firms' initial exposure to the facility-level GHG emissions mandate. The generalized DID equation, estimated using the Ordinary Least Squares (OLS) method, is specified as follows:

$$ln(firmE)_{fit} = \alpha_f + \alpha_{it} + \gamma * X_{ft} + \beta * GHGRP_{ft} + \epsilon_{it} \tag{1}$$

Here, f indexes the firm, i represents the Fama-French 12 industry classification, and t denotes the fiscal year. The dependent variable, ln(firmE), is the natural logarithm of voluntarily disclosed firm-level emissions. This logarithmic transformation aids in interpreting results as percentage changes and reduces the influence of outliers. The main policy

variable of interest, GHGRP, is a binary indicator set to 1 starting in the year a firm first becomes subject to the GHGRP's implementation and in all subsequent years, and 0 otherwise. This variable captures contemporaneous changes in firm-level emissions in response to the program. To examine behavioral changes that are likely to occur after the program's implementation, I include lagged values of the GHGRP variable.

Consistent with prior research on mandatory greenhouse gas reporting (e.g., Downar et al. (2021), Yang et al. (2021), Tomar (2022)), the model includes control variables for key firm characteristics, such as firm size, market-to-book ratio, AI, and book leverage. Additional controls account for operating performance, capital structure, IO, and analyst coverage. To address unobservable heterogeneity, firm fixed effects and industry-year fixed effects are included, capturing time-invariant firm characteristics and industry-specific trends, respectively. Standard errors are clustered at the firm level to ensure robust statistical inference.

4.1.2 Main Results

Table 4 presents the findings examining hypothesis H1. The results from the three specifications assess the impact of the facility-level GHG emissions transparency regulation (GHGRP) on firm-level emissions (ln(firmE)) over time. The analysis focuses on the contemporaneous and lagged effects of the GHGRP on firm behavior.

In specification (1), the contemporaneous effect of the GHGRP (GHGRP(0)) is statistically insignificant (t=−0.53), indicating no immediate reduction in firm-level emissions during the year the regulation is implemented. However, in specification (2), the one-year lagged effect (GHGRP(+1)) is significant at the 10% level (t=−1.82), with a coefficient of −0.08. This indicates that firms reduce their emissions by approximately 8% one year after their initial exposure to the mandate. By the second year, as shown in specification (3), the effect becomes highly statistically significant at the 1% level (t=−2.66), with a coefficient of −0.11. This suggests that firms reduce their emissions by approximately 11% two years after the regulation takes effect. These reductions highlight a stronger and more sustained

response as firms adapt to the transparency requirements.

In terms of economic magnitude, the reductions in emissions at both GHGRP(+1) and GHGRP(+2) are substantial. The 8% reduction after one year and 11% reduction after two years reflect meaningful changes in firm behavior, likely driven by operational adjustments and investments in emissions-reducing strategies. Overall, the findings support hypothesis H1, demonstrating that facility-level transparency regulation under the GHGRP leads to reductions in firm-level GHG emissions. The reductions are not immediate; significant effects only begin to emerge one year after the regulation's implementation. This delayed response underscores the time firms require to adapt their operations and strategies to transparency-driven pressures, with robust statistical and economic evidence affirming the regulation's effectiveness.

4.1.3 Dynamic Effects and Goodman-Bacon Decomposition

The difference-in-differences (DID) methodology relies on the assumption of parallel pre-trends between treated and control firms. To validate this assumption, I analyze the dynamic effects of the facility-level GHG information disclosure mandate on firm-level emissions in the years before and after its initial implementation, relative to control firms. Specifically, Figure 1 visually illustrates the estimated coefficients and their 90% confidence intervals for a series of policy dummy variables. These variables represent each of the two years preceding the mandate (T=−2 and T=−1), the year the mandate was first implemented (T=0), and subsequent years (T=1 through T=4+, where T=4+ aggregates year 4 and all later years).

$$ln(firmE)_{fit} = \alpha_f + \alpha_{it} + \sum_{T=-2}^{T=+4} \beta_T * GHGRP_{ft}(T) + \epsilon_{it} \tag{2}$$

The coefficients for the pre-treatment periods (T = −2 and T = − 1) are close to zero and statistically insignificant, as indicated by the wide confidence intervals overlapping zero.

Table 4: Changes in Firm-Level Emissions Around the Facility-Level GHG Transparency Regulation

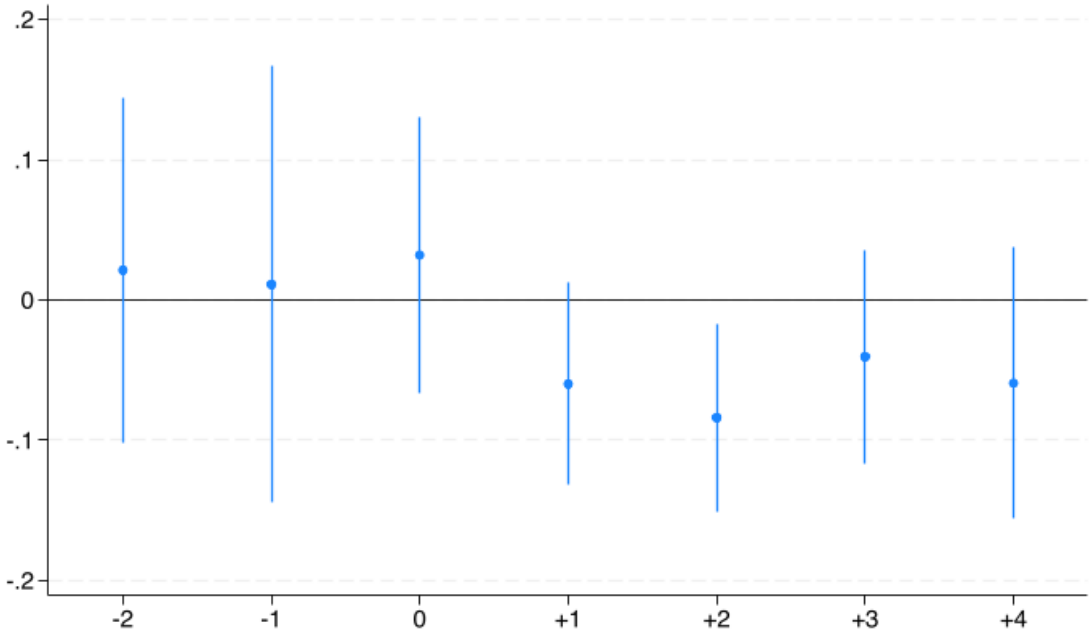
	ln(firmE)		
	(1)	(2)	(3)
GHGRP(0)	-0.02		
	(-0.53)		
GHGRP(+1)		-0.08*	
		(-1.82)	
GHGRP(+2)			-0.11***
			(-2.66)
Size	0.64***	0.63***	0.63***
	(6.39)	(6.37)	(6.38)
BM	0.07	0.07	0.07
	(1.00)	(1.01)	(1.01)
AI	0.59*	0.58*	0.57*
	(1.86)	(1.84)	(1.83)
Leverage	-0.18	-0.18	-0.17
	(-0.89)	(-0.87)	(-0.86)
Cash	0.37*	0.34	0.35
	(1.73)	(1.58)	(1.63)
ROA	0.34	0.33	0.33
	(0.77)	(0.76)	(0.76)
Dividend	0.26	0.15	0.09
	(0.28)	(0.16)	(0.10)
IO	-0.08	-0.08	-0.08
	(-0.47)	(-0.49)	(-0.46)
Analysts	-0.02	-0.02	-0.02
	(-0.51)	(-0.53)	(-0.58)
Observations	1,890	1,890	1,890
Adj R2	0.984	0.984	0.984
Firm FE	Yes	Yes	Yes
FF12-Year FE	Yes	Yes	Yes

This table presents the main results of the GHGRP's impact on firm-level GHG emissions. The dependent variable is the natural logarithm of firm-level emissions voluntarily disclosed by firms before and after the implementation of the facility-level transparency regulation. The primary policy variable of interest, GHGRP, is a binary indicator equal to 1 starting in the year a firm first becomes subject to the GHGRP and continuing in all subsequent years, and 0 otherwise. This variable captures contemporaneous changes in firm-level emissions in response to the program. To evaluate behavioral changes that may occur in the years following the program's implementation, lagged values of the GHGRP variable are included in the analysis. Firm and industry-year fixed effects are included to control for unobserved heterogeneity across firms and industries over time. Robust standard errors, clustered by firm, are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

This result supports the parallel-trend assumption, confirming that treated and control firms exhibited similar trends in firm-level emissions before the regulation's implementation. Similarly, the coefficient for T = 0 (the year of initial disclosure) is also statistically insignificant, suggesting no immediate effect of the facility-level transparency regulation on firm-level emissions. Post-treatment, the results show a significant decline in emissions starting at T = +1, with the coefficient becoming more negative by T = +2. This pattern indicates that firms begin to meaningfully reduce their emissions one year after their initial disclosure, with these reductions becoming more pronounced two years after the regulation's implementation. The coefficients for T = +3 and T = +4 remain negative, suggesting that the emissions reductions persist over time, though the magnitude stabilizes rather than intensifies further. Overall, the figure provides compelling evidence that the facility-level GHG transparency regulation effectively drives significant reductions in firm-level emissions, with the effects materializing one year after the initial disclosure. This delayed response underscores the time required for firms to adapt their operations and strategies to meet the demands of transparency-driven pressures.

The generalized DID estimator essentially represents a weighted average of all conceivable standard DID estimates between treated and control observations. Recent studies (Goodman-Bacon (2021), Baker et al. (2022)) highlight the potential bias that can arise when already-treated firms are included in the control group, as the treatment effect may vary over time. To address this issue, I apply the methodology proposed by Goodman-Bacon (2021) to decompose the generalized DID estimate into components based on distinct sets of control firms. For the decomposition analysis, a balanced panel without control variables is required. Therefore, I limit the sample period to 2009–2012 to ensure a robustly balanced panel. Table 5 presents the Bacon decomposition results, illustrating how the overall treatment effect (GHGRP(+1)) is constructed from comparisons across different timing groups under the facility-level GHG transparency regulation. The most substantial contribution comes from the "Never vs Timing" group, which has a Beta coefficient of -0.10 and a total

Figure 1: Dynamics of GHGRP Impact on Firm-Level Emissions Changes



e

This figure illustrates the dynamic effects of the GHGRP's facility-level transparency regulation on firm-level GHG emissions. The dependent variable is the natural logarithm of firm-level emissions, observed across two years prior to the mandate (T = −2 and T = −1), the year of implementation (T = 0), and subsequent years (T = +1 through T = +4). The primary policy variable consists of policy dummies that measure the temporal impact of the regulation on emissions relative to the pre-treatment baseline. The figure presents the estimated coefficients for these policy dummies, accompanied by 90% confidence intervals, providing a clear depiction of both the magnitude and statistical significance of the regulation's effects over time. This visualization highlights the delayed but sustained reductions in emissions following the regulation's implementation, offering insights into the evolving impact of transparency-driven policies on corporate environmental behavior.

Table 5: Goodman-Bacon Decomposition

	ln(FirmE)	
	Beta	std. err
Overall Estimate	-0.10	0.03
Control Group Type	Beta	Total weight
Early vs Late	-0.08	0.05
Late vs Early	-0.07	0.025
Never vs Timing	-0.10	0.923

This table presents the Goodman-Bacon decomposition of the generalized DID estimator, which breaks down the overall treatment effect of the GHGRP (+1) into components based on comparisons across distinct timing groups. The analysis ensures robustness by limiting the sample to a balanced panel from 2009–2012, as required for accurate decomposition.

weight of 92.3%. This indicates that the generalized DID estimates are primarily driven by comparisons between the treatment group and firms that were either treated later or never treated, highlighting their importance for deriving robust insights into the impact of the facility-level GHG transparency regulation on firm-level GHG emissions reductions.

4.2 H2: Impact of Facility-Level GHG Transparency Regulation on Firm-Level Climate Change Concerns

In the H1, I find that firms subject to the GHGRP reduce their firm-level GHG emissions by an average of 8 to 11% more than firms without regulated facilities in the years following the program's implementation. However, alternative explanations for the observed reduction in firm-level emissions warrant consideration. For instance, reductions in firm-level emissions may result from changes in reporting methodologies or localized facility-level improvements rather than genuine operational progress or firm-wide sustainability efforts.

I predict that the effectiveness of facility-level transparency regulation in promoting firm-level change depends on its ability to elevate firm-level climate change concerns, driving comprehensive emissions reductions aligned with an integrated sustainability strategy. A key method for evaluating whether facility-level regulation influences firm-wide behavior is to analyze how it shifts organizational priorities and public messaging, particularly in forums

where management engages with key stakeholders. Earnings conference calls provide real-time insights into how management frames climate-related risks and opportunities, revealing the extent to which climate concerns permeate the organization and shape strategic decisions.

To test this H2, I examine whether firms subject to facility-level GHG transparency regulation experience a simultaneous increase in overall climate change concerns and negative regulatory sentiment in earnings conference calls, compared to firms without regulated facilities. This is modeled using the following equation:

$$\begin{cases} ClimateConcerns_{fit} \\ NegRegSenti_{fit} \end{cases} = \alpha_f + \alpha_{it} + \gamma * X_{ft} + \beta * GHGRP_{ft} + \epsilon_{it} \tag{3}$$

The empirical setup mirrors the main equation 1 with the dependent variables adapted to the climate change exposure measures introduced by Sautner et al. (2023). ClimateConcerns measures the relative frequency of bigrams related to overall climate change appearing in earnings call transcripts. This captures the level of attention that management and analysts devote to climate-related issues in these discussions. NegRegSenti identifies bigrams associated with regulatory discussions on climate change, conditioned on the presence of negative tone words as defined by Loughran & Mcdonald (2011). This metric reflects firms' perceptions of regulatory risks linked to climate policies, providing a detailed view of the negative sentiment surrounding regulatory climate exposure. The main policy variable of interest, GHGRP, is a binary indicator set to 1 starting in the year a firm first becomes subject to the GHGRP's implementation and in all subsequent years, and 0 otherwise. By examining these measures, this analysis evaluates how facility-level transparency regulation influences firm-wide climate concerns and the framing of regulatory risks.

The results in Table 6 provide evidence supporting H2. Firms subject to facility-level GHG transparency regulation (GHGRP) exhibit a significant increase in firm-level climate change concerns and negative regulatory sentiments in earnings conference calls, as reflected

in columns (1) and (2), respectively. The coefficient for GHGRP is positive and statistically significant at the 5% level (0.20, t=2.10). This indicates that facility-level transparency regulation elevates the attention paid to climate-related issues in earnings calls. For NegRegSenti, the GHGRP coefficient is also positive and statistically significant at the 5% level (0.11, t=1.98). This finding suggests that firms under facility-level GHG transparency regulation perceive increased regulatory risks and convey these concerns in a more negative tone during earnings calls. Overall, the findings indicate that facility-level GHG transparency regulation not only heightens firm-level climate change concerns but also intensifies negative sentiments about regulatory risks, influencing organizational priorities and public messaging. The significant GHGRP coefficients in both models support the hypothesis that such granular regulation drives comprehensive behavioral and communicative changes across firms, even when transparency is confined to the facility level.

4.3 H3: Impact of Facility-Level GHG Transparency Regulation on Firm-Level Green Innovations

While H2 demonstrates that facility-level transparency regulation raises climate change concerns across the organization, ruling out alternative explanations necessitates that these heightened concerns lead to tangible and comprehensive adjustments in emissions practices. Such changes should signify a firm-wide integration of sustainability into the overall strategy, rather than being limited to localized efforts aimed solely at regulatory compliance. To evaluate this, H3 tests whether firms subject to facility-level regulation generate more green innovations compared to non-GHGRP firms in the years following the program's implementation. This relationship is modeled as follows:

Table 6: Impact of Facility-Level GHG Transparency Regulation on Firm-Level Climate Change Concerns

	(1) ClimateConcerns	(2) NegRegSenti
GHGRP	0.20**	0.11**
	(2.10)	(1.98)
Size	-0.02	-0.01
	(-0.13)	(-0.10)
BM	-0.12	0.01
	(-0.57)	(0.08)
AI	0.22	-0.04
	(0.42)	(-0.07)
Leverage	0.30	-0.08
	(0.56)	(-0.10)
Cash	-0.46	-0.37
	(-0.88)	(-1.36)
ROA	0.36	-0.87
	(0.63)	(-1.00)
Dividend	-2.25	1.95
	(-1.20)	(1.51)
IO	-1.54*	1.17*
	(-1.82)	(1.92)
Analysts	0.15	-0.08
	(0.80)	(-0.77)
Observations	1,890	1,890
Adj R2	0.888	0.250
Firm FE	Yes	Yes
Industry-Year FE	Yes	Yes

This table presents the results of the impact of the GHGRP on firm-level climate change concerns and regulatory sentiment as discussed during earnings conference calls. The dependent variables are ClimateConcerns and NegRegSenti, which capture the frequency of climate-related discussions and the negative sentiment associated with regulatory risks, respectively, in the transcripts of these calls (Sautner et al. (2023)). The primary policy variable of interest, GHGRP, is a binary indicator equal to 1 starting in the year a firm first becomes subject to the GHGRP and continuing in all subsequent years, and 0 otherwise. This measures the contemporaneous impact of facility-level GHG transparency regulation on firm-wide climate change concerns and regulatory sentiment. Firm and industry-year fixed effects are included to control for unobserved heterogeneity across firms and industries over time. Robust standard errors, clustered by firm, are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

$$LowCarbonPatents_{fit} = \alpha_f + \alpha_{it} + \gamma * X_{ft} + \beta * \begin{cases} GHGRP_{ft}(+1) \\ GHGRP_{ft}(+2) \end{cases} + \epsilon_{it} \quad (4)$$

The empirical setup parallels the main equation 1, with the dependent variable adapted to represent the number of low-carbon patents developed by a firm. Low-carbon patents are classified according to the Cooperative Patent Classification (CPC) Y02 class, which identifies technologies with environmental benefits (Sautner et al. (2023), Cohen et al. (2024)). Data on firm-level patents are sourced from the United States Patent and Trademark Office (USPTO) and linked to public firms' patent records (Kogan et al. (2017)). To isolate the effect of facility-level regulation on green innovations that emerge after the program's implementation, I include lagged values of the GHGRP variable (e.g., GHGRP(+1) and GHGRP+2)). This captures the delayed yet potentially transformative impact of transparency regulation on firm-level green innovation.

The results presented in Table 7 provide empirical support for H3, suggesting that facility-level GHG transparency regulations foster firm-level green innovation. The coefficient for GHGRP(+1) is positive and statistically significant at the 5% level (11.65, t = 2.10 t=2.10), indicating that facility-level transparency regulations have a delayed but notable impact on the development of low-carbon patents one year after implementation. Similarly, GHGRP(+2) exhibits a positive coefficient (11.12, t=1.94), significant at the 10% level, further supporting the sustained influence of transparency regulation on green innovation two years post-implementation. These findings highlight that the regulatory effect unfolds over time, consistent with the hypothesis that heightened organizational climate change concerns drive tangible innovations. By promoting low-carbon patent development, the GHGRP plays a pivotal role in integrating sustainability into firms' broader strategic objectives.

Table 7: Impact of Facility-Level GHG Transparency Regulation on Firm-Level Green Innovations

	(1)	(2)
	LowCarbonPatents	
GHGRP(+1)	11.65**	
	(2.10)	
GHGRP(+2)		11.12*
		(1.94)
Size	7.98	7.72
	(1.58)	(1.56)
BM	0.88	0.84
	(0.46)	(0.44)
AI	-4.84	-4.76
	(-0.50)	(-0.49)
Leverage	-4.72	-4.96
	(-0.35)	(-0.37)
Cash	-13.46	-15.87
	(-1.05)	(-1.19)
ROA	15.65	15.71
	(1.33)	(1.32)
Dividend	71.25	69.62
	(1.23)	(1.16)
IO	-32.52**	-33.16**
	(-2.05)	(-2.05)
Analysts	1.37	1.48
	(0.81)	(0.86)
Observations	1,890	1,890
Adj R2	0.854	0.854
Firm FE	Yes	Yes
Industry-Year FE	Yes	Yes

This table presents the results of the impact of the GHGRP on firm-level green innovation. The dependent variable is the number of low-carbon patents developed by a firm, classified according to the Cooperative Patent Classification (CPC) Y02 class, which identifies technologies with environmental benefits (Sautner et al. (2023), Cohen et al. (2024)). Firm-level patent data are sourced from the United States Patent and Trademark Office (USPTO) and linked to public firms' patent records (Kogan et al. (2017)). The primary policy variables of interest, GHGRP(+1) and GHGRP(+2), are lagged indicators equal to 1 in the first and second years, respectively, after a firm becomes subject to the GHGRP and 0 otherwise. These variables measure the delayed impact of facility-level GHG transparency regulation on green innovation, capturing the time it may take for firms to develop and file environmentally beneficial patents in response to the program. The empirical setup includes firm and industry-year fixed effects to control for unobserved heterogeneity across firms and industries over time. Robust standard errors, clustered by firm, are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

4.4 H-4: The Sunshine Mechanism of Market Penalties for Emissions Discrepancies

4.4.1 Firm-Level Emission Discrepancies: Underreporting and the Notion of "Bad News"

The "sunshine mechanism" of facility-level GHG transparency regulation plays a pivotal role in exposing discrepancies in voluntary firm-level emissions disclosures. Standardized and verified facility-level GHG data, enforced by the EPA, reveal whether firm-level reports align with facility-level emissions. When mandatory disclosures uncover underreporting, they highlight misleading voluntary reports, serving as "bad news" for investors and triggering negative market reactions. These cases underscore the essential role of transparency in uncovering corporate misreporting and reinforcing accountability.

Table 8 illustrates these discrepancies. Firms voluntarily report an average of 31.8 million metric tons of GHG emissions at the organizational level, with a median of 20.0 million metric tons. However, the range of these disclosures is wide, from 33,164 to 143 million metric tons, reflecting inconsistent reporting practices. In contrast, standardized facility-level data reveal significantly higher emissions, with an average of 188.2 million metric tons and a median of 35.8 million metric tons. Facility-level emissions range from 131,527 to an extraordinary 1.29 billion metric tons, clearly indicating widespread underreporting in voluntary firm-level disclosures.

The stark contrast between firm-level and facility-level emissions highlights the value of the "sunshine mechanism." Facility-level transparency exposes discrepancies, providing stakeholders—including investors, regulators, and the public—with consistent and reliable information. This transparency fosters accountability by discouraging underreporting, enabling informed stakeholder feedback, and encouraging firms to align their environmental practices with societal and regulatory expectations. Ultimately, these findings reinforce the critical role of standardized facility-level reporting in revealing environmental performance

Table 8: Comparing Firm-disclosed Emissions to Aggregated Facility Emissions: Underreporting

Underreporting cases	Firm-disclosed Emissions	Aggregated Facility Emissions
N	175	175
mean	31,846,553	188,164,285
std	36,174,807	386,424,891
min	33,164	131,527
25%	5,259,330	8,529,088
median	19,974,600	35,760,559
75%	39,790,150	90,679,353
max	143,000,000	1,288,226,838

This table compares firm-disclosed emissions with aggregated facility-level emissions for cases of underreporting for the same reporting year. Firm-disclosed emissions refer to the voluntary greenhouse gas (GHG) emissions reported by firms at the organizational level, whereas aggregated facility-level emissions represent the total emissions from individual facilities owned by these firms, as reported under the Greenhouse Gas Reporting Program (GHGRP)

gaps and driving meaningful corporate accountability.

4.4.2 Standard Event Study Methodology

To assess the stock market response when prior firm-level underreporting is revealed through the mandated public disclosure of facility-level GHG emissions by the EPA, I employ a standard event study methodology. To provide a comprehensive perspective, I also analyze the opposite cases of overreporting, where firms report higher firm-level emissions compared to aggregated facility-level emissions. This overreporting is a natural occurrence since firm-level emissions are a superset of facility-level emissions. The cumulative abnormal return (CAR) is calculated over the event window [0,+4], corresponding to the disclosure events detailed in Table 1. The methodology can be summarized by the following equations:

$$K_{it} = b_i[E(R_m) - R_f] + s_i E(SMB) + h_i E(HML) + m_i E(MOM) \tag{5}$$

$$e_{it} = R_{it} - K_{it} \tag{6}$$

$$AR_t = \frac{1}{N}\sum_{i=1}^{N} e_{it} \tag{7}$$

$$CAR(0,+4) = \sum_{t=0}^{+4} AR_t \tag{8}$$

In the given equations, i represents firm (security) and t corresponds to the announcement dates of facility-level GHG information. To isolate market effects linked to mandatorily disclosed GHG information, the benchmark return (K_{it}) incorporates the Fama-French three factors (Fama & French (1996)) and the momentum factor (e.g., Jegadeesh & Titman (1993), Carhart (1997)). Abnormal return(e_{it}) is the difference between the return conditional on the event and the expected return unconditional on the event. The average abnormal return (AR_t) indicates a sample of the cross-sectional mean abnormal return of N securities for any period t. The cumulative abnormal return ($CAR(0,+4)$) represents the abnormal performance measure the sum of each date's average abnormal performance with an event window from 0 to +4. Following Campbell et al. (1998), the test statistic is calculated as follows:

$$T - statistics = \frac{CAR(0,+5)}{[D * \sigma^2(AR_t)]^{1/2}}$$

where $\sigma^2(AR_t)$ is the variance of the one-period mean abnormal return and D indicates the total number of dates in the event window.

4.4.3 H4: Event Study Results

The event study results reveal distinct stock market reactions to facility-level GHG disclosures for underreporting and overreporting cases. For underreporting firms, the cumulative

abnormal return (CAR) is -0.49%, with a statistically significant t-statistic of -2.37. This finding highlights the negative market response when discrepancies in voluntary emissions disclosures are exposed through mandatory facility-level reporting, suggesting that investors penalize firms for perceived misrepresentation. In contrast, for overreporting cases, the CAR is effectively zero (0.00%), with a t-statistic of 0.01, indicating no significant market reaction. This neutral response likely reflects the expectation that firm-level emissions, as a superset of facility-level emissions, may reasonably exceed the aggregated facility-level figures without raising investor concern.

The accompanying figure further highlights these dynamics over the event window. For underreporting firms (red line), the CARs exhibit a persistent downward trend following disclosure, reflecting sustained negative feedback from investors. In contrast, the CARs for overreporting firms (blue line) remain flat, indicating no discernible market response. Overall, these findings demonstrate the "sunshine mechanism" of facility-level GHG disclosures in exposing corporate misreporting and eliciting negative feedback from equity investors, reinforcing the importance of transparency in promoting accountability and maintaining market trust.

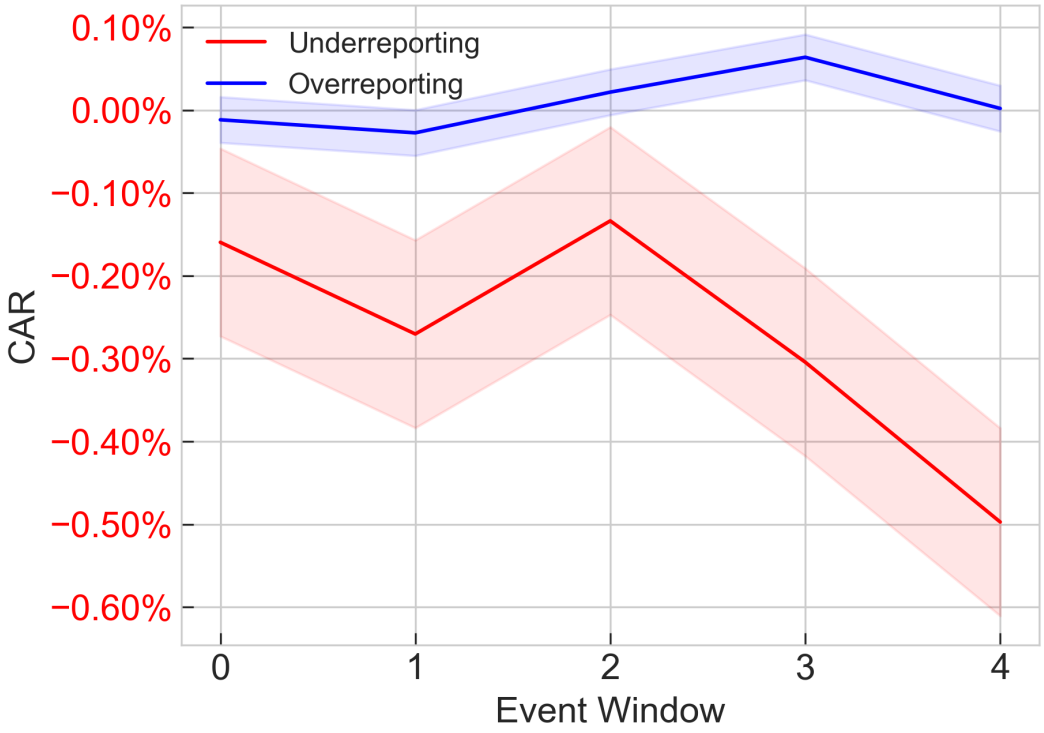
4.5 H-5: The Sunshine Mechanism of Stakeholder Reactions and Environmental Ratings

This section explores how facility-level GHG transparency regulation influences broader stakeholder perceptions, as reflected in third-party environmental ratings such as the MSCI Environment Pillar Score. These ratings provide independent evaluations of a firm's environmental performance, offering valuable insights into how stakeholders—including investors, consumers, and advocacy groups—perceive a firm's sustainability efforts.

Given that all firms in the sample had already voluntarily disclosed their firm-level emissions before and after the facility-level regulation, one might expect the regulation to have minimal additional impact on their ESG ratings, as firms were already providing value-

Table 9: Market Reactions for Emissions Discrepancies

	CAR	T-statistics	N
Underreporting	-0.49%	-2.37	175
Overreporting	0.00%	0.01	472



This table and figure present the results of the impact of facility-level GHG disclosures on cumulative abnormal returns (CAR) for underreporting and overreporting cases. The dependent variable is the CAR, which measures the abnormal stock performance over the event window [0,+4] surrounding the disclosure dates. The primary focus is on the underreporting and overreporting of emissions, where underreporting occurs when facility-level GHG disclosures reveal lower firm-level emissions than expected, and overreporting occurs when firm-level emissions exceed facility-level totals, a natural result since firm-level emissions are a superset of facility-level data.

relevant information through voluntary disclosures (e.g., Matsumura et al. (2014), Griffin et al. (2017)). However, the granular transparency introduced by the regulation may uncover inconsistencies, gaps, or potential misreporting, thereby activating a "sunshine mechanism" that brings previously unnoticed corporate shortcomings to light from a societal perspective. This mechanism prompts third-party organizations to reassess these firms' environmental practices. If voluntary emissions disclosures fail to align with the more detailed, mandatory facility-level data—or if emissions exceed stakeholder expectations—firms may face declining ESG ratings, leading to negative stakeholder reactions.

To evaluate this, the empirical approach measures how facility-level GHG disclosures affect the MSCI Environment Pillar Score, a proxy for stakeholder perceptions of environmental performance. The model is specified as follows, incorporating industry and year fixed effects, with standard errors clustered at the firm level:

$$EnvironmentScore_{fit} = \alpha_f + \alpha_i + \gamma * X_{ft} + \beta * GHGRP_{ft} + \epsilon_{it} \tag{9}$$

Here, the dependent variable is the MSCI Environment Pillar Score, and the key policy variable, GHGRP, is a binary indicator set to 1 starting in the year a firm becomes subject to the GHGRP and remains 1 in subsequent years. This analysis examines how granular transparency regulation influences external perceptions and corporate accountability.

The results, presented in Table 10, provide strong empirical support for H5. Firms subject to the GHGRP experience a significant contemporaneous decline in their MSCI Environment Pillar Scores. The coefficient for GHGRP is -0.45 and statistically significant at the 1% level (t=-2.65), indicating that facility-level transparency regulation triggers lower environmental ratings compared to unregulated firms. These findings confirm that heightened scrutiny exposes gaps in environmental practices, leading third-party evaluators and stakeholders to react negatively. The decline in ratings underscores the critical role of facility-level GHG disclosures in uncovering environmental performance gaps and reinforcing corporate accountability. By providing standardized and detailed emissions data, the GHGRP enables

stakeholders to identify areas of underperformance, compelling firms to reassess their environmental strategies. The negative impact on ratings highlights how transparency drives firms to address stakeholder concerns and align with broader societal expectations.

5 Conclusion and Policy Implication

This study explores the broader organizational impacts of facility-level GHG transparency regulation, focusing on the U.S. Environmental Protection Agency's (EPA) Greenhouse Gas Reporting Program (GHGRP). By examining firms that voluntarily disclosed firm-level GHG emissions before and after the GHGRP's implementation, the analysis provides causal evidence of how granular, facility-level transparency regulations influence firm-wide decision-making. The findings reveal that facility-level transparency regulation generates significant organizational spillover effects. Firms subject to the GHGRP reduce their firm-level GHG emissions by an average of 8 to 11% more than firms without regulated facilities, indicating that facility-level transparency incentivizes broader environmental accountability. These reductions go beyond operational changes at regulated facilities, extending to strategic adjustments across the organization. Evidence of deeper organizational change includes heightened climate change concerns, as reflected in earnings conference calls, and an increase in low-carbon patent development. These findings highlight the pivotal role of transparency as a "sunshine mechanism," driving firms to address stakeholder concerns and align their practices with societal expectations. The study also sheds light on potential negative feedback mechanisms triggered by facility-level transparency. When discrepancies between voluntary firm-level emissions disclosures and facility-level data are uncovered, firms face significant reputational and market penalties. The findings indicate a negative stock market reaction of -0.49% following disclosures of underreporting during short event windows, amounting to an estimated market value loss of approximately $49 million. Additionally, firms subject to the GHGRP experience notable declines in environmental ratings, reflecting negative stakeholder

Table 10: The Sunshine Mechanism of Stakeholder Reactions and Environmental Ratings

	(1) EnvironmentScore
GHGRP	-0.45***
	(-2.65)
Size	0.41***
	(6.50)
BM	-0.64***
	(-2.93)
AI	-0.22
	(-0.82)
Leverage	0.38
	(0.76)
Cash	0.42
	(0.72)
ROA	0.88
	(0.79)
Dividend	0.55
	(0.16)
IO	-0.44
	(-0.98)
Analysts	-0.02
	(-0.16)
Observations	1,730
Adjusted R-squared	0.208
Industry FE	Yes
Year FE	Yes

This table presents the results of the impact of the GHGRP on firms' environmental performance as measured by their MSCI Environment Pillar Scores. The dependent variable, Environment Pillar Score, offers an independent evaluation of a firm's environmental practices, covering key areas such as carbon emissions, climate change vulnerability, and natural resource management. The primary policy variable of interest, GHGRP, is a binary indicator set to 1 starting in the year a firm becomes subject to the GHGRP's implementation and remains 1 in all subsequent years. This variable captures the contemporaneous effect of facility-level GHG transparency regulation on third-party assessments of a firm's environmental performance. The empirical model incorporates industry and year fixed effects to control for unobserved heterogeneity across industries and time-specific shocks. Standard errors are clustered at the firm level to ensure robust statistical inference. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

sentiment and broader reputational risks associated with increased transparency.

From a regulatory and policy perspective, these findings highlight the need for standardized and verifiable disclosure mechanisms to enhance the effectiveness of transparency regulations. The recent U.S. Securities and Exchange Commission (SEC) rule mandating the disclosure of Scope 1 and Scope 2 GHG emissions (US SEC (2024)) represents progress in corporate transparency. However, its reliance on firm-specific calculation methodologies undermines comparability across firms and over time, limiting its ability to enforce accountability. In contrast, the GHGRP's standardized, facility-level disclosures—verified through a consistent methodology—enable more reliable cross-firm comparisons and facilitate the detection of underreporting. This study underscores that transparency only drives market discipline and accountability when paired with standardized, comparable data that enables tangible negative feedback. Without such mechanisms, firms lack meaningful incentives to align with societal expectations. These findings have important implications for regulators, investors, and corporate decision-makers. For regulators, prioritizing standardized reporting frameworks is essential to strengthening market discipline and corporate accountability. A well-structured transparency regime provides stakeholders with objective, actionable insights while preventing confusion and greenwashing. By improving the comparability and credibility of emissions disclosures, regulation can better align corporate behavior with societal climate goals, mitigate reputational risks, and drive meaningful organizational change.

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