Going Green: The Effect of Environmental Regulations on Firms

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Abstract

This paper studies the effect of environmental regulations on firm valuation by constructing a time-varying and industry-specific measure of EPA regulatory restrictions. We find that significant increases in EPA regulation restrictions are associated with an improvement in the value of the regulated firms. Investigating the potential underlying mechanism, we find that stricter EPA regulations induce green innovations and increase the marginal performance of R&D in regulated firms, reflecting an increase in innovation incentives. Moreover, the positive valuation effect is more pronounced for firms with entrenched and myopic managers, and concentrates in firms without financial constraints. Collectively, our findings are consistent with the idea that stricter environmental regulations can serve as an external disciplinary mechanism to induce value-enhancing green investment.

Keywords: Environmental Regulation, EPA, Corporate Governance, Firm Valuation, Green Innovation

JEL-Classification: K32, L51, M40, O44, Q58

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1 Introduction

With growing concerns about climate risk, firms are increasingly being held accountable for the consequences of their operations on the environment. In the United States, the Environmental Protection Agency (EPA), as the major regulatory body of environmental issues, has issued hundreds of regulations since 1970 that regulate a wide range of environmental activities carried out by firms, such as emissions of pollutants, management of hazardous waste, and efficient use of energy. What all these regulations have added up to for the regulated firms is largely unknown and becoming a question of central importance in both policy and research (Shapiro and Walker 2018).[1]

A common belief posits that these environmental regulations impose significant costs on regulated firms, reducing their productivity of the regulated firms (e.g., Palmer *et al.* 1995, Greenstone *et al.* 2012), thereby destroying shareholder value (e.g., Blacconiere and Northcut 1997). However, some studies suggest that protecting the environment does not have to sacrifice productivity (e.g., Acemoglu *et al.* 2012). Moreover, stricter environmental policies have the potential to induce managers to develop green innovations and adopt sustainable business practices that can lead to reduced energy costs and operational efficiencies (e.g., Porter and Van der Linde 1995; Jaffe *et al.* 1995; Ambec *et al.* 2013).[2] Environmental regulations, by increasing the cost of using existing production technologies and holding managers accountable for environmental violations, may reduce agency frictions and incentivize managers to invest in green innovations. If firms do engage in green innovations and these innovations are value enhancing, then firm value could increase. According to this view, in the absence of environmental regulations, managers might not voluntarily engage in green innovation if they are entrenched and short-term focused, even if such innovation has a positive net present value. More specifically, due to the separation of ownership and control, managers may not always have aligned interests with shareholders, leading to a potential reluctance to engage in value-enhancing projects (Jensen and Meckling 1976). This is particularly true for projects where the cash flow materializes in the long run but carries significant short-term costs – environmental

[1] On June 30th, 2022, the Supreme Court ruled to restrict the EPA's authority in policy-making. While the motivation for the ruling was politically complicated, it sparked a wild discussion about the overall economic effect of EPA regulations. See, e.g., "Supreme Court Puts Brakes on EPA in Far-Reaching Decision" at: https://www.wsj.com/articles/supreme-court-limits-environmental-protection-agencys-authority-11656598034.

[2] Anecdotal evidence suggests that EPA regulations could play a significant role in driving green innovation in firms. For example, the EPA's stricter fuel efficiency standards for vehicles have led to the development of more fuel-efficient engines and the proliferation of electric and hybrid vehicles. Similarly, stricter regulations on greenhouse gas emissions have spurred the development of cleaner energy sources such as solar and wind power.

projects, by their very nature, are likely to fit this profile.[3] Therefore, environmental regulation could potentially benefit shareholders of the regulated firms through a less studied mechanism: serving as an external disciplinary force to mitigate agency frictions by inducing managers to take value-enhancing green investment. While several studies show that green practices are positively associated with financial performances (e.g., Hart and Ahuja 1996, Russo and Fouts 1997, Clarkson *et al.* 2011) and that environmental regulations can spur green innovation (e.g., Aghion *et al.* 2016), there is little systematic evidence that these regulations can benefit shareholders.

In this paper, we attempt to fill this gap by examining empirically whether environmental regulations from the EPA can benefit shareholders as reflected in the valuation of the firms. The empirical challenge is that EPA regulations are overlapping in nature, and thus it is difficult to apply standard quasi-experimental research designs to isolate the effect of individual regulations one at a time. Indeed, many EPA regulations have not been analyzed through policy evaluation tools and do not have natural control groups. Moreover, firms' environmental policies at a given point in time tend to respond to the whole package of effective environmental regulations, instead of individual regulations.

To this end, we develop a tractable approach to examine the effect of the total EPA regulation restrictions on firm value and environmental policies. Our approach is motivated by the environmental economics literature (Shapiro and Walker 2018) that models the effect of total EPA regulations. Specifically, we use newly available data to develop an index to capture the total level of EPA restrictions imposed on each industry for each year, which we call the EPA Index ($\boldsymbol{EPAIndex}$).[4] This index is based on the text of all effective EPA rules contained in the Code of Federal Regulations (CFR) since 1973 and the machine-learned relevance of the regulations to each industry. The idea is that regulations create binding obligations or designate prohibited activities for regulated entities, and such binding obligations can be captured by certain terms and phrases in the regulatory text.[5] Furthermore, a given regulation (e.g., one that is related to waste management) will affect some industries (e.g., construction) to a greater degree than others (e.g.,

[3] The broader economic research highlights the important role of external pressure for managers to take innovation projects, as these projects are usually risky and typically take many years to yield results (e.g., Holmstrom 1989, Stein 1989, Edmans 2009, Manso 2011, Asker *et al.* 2015). In a survey, Graham *et al.* (2005) find that 78% of executives would sacrifice long-term value to meet short-term earnings targets, including long-term innovation activities.

[4] Industry groups are based on the six-digit NAICS classification.

[5] Following legal studies, these words include *shall, must, may not, prohibited,* and *required.*

financial). Our measure picks up both the amount of regulation in the form of restrictions and the relevance of regulations to a given industry, rendering it a unique and potent tool to investigate our research question.[6]

Using this index, we examine a sample of U.S. publicly listed companies from 1974 to 2021. We focus on public firms because we can measure their shareholder value and their data is largely available. Additionally, public corporations are particularly relevant for our research due to the inherent agency problems stemming from the separation of ownership and control between shareholders and managers (e.g., see La Porta *et al.* 1999). However, we caution that our results based on public firms may not speak to their private counterparts. Since private firms have different ownership structure than public firms, the valuation implications might be different.

We first validate our measure by exploring the evolution of EPA regulations and the industry-specific $EPAIndex$. We find that the total restrictions of EPA regulations have been increasing since the mid-1970s. The increases are notably concentrated around the adoption of important environmental regulations and programs, such as the Pollution Prevention Act and the Greenhouse Gas Permit Programs. We also find that sectors that we ex ante expect to be heavily (lightly) regulated by the EPA, such as the manufacturing (real estate) sector, have the highest (lowest) average $EPAIndex$ during our sample period. In addition, we document that significant increases in restrictions as reflected by the changes of EPA index correspond to the implementation of important industry-specific environmental regulations, such as the Toxic Substance Control Act in 1976 for the Oil and Gas industry and the Chemical Safety Information, Site Security, and Fuels Regulatory Relief Act in 1999 for the Chemical Manufacturing industry. These results provide support that our measure meaningfully captures the total restrictions of EPA regulations and can identify industry-specific variations.

To examine the effect of EPA regulations, it is important to find changes in the regulations that are not driven by the regulated firms. The ideal experiment is to compare two identical firms where one receives an exogenous increase in environmental regulation restrictions. However, this ideal experiment is clearly not possible and we cannot randomize environmental regulation restrictions at large scale. To get closer to this experiment, we follow Bertrand and Mullainathan (2003) and

[6] Note that by using this method, we do not intend to capture the variation in the strictness within a given regulation, such as changes in the thresholds for compliance with toxic release standard.

Fresard (2010) to design a quasi-experiment empirical strategy by identifying large changes in EPA restrictions for each industry and designating firms that experience the large changes as treatment firms. We define a change as "large" if the change in the EPA restrictions for a given industry in a given year exceeds two standard deviations from the industry mean. The assumption is that, for a given firm, large changes to industry-level EPA restrictions are plausibly unrelated to this firm's economic condition. To support this assumption, we show that a large set of firm level characteristics do not predict future industry level regulation changes. Accordingly, the staggered occurrences of large changes in the level of EPA restrictions across different industries and years allow us to potentially disentangle the effect of EPA regulations from other confounding forces that shape firms' environmental strategies and value during the same period. Moreover, in later tests, we find evidence consistent with the parallel trend assumption.

Adopting our research design, we begin by examining the relationship between EPA regulations and emissions of the regulated firms. We find a significant reduction in toxic chemical emissions following large increases in EPA regulation restrictions, which suggests the efficacy of environmental protection regulations, consistent with the literature studying individual regulations (e.g., Currie and Walker 2019). Moreover, we show that non-EPA regulations are not associated with reductions in pollution, and thus our results also demonstrate the validity of using the $EPAIndex$ as a means of measuring environmental regulations.

Turning to our main results, we examine the relationship between EPA regulations and firm valuation, measured by Tobin's Q. We use Tobin's Q as it captures investor valuation of firms taking into account both the potential costs and benefits of regulations (e.g., Shleifer and Wolfenzon 2002, Greenstone *et al.* 2006).[7] It is ex ante unclear how EPA regulations would affect firm value. On the one hand, stricter environmental regulations can be costly and have negative effects on firms. On the other hand, they could have the potential to mitigate agency frictions and induce managers to develop value-enhancing long-term projects that can improve shareholder value. Ultimately, it is an empirical question how EPA regulations affect firm value. We find that following stricter EPA regulations, the valuation of the affected firms significantly increases. Firms that are exposed to large increases in EPA regulation restrictions experience a 5.64% increase in Tobin's Q relative to

[7] Our results hold when using alternative measure of shareholder values, including the analysts' long-term sales growth forecast and the market-to-book ratio.

the sample standard deviation. This positive association is stronger for firms subject to greater EPA regulatory scrutiny, including those located in states with more frequent EPA enforcement actions, and during periods when the EPA has more financial resources to make and enforce regulations. In further analyses, we find evidence consistent with the parallel trend assumption: the differential positive associations between EPA regulations and firm value for treated and control firms only materialize after large changes in EPA regulation restrictions – no differential effects are observed in the years leading up to such changes. Overall, the results suggest that environmental regulations could benefit shareholders.

Next, we investigate the potential underlying mechanism behind the positive relationship between EPA regulations and firm valuation. According to the aforementioned argument, stricter EPA regulations can benefit shareholders by motivating managers to develop value-enhancing long-term projects that otherwise will not be taken due to agency frictions. An important implication of this mechanism is that stricter EPA regulations should lead to more innovation, especially green innovations, and that these investments are value-enhancing. Empirically, we first show that following stricter EPA regulations, firms increase their overall innovation, especially green innovations, measured by the number of total patent filings and environmentally-related patent filings, respectively. Treatment firms experience a 0.7% increase in the number of green patents than control firms. In the dynamic analyses, we find that there is no pre-trend and most of the significant change in innovation occurs three or more years after large increases in EPA regulation restrictions, consistent with the notion that innovation is a long-term process. We also find that the patents receive 1.6% more citations subsequently, suggesting that these innovations are of higher quality. Second, we find that firms that experienced higher value increase around stricter regulation experience a larger increase in future green innovation, suggesting that the value increase is indeed associated with the expectation that firms will increase their innovation activity in the future. Third, we examine if the investments for the innovations are value-enhancing as predicted. We find that subsequent to stricter EPA regulations, regulated firms experience significant increases in the marginal performance of R&D investment and the efficiency of investments. Similar to the innovation results, most of the significant change in investment efficiency occurs three or more years after large increases in EPA regulation restrictions. Collectively, our results suggest that innovation induced by environmental regulations can be a crucial factor contributing to the increase in firm value.

To the extent that EPA regulations can induce managers to engage in value-enhancing long-term investments, shareholder of firms with more severe agency frictions should value the external pressure more, because motivating managers to innovate are more challenging for such firms. A large stream of the literature suggests that firms with entrenched or myopic managers may substantially under-invest in long-term innovative projects, such as green initiatives (Holmstrom 1989, Edmans 2009, Asker *et al.* 2015). Accordingly, we follow the literature and use measures of management entrenchment and managerial myopia to proxy for agency frictions. Consistent with the prediction, we show that firms subject to more agency frictions experience a larger valuation increase subsequent to stricter EPA regulations. Overall, our results suggest that environmental regulations can serve as an external disciplinary force to induce value-enhancing green investment and thus reduce agency frictions.

We next explore the heterogeneity of EPA regulations on firms. We first show that the valuation increase following EPA regulations concentrates in firms without financial constraints. Specifically, for regulated firms that are more financially constrained, the positive effect of EPA regulations on their value and investment are mitigated. For firms facing high financial constraints, EPA regulations could even have negative effects on their value. This result suggests that the ability of a regulated firm to benefit from EPA regulations is contingent on having sufficient financial resources to undertake value-enhancing projects.

To further understand the heterogeneous effects of different EPA regulations, we use topic modeling analysis based on machine learning algorithms to identify the underlying topics in the EPA regulatory text. This analysis generates 14 distinctive topics; thus we decompose the EPA Index into 14 topic-specific indices. We find significant heterogeneity in the relationship between different EPA regulation types and firm value. For example, the topic labeled "Wastewater pretreatment technology," which is closely related to technology development, has the largest positive association with firm value. However, the topic labeled "Cost and Administrative" is negatively associated with firm value. The results suggest that more regulation restrictions are not necessarily better because some EPA regulations could be costly and negatively affect firm value. Rather, only effectively-designed ones could be beneficial to affected firms.

In this paper, we focus on how EPA regulations may function as an external disciplinary force to firms subject to agency frictions. However, there could be other forces that drive the positive relationship between environmental regulations and firm value. We would like to highlight that although these other mechanisms may co-exist with our documented channel, they are unlikely to explain both our cross-sectional analyses on agency frictions and the results on innovation. Still, we explore some of these alternative channels. The first alternative explanation we explore is whether a disproportional regulatory burden falls on small firms to the benefit of larger ones, which may be induced by small firms' lack of economies of scale to handle the fixed-cost component of compliance (Brock and Evans 1985) or large firms' lobby activities (Salop and Scheffman 1983). We find that the valuation effect of EPA regulations is similar for large and small firms, and that our main results are not driven by weak firms exiting the stock market when we conduct additional tests that require firms to exist both before and after the regulation restriction increases. In addition, at the sector level, we examine the number of total establishments, firms, and employees using the Statistics of U.S. Business (SUSB) data, and we do not find significant changes in firm composition following stricter environmental regulations. Furthermore, the results are robust to controlling for industry-level competition and firms' total spending of lobby for issues broadly relating to environmental regulations. Second, we examine whether the valuation results are driven by investor attention to green companies. Inconsistent with this interpretation, we find that our main results hold at times of both high and low investor attention to environmental, social, and corporate governance (ESG) topics. Third, we do not find differential results for consumer-oriented versus non-consumer-oriented industries. Fourth, we show that the relationship between EPA regulations and firm valuation is similar for firms facing high and low environmental policy uncertainties, which is inconsistent with the view that the results are driven by reduction in regulatory uncertainty.

Lastly, we conduct additional analyses and robustness tests. First, to address the concern about reverse causality, we examine whether the treatment firms and control firms share similar trends regarding the outcomes prior to large regulation restriction changes. For example, if EPA regulations specifically target firms with increasing innovative output or value, we should expect to observe a pattern where the targeted firms exhibit higher innovation activities prior to EPA regulations compared to the control firms. Overall, we do not find any significant differences in Tobin's Q, the number of green patents, patent citations, or R&D intensity between the treatment and control firms in the years leading up to such changes. Rather, the significant and positive associations between EPA regulations and firm outcomes only materialize after large changes in

EPA regulation restrictions. Second, we show that our results are unlikely to be explained by concurrent regulation changes. Changes in non-EPA regulations do not predict changes in firm value and future innovations, and the effect of EPA regulations survives after controlling for concurrent non-EPA regulations. Third, we show that our results are not driven by other ESG-related forces, as the results remain after controlling for firms' ESG performance. Fourth, our results are robust to alternative estimation windows and alternative industry classification using text-based industry network classification.

This paper contributes to the literature in several ways. First, we attempt to understand whether and how environmental regulations affect firms value. Since 1982, public companies have been obligated to disclose information related to their compliance with environmental regulations in their annual reports, suggesting that such information is considered value-relevant. However, the existing literature has little evidence related to the direct effect of enacted environmental regulations on firm value.[8] Prior studies reach mixed conclusions regarding the impact of environmental regulations on firms' productivity, growth, investment, and innovation (e.g., Jaffe and Palmer 1997, Rubashkina *et al.* 2015, Ambec *et al.* 2013, Greenstone *et al.* 2012, Brown *et al.* 2022). In this paper, we study the effect of environmental regulations on firm valuation and apply a flexible approach that accounts for all effective rules of the EPA. Our approach echoes the environment literature (Shapiro and Walker 2018) that models the effect of total environmental regulations. We find that environmental regulations from EPA systematically affect firms' environmental strategies and value.

Second, we add to the research strain that examines how regulations operate as an external governance mechanism on firm outcomes (e.g., La Porta *et al.* 2000). Prior studies show that anti-takeover laws that govern the market for corporate control shape corporate innovation (e.g., Atanassov 2013, Sapra *et al.* 2014), labor mobility (Dey and White 2021), and value (Bhojraj *et al.* 2017). Regulations that govern firms' dismissal of employees (Acharya *et al.* 2014) can also affect corporate innovation and performance. More broadly, this paper relates to the corporate governance theories that highlight how agency frictions affect long-term investment and growth (e.g., Holmstrom 1989, Stein 1989, Manso 2011), and the important role of outside pressure in

[8]Related literature suggests that a company may voluntarily choose to expand its business into a country with stricter environmental regulations, and its valuation tends to be higher relative to firms in its home country (e.g., Dowell *et al.* 2000).

mitigating these frictions. A number of studies show various mechanisms providing such pressure, such as compensation packages (Edmans *et al.* 2017) and product market competition (Giroud and Mueller 2011). In this paper, we attempt to show that environmental regulations could provide such pressure by inducing managers in firms subject to agency frictions to engage in value-enhancing long-term projects.

Finally, we contribute to the growing literature on the corporate effect of environmental-related factors (e.g., see the review papers from Hong *et al.* 2019, Christensen *et al.* 2021 and Giglio *et al.* 2021). Prior studies show that various environmental factors, such as liabilities (e.g., Barth and McNichols 1994, Hughes 2000), environmental performance (e.g., Hamilton 1995, Clarkson *et al.* 2011, Khan *et al.* 2016, Bolton and Kacperczyk 2021, Hsu *et al.* 2023), disclosures of environmental risk or performance (e.g., Blacconiere and Patten 1994, Christensen *et al.* 2017, Chen *et al.* 2018), and sustainability-related hiring (Darendeli *et al.* 2022) can affect firm value and environmental strategies. Studies in this literature often use measures of carbon intensity or environmental friendliness as proxies for expected regulatory climate risk (Giglio *et al.* 2021). We directly measure enacted environmental regulation restrictions based on a complete list of EPA rules and provide empirical evidence that environmental regulation is an important factor driving firms' green strategies and valuation.

The rest of the paper is organized as follows. Section 2 discusses the institutional background and develops hypotheses. Section 3 describes the data and outlines the methodological details for the construction of the EPA Index. Section 4 presents research design and the main empirical results. Section 5 discusses the additional analyses. We conclude in Section 6.

2 Institutional Background and Hypotheses Development

2.1 Institutional Background

In 1970, in response to heightened public concerns about pollution, the EPA was established to develop and enact federal regulations to protect human health and the environment.[9] Initially, the EPA was charged with the administration and enforcement of the Clean Air Act (1963), the Federal Environmental Pesticide Control Act (1972), and the Clean Water Act (1972). By the

[9] The EPA regulations are all codified under Title 40 of the Code of Federal Regulations (CFR Title 40), which is the official record of effective rules created by the federal government and is revised annually.

mid-1990s, the EPA enforced 12 major statutes, including laws designed to control uranium mill tailings, ocean dumping, and safe drinking water. In addition to drafting, enacting, and enforcing new regulations, the EPA continues to refine existing ones. In 1987, the Clean Water Act was reauthorized, and in 1990, the Clean Air Act (CAA) was also reauthorized with amendments. As of 2021, the EPA consists of 12 divisions and has 10 regional offices with 14,297 employees who oversee the implementation of diverse programs in different regions and industries. To ensure that the regulated community complies with environmental laws and regulations, the EPA conducts inspections, evaluations, and investigations, and enforces its findings through fines, sanctions, and other procedures (e.g., civil and judicial procedures).

The EPA's environmental standards typically require and incentivize firms to reduce pollution and achieve compliance in two primary ways: pollution prevention at the source and pollution cleanup. Pollution prevention, as formally defined by the EPA under the Pollution Prevention Act (P2 Act) of 1990, generally refers to practices that reduce the amount and associated environmental effect of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment prior to recycling, treatment, or disposal.[10] To prevent pollution at the source, companies can modify equipment, technology, and production processes, reformulate or redesign products, substitute raw materials, and improve housekeeping, maintenance, training, or inventory control. Pollution cleanup generally refers to handling pollution after it is produced, and is typically achieved through practices like waste management, recycling, energy recovery, and treatment and disposal of hazardous substances, pollutant, or contaminants.[11]

[10] See, e.g., https://www.epa.gov/p2/pollution-prevention-law-and-policies

[11] One of the EPA's compliance strategies is to design regulations and standards that incentivize companies' use of innovative and alternative technologies for pollution reduction. For example, on September 23, 2021, the EPA issued a final rule establishing a comprehensive program to cap and phase down the production and consumption of climate-damaging hydrofluorocarbons (HFCs), as mandated by the American Innovation and Manufacturing (AIM) Act enacted in December 2020. This regulation aims to encourage manufacturers to develop climate-friendly and energy-efficient HFC alternatives and new technologies. Additionally, the EPA has introduced various programs to promote energy efficiency, environmental stewardship, sustainable growth, air and water quality, and pollution prevention. Some of these infuse direct financial support into businesses to promote innovation and develop environmentally progressive technologies. Overall, the EPA increasingly uses incentive-based policies to address environmental issues, theorizing that well-designed market-based regulatory approaches offer firms flexibility to pursue the least costly abatement method and incentivize technological innovation.

2.2 Related Literature and Conceptual Framework

Public concerns over the impact of firm activities on the environment and the limit of market forces in addressing these environmental issues have given rise to the demand for environmental regulations. Prior studies on environmental regulations primarily focus on the intended impact of environmental regulations on improving water or air quality (e.g., Henderson 1996; Chay and Greenstone 2005). However, the systematic effect of environmental regulations on firms is still unclear and is at the center of public and academic debate. Many earlier studies have investigated individual regulations, such as those from the Clean Air Act or the Clean Water Act, and thus are limited in speaking to the broader effect of environmental regulations, which require firms to comply with a range of enacted regulations at any given time. Furthermore, evidence regarding how environmental regulations impact firm performance and investments based on individual regulations is mixed, and as a result, it is not clear how EPA regulations affect firms overall.

On the one hand, a stream of literature suggests that stricter environmental regulations can be costly and have negative effects on firms. Direct compliance costs associated with the regulations can be substantial (Jaffe *et al.* 1995, Joshi *et al.* 2001), and firms may need to divert resources from other profitable projects for pollution abatement (e.g., Gray and Shadbegian 1998). Therefore, the implementation of environmental regulations can increase production costs and reduce firm profits and productivity (e.g., Palmer *et al.* 1995, Joshi *et al.* 2001, Greenstone *et al.* 2012).[12] In addition, with stricter environmental regulations, firms could be subject to strong sanctions and litigation risk (e.g., Barth and McNichols 1994, Hughes 2000). Because of the costs associated with environmental regulations, investors may assign low valuations to firms that need to comply with a large number of environmental regulations. Accordingly, Blacconiere and Northcut (1997) study stock price reactions to the EPA Superfund Amendments and Reauthorization Act (SARA) of 1986 and find that firms with greater exposure to Superfund costs experienced a more negative market reaction.

On the other hand, certain theoretical works suggest that properly designed environmental regulations can benefit firms by inducing value-enhancing innovative activities (Porter 1991, Porter and Van der Linde 1995). To comply with stricter environmental regulations, firms may invest

[12] As a result of costs, firms may respond by migrating to other jurisdictions (e.g., Levinson 1996). However, as discussed in Carruthers and Lamoreaux (2016), the empirical findings on firm locations are mixed.

in technologies that lead to green innovations and improved production processes, and thus can reduce emissions and increase efficiency at the same time. Such investments could help firms achieve cost advantages and increase their overall productivity levels.[13] Empirically, studies find supporting evidence that more exposure to environmental regulations can promote innovation activities (Rubashkina *et al.* 2015), have a positive effect on R&D expenditures(Jaffe and Palmer 1997, Brown *et al.* 2022), improve corporate productivity (Lyon and Maxwell 1999), and increase market shares (Ambec *et al.* 2013). Relatedly, some studies show that efforts to reduce emissions are positively associated with the "bottom line" and profit growth, especially for firms with the highest emission levels and in the long run (Hart and Ahuja 1996, Russo and Fouts 1997, Clarkson *et al.* 2011).

In a world without agency conflicts, one would expect that managers should have voluntarily adopt all actions that could maximize shareholders' values in the absence of environmental regulations. However, due to the separation of ownership and control, managers may not have aligned interests with shareholders to always engage in value-enhancing projects (Jensen and Meckling 1976). Moreover, managers might not voluntarily engage in green innovation if they focus on short-term gains at the expense of long-term growth, even if such innovation has a positive net present value. Research shows that managers may under-invest in value-enhancing projects due to agency frictions (e.g., Holmstrom 1989, Stein 1989, Manso 2011). For example, a large research stream focuses on how managerial myopia may deter firms' pursuit of optimal investments. This is especially true for innovative projects that are usually risky and typically take many years to yield results (e.g., Holmstrom 1989, Edmans 2009, Asker *et al.* 2015).[14] In a survey, Graham *et al.* (2005) find that 78% of executives would sacrifice long-term value to meet short-term earnings targets, including innovation activities that are inherently high-risk, unpredictable, and long-term. Therefore, in the absence of environmental regulations, managers might not have the proper incentives to engage in green innovation.

[13] Porter *et al.* (1995) discuss two broad categories of innovation in response to environmental regulation: (1) new technologies and approaches that minimize the cost of dealing with pollution once it occurs; (2) improving resource productivity to address the root causes of pollution.

[14] Empirically, Dechow and Sloan (1991) find that CEOs cut R&D spending in their final years in office due to their focus on short-term performance. Bushee (1998) finds that managerial myopia induced by transient institutional investor holding is associated with low R&D spending. Bens *et al.* (2002) document that managers cut R&D spending after stock option exercises to avoid diluting earnings per share. Laux and Ray (2020) show that firms reduce innovative activities to compensate for short-term earnings pressures.

Environmental regulations increase the cost of continuing using the existing production technologies for the regulated firms, and in some cases, directly hold managers accountable for the failure to reach environmental targets.[15] Therefore, environmental regulations can create incentives for managers to invest in green technologies and innovation to comply with environmental regulations. Existing case studies show that environmental regulations induce technological innovation. For example, Taylor *et al.* (2005) find that following the CAA requirement that electric utilities install scrubbers to remove pollutants from power plant smokestacks, companies developed new scrubbers that were much less expensive than the utilities' initial projections. Empirically, Jaffe and Palmer (1997) analyze a panel of manufacturing industries and find that lagged environmental compliance expenditures have a significant positive effect on R&D expenditures. Lanjouw and Mody (1996) compare patents in different countries and find that rising environmental compliance costs influence subsequent increases in environmental patenting rates. Johnstone *et al.* (2010) examine the effects of different renewable energy policies and find that certain types of environmental policies, such as tradable energy certificates, can induce technological innovation. Based on the previous discussion, the overall impact of environmental regulations on firm value is ultimately an empirical question.

3 Data and Measurement

To systematically examine the effect of EPA regulations, we build an index that captures the total restrictions imposed on each industry per year based on the universe of effective EPA regulations. Our data source is from the Mercatus Center RegData Database (McLaughlin and Nelson 2021), which uses both electronic copies of the complete annual CFR data after 1997 and scanned book pages for the years 1973–1996. In this section, we describe the construction of the yearly EPA Index from 1974 onward, then validate the index by examining its characteristics and key EPA regulation restriction changes.

[15] For example, former Long Island defense contractor and its CEO were ordered to pay over $48 million in cleanup costs and penalties for environmental violations (https://www.justice.gov/usao-edny/pr/former-long-island-defense-contractor-and-its-ceo-ordered-pay-over-48-million-cleanup). CEOs may also have adverse career outcomes following environmental violations (see e.g., https://arstechnica.com/cars/2015/09/volkswagen-ceo-resigns-amid-emissions-test-cheating-scandal/)

3.1 Measuring the *EPA* Index

3.1.1 Part-Level EPA Regulation Restriction

The *EPA* Index has two components: (1) the restrictiveness of each EPA regulation and (2) the relevance between EPA regulations and industry groups. To quantify restrictions, we use the text of all effective EPA regulations contained in CFR-40 (e.g., Al-Ubaydli and McLaughlin 2017, Gutierrez and Philippon 2017). CFR Title 40's printed volumes are revised each July and issued once per calendar year. New regulations that take effect during the year will be added to the revised version, and rescinded regulations will be removed. The CFR text is subdivided into chapters, subchapters, parts, sections, subsections, paragraphs, and subparagraphs, with varying levels of consistency. Each part tends to focus on a set of related issues that bear similar relevance across certain industries. Therefore, the part level is consistently referenced in the regulatory text. For example, parts 50-90 are air-related regulations, and parts 100-149 are about water programs, and part 700-799 contain regulations under the Toxic Substances Control Act. Throughout this paper, we use the regulatory text in each CFR part as the unit of the analysis.

To quantify regulatory restrictiveness, the legal literature has proposed certain terms and phrases typically used in legal documents to create binding obligations or designate prohibited activities. These words include *shall, must, may not, prohibited,* and *required.*[16] Rather than merely counting the number of new rules or the number of pages added to the CFR, this approach meaningfully measures the total amount of regulations' restrictiveness, which captures the intention of regulation to create binding obligations or designate prohibited activities (Al-Ubaydli and McLaughlin 2017). We scale the number of restrictive words by the total number of words in each part to get a part-level restrictiveness ratio, denoted by $RestrRatio_{p,t}$, where p and t index parts and years, respectively. The part-level word counts are from the Mercatus Center RegData Database. [17]

3.1.2 Industry-Year Relevance Score

The second component of the *EPA* Index is the industry relevance of EPA rules. Since EPA

[16] For example, part 63 subpart GGG in 2014 has more than 180 "must" and 800 "shall". Danet (1980) and Trosborg (1995) examine the use of the English language in the legal process and find that word choices like "shall" and "must" are employed to impose a high degree of obligation on the addressee.

[17] Note that our measure does not intend to capture the changes in the thresholds of regulations, although it could be another interesting aspect of regulations.

regulations do not uniformly affect firms across industries, they are subject to varied levels of total EPA restrictions. [18] Therefore, our next step is to capture the variation in relevance of each EPA regulation by industry. The Mercatus Center (McLaughlin and Nelson 2021) has developed supervised machine-learning algorithms to estimate industry-level scores that indicate a CFR part's likelihood of targeting a six-digit NAICS industry. We use this score to identify the regulations relevant to each industry. The Center uses the Federal Register as training data and searches all proposed and final rules published therein from 2000 to 2016 for exact matches of either the full NAICS industry name, parent industry name, or child industry name as indicators of direct relevance to a given industry. Using this training sample, they build classification models that learn what text patterns can best identify a specific industry. To build the models, they employ two algorithms: logistic regression with a Lasso penalty and Random Forests. To assess the models' effectiveness, e.g., in mitigating overfitting and obtaining low bias and variance, the Center tunes and compares them through fivefold cross-validation and uses the average F1 score across all classes. Then they apply the prediction models to each CFR part and estimate the relevance scores of the part text to each industry. Therefore, each CFR part has a relevance score for each six-digit NAICS industry. We refer interested readers to McLaughlin and Nelson (2021) for more detail about the estimation process.

The relevance score falls between 0 and 1, where a higher score indicates a greater likelihood that a given text targets an industry. Because the CFR is revised annually, the relevance scores are also updated every year. We refer to the relevance scores as $Relevance_{j,p,t}$, where j indexes six-digit NAICS industries, p indexes parts, and t indexes years. The final sample includes part-level relevance scores for 1,034 six-digit NAICS industries for each year from 1973 to 2019.

3.1.3 The Industry EPA Index

Using the part-level restrictiveness ratio ($RestrRatio_{p,t}$) and the part-industry-level relevance score ($relevance_{j,p,t}$), we construct a time-varying and industry-specific EPA regulatory restriction index. First, we calculate the total EPA restrictions imposed on each industry per year. For industry

[18] See, the EPA's regulatory information by business sector at https://www.epa.gov/regulatory-information-sector. EPA also lists specific regulations and their corresponding CFR regulation text that apply to individual industries. For example, 40 CFR part 63 subpart GGG contains regulations that are particularly relevant to the pharmaceuticals production industry, as discussed in https://www.epa.gov/stationary-sources-air-pollution/pharmaceuticals-production-industry-national-emission-standards.

j in year t, we calculate its exposure to part p by multiplying the part-level restrictiveness ratio with the relevance score of the part to the industry, denoted by

$$IndRestrRatio_{j,p,t} = RestrRatio_{p,t} \times Relevance_{j,p,t} \tag{1}$$

To reflect that lengthier parts are typically more important, we assign a weight to each part based on the part's size. Specifically, we use the total number of words in a part scaled by the total number of words in all EPA parts as the weight, denoted by $Weight_{p,t}$.[19] Then, we aggregate all EPA parts to obtain the level of total EPA restrictions for industry j in year t, denoted by $EPAIndex^{Ind}_{j,t}$

$$EPAIndex^{Ind}_{j,t} = \sum_{p} IndRestrRatio_{j,p,t} \times Weight_{p,t} \tag{2}$$

The $EPAIndex^{Ind}_{j,t}$ is a time-varying and industry-specific measure of EPA restrictions, which we denote as the EPA Index.

3.1.4 Validating the EPA Index

We conduct a series of analyses to validate our measure of EPA regulation restrictions. First, we show that total restrictions increase in the full sample following the passage of significant regulations. Second, we rank sectors by their average EPA Index. Third, we examine the evolution of the EPA Index for selected representative industries.

Figure 1 presents the time series of the average level of total EPA regulation restrictions from 1974 to 2019. The graph shows that restrictiveness level has increased over time. The first significant increase corresponds to the passage of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also called "Superfund," in 1980. This act authorized the EPA to regulate sites contaminated by hazardous waste disposal and established a funding mechanism for assessment and cleanup. The restrictiveness level further rose when the Clean Air Act was amended in 1990 and the Energy Star program was launched in 1992. Between 1994 and 2007, overall EPA regulation restrictions increased rapidly. These escalations substantiate that the total restrictions of EPA regulations generating our EPA Index capture the intensity of environmental policies over time.

[19] Both relevance score and weight are in percentage.

Table 1 presents the average EPA indices at the NAICS sector level during the period between 1974 and 2019. We find that Manufacturing is the most heavily regulated sector by EPA, with a mean EPA Index of 9.447. Such finding is consistent with Shapiro and Walker (2018) where environmental regulations are main the driving forces in the reduction of air pollution emissions in the manufacturing sector. The second most-regulated sector is the retail trade sector, e.g., its hazardous waste control is heavily regulated.[20] Not surprisingly, the waste management, agriculture, utilities, and mining sectors are also among the top regulated sectors based on their EPA indices, whereas the finance and the real estate sectors have the lowest mean EPA indices. The findings further validate our index that sectors expected to be more heavily regulated by the EPA tend to have higher EPA indices.

Figure 2 presents the time series of changes in EPA indexes for selected representative industry groups. For the Oil and Gas industry (NAICS code 211), the jump of EPA Index in 1976 corresponds to the passage of the Toxic Substances Control Act, and in 1987 to the passage of the Water Quality Act. In addition, the index indicates significant increases in total restrictions in the early 1980s and around 2008. During these periods, the EPA issued several acts, including the Environmentally Hazardous Chemical Act in 1985 and the amendment of the final rule for air pollution emissions control, released at the end of 2008. For the Chemical Manufacturing industry (NAICS code 325), the restrictiveness of EPA regulations significantly increased in 1990 and 1997, following the Clean Air Act Amendment and the Ozone National Ambient Air Quality Act, respectively, suggesting that air quality regulations exert a major impact on the Chemical Manufacturing industry. There is another sizable increase around 1999, following implementation of the Chemical Safety Information, Site Security and Fuels Regulatory Relief Act, which directly regulates chemical use.

Overall, the above evidence suggests that our EPA Index can capture variation in the restrictiveness of environmental protection regulations for different industries.

3.2 Sample and Descriptive Statistics

Firm financial and accounting information comes from the Compustat quarterly database. Since the EPA Index is constructed every July, we identify firms' fiscal quarter immediately following

[20] See "Strategy for Addressing the Retail Sector under the Resource Conservation and Recovery Act's Regulatory Framework", https://www.epa.gov/hwgenerators/strategy-addressing-retail-sector-under-resource-conservation-and-recovery-acts.

July. For example, the fiscal quarter that immediately follows July in year t for a December-fiscal-year-ending firm is the third fiscal quarter that ends in September in year t. We calculate the firm's Tobin's Q at the end of the identified fiscal quarter.[21] Next, we add other firm-level characteristics, including size, SG&A intensity, R&D intensity, leverage, return-on-assets (ROA), cash, institutional ownership, and industry-level sales growth measured in the fiscal quarter preceding the Tobin's Q measure.

We obtain facility-level toxic release data from the EPA Toxic Release Inventory (TRI) website. This data tracks the emission of toxic chemicals reported by industrial facilities, and is widely used in the literature to measure firms' environmental performance (e.g., Choy *et al.* 2021).[22] We obtain information on firm patents from a comprehensive patent database developed by Kogan *et al.* (2017) that includes the number of patents filed each year, their citations, and the classification codes used between 1926 and 2019. [23] We further identify firms' green patents following the procedure published by the Organization for Economic Cooperation and Development (OECD) (Haščič and Migotto 2015), and we identify environmentally-related patents from the full patent database based on the Cooperative Patent Classification (CPC) codes. The CPC system classifies patents based on their underlying technologies; green patents are those with environmentally-related technologies[24]

Our main test sample consists of 107,169 firm-year observations from 1980 to 2019 with non-missing variables[25] Appendix A defines the variables and provides detail regarding their construction and data source. All continuous variables are winsorized at the 1st and 99th percentiles to mitigate the influence of outliers. Table 2 presents summary statistics of the variables used in various tests.

[21]Using an annual-level sample generates similar results.

[22]Industrial facilities that have at least ten full-time employees in TRI-listed industries and those that use and emit TRI-listed chemicals exceeding certain thresholds are mandated to report their chemical releases to the TRI. To match the facility-level data with Compustat firms, we first match the names of the parent companies of each facility from the TRI database with the Compustat firm names using a fuzzy matching technique. Then, we manually check all matches to ensure that they are correct.

[23]The patent database complied by Kogan *et al.* (2017) is available online and extended till 2020 (https://github.com/KPSS2017/Technological-Innovation-Resource-Allocation-and-Growth-Extended-Data). An important concern about patent data is the potential truncation bias as discussed in Lerner and Seru (2022). The newer and more complete data we use has corrected for the potential truncation bias.

[24]For example, the CPC code B01D53/34-72 identifies post-combustion technologies related to the chemical or biological purification of waste gases. The CPC codes starting with Y02E identify technologies related to climate change mitigation relevant for energy generation and transmission of distribution.

[25]Institutional ownership data became available in 1980. All our results hold without requiring the availability of institutional ownership data.

4 Main Empirical Tests

4.1 Empirical Strategy

To test the effect of EPA regulations on firms, we follow the research designs in Fresard (2010) and Valta (2012) and implement a generalized difference-in-differences strategy by identifying large changes in EPA restrictions at the industry-year level for each six-digit NAICS code.[26] We consider treatment (control) firms as firms in industries that are (are not) exposed to large changes in EPA regulation restrictions. For a given firm, large changes to industry-level EPA restrictions are plausibly unrelated to an individual firm's economic conditions. In untabulated results, we regress the future $EPA\ index$ on current firm characteristics used in our analyses and find that none of the firm characteristics predict future EPA regulations. To account for the expectation that a regulation's effects extend beyond the year of initiation, we create the variable $PostEPA_{j,t}$ that equals 1 (-1) for the four-year periods between year t and t+3, where year t marks the year when industry j experiences a larger than two-standard-deviation increase (decrease) in the EPA Index relative to the average increase (decrease) in industry j, and zero otherwise.[27] We then estimate the following ordinary least squares (OLS) regression for our main tests:

$$Y_{i,t+n} = \beta \times PostEPA_{j,t} + \delta \times X_{i,t} + \eta \times Z_{j,t} + \alpha_i + \lambda_t + \epsilon \tag{3}$$

where the subscripts i, j, and t index firms, industries, and time, respectively. Y is an outcome variable of firm i in time $t+n$, where n is the number of time periods after the current time period t. $X_{i,t}$ and $Z_{j,t}$ are firm- and industry-level control variables that may be associated with firm outcome variables based on the prior literature, including firm size ($Size$), SG&A intensity ($SG\&A$), R&D intensity ($R\&D$), firm leverage ($Leverage$), return-on-assets (ROA), cash balance ($Cash$), institutional ownership (IO), and industry-level sales growth ($IndSalesGrowth$), measured in the period preceding the dependent variable. Across all specifications, we include firm fixed effects (α_i) and year fixed effects (λ_t) to control for any time-invariant firm- and time-specific characteristics that can affect firm value and corporate policies. Standard errors are clustered at the six-digit NAICS

[26] Fresard (2010) and Valta (2012) use sizable import tariff reductions at the industry-year level to identify intensified competition.

[27] All our inferences remain the same if we set $PostEPA_{j,t}$ equals to 1 (-1) for 1 to 3 year-periods starting in year t for the affected industry j.

code level. This approach allows us to compare firm outcomes in industries that have experienced large restriction changes to those that have not experienced large restriction changes. The generalized difference-in-differences research design relies on an important identification assumption that treated and control firms share parallel trends before the treatment. In Section 5, we test the parallel trend assumption and find no preexisting trends.

4.2 EPA Regulations and Environmental Outcomes

First, we investigate whether EPA regulations successfully reduce pollution and improve environmental issues. To test this, we examine one-year-ahead toxic chemical releases following EPA regulations. We obtain the necessary data from the EPA's Toxic Release Inventory (TRI) database, which lists toxic chemical emissions by industrial facility, including chemicals that can cause cancer and other chronic diseases. We apply the baseline model and examine the effect on pollution at the facility-chemical level. Since the list of chemicals that requires reporting to the TRI database vary over time, examining facility-chemical level data mitigates the concern that our results are driven by the inclusion or exclusion of a certain chemical in the TRI database. Following prior literature, we include facility-chemical-level fixed effects and chemical-year fixed effects to control for time-invariant heterogeneity at the facility-chemical level and the chemical-year level. e also include firm- and industry-level control variables. Standard errors are clustered at the firm level.

Table 3 presents results for the effects of EPA regulation on future facility-level toxic releases. We find that stricter regulations are associated with a statistically significant reduction in total toxic chemicals at the facility level in the following year. The effect is economically significant: firms subject to large increases in EPA restrictions experience a 6.7%–8.2% decrease in total toxic releases (in tons). These results suggest that EPA regulations are effective and that more restrictive regulations can reduce pollution and thereby ameliorate environmental issues.

4.3 EPA Regulations and Firm Valuation

We then turn to our main result and examine the relationship between EPA regulations and firm valuation. As discussed in the hypothesis development section, in theory, the effect of EPA regulations on firm valuation is unclear. EPA regulations may lead to excessive compliance burden, resulting in a decrease in firm value, but can also correct under-investment, leading to increased firm value. In this subsection, we empirically examine the relationship between EPA regulations and firm valuation to gauge the valuation effect of EPA regulation restrictions on firms. To assess firm valuation, we use Tobin's Q, which is measured as the market value of equity plus the book value of debt scaled by the book value of assets. The measure, developed from the q-theory literature, reflects the market's valuation of a firm relative to its book value (e.g., Tobin 1969, Hayashi 1982).

Panel A of Table 4 presents the regression results of the effect of EPA regulations on firm value. Column (1) shows the baseline regression results without any control variables, and column (2) presents the results including additional control variables that may affect firm values as suggested in the literature. The coefficient of $PostEPA$ is 0.157, which suggests that firms exposed to large increases in EPA regulation restrictions experience a 5.64% increase in Tobin's Q relative to the sample standard deviation. Including control variables does not significantly alter the coefficient estimate of $PostEPA$. In column (3), we further control for the impact of industry-level competition, measured by the industry sales Hirfindahl-Hirschman Index of the 6-digit NAICS code industry that the firm is in, and the lobby interest of firms, measured by the total spending of lobby for issues broadly relating to environmental regulations. The idea is that the response of firm value following stricter EPA regulations might be impacted by the competitive environment that firms face, as higher compliance costs associated with regulations might drive out certain firms in the market and change the competition environment. In addition, we may expect that the valuation implication of EPA regulations is impacted by firms' lobby activities, as prior literature on lobby (e.g., Lyon and Maxwell 2004) suggests that firms spending more on lobbying relating to environmental regulation issues, either for or against, are more likely to respond to changes in EPA regulations. We show that the coefficient on $PostEPA$ remains positive and significant after these additional forces are controlled for, suggesting that our results hold even considering the forces of market competition. Additionally, we test whether the effect on firm value is symmetric with increased or decreased regulatory restrictiveness. In untabulated results, we find that while firm value significantly increases following a large increase in regulation restrictions, there are no significant results for decreases, suggesting that regulation has a stronger effect than deregulation.[28] Also, we do not find a reduction of firms' assets in place, suggesting that the increase in Q is unlikely to be mechanically driven by divestment. Lastly, we use market capitalization scaled by lag total

[28] We also replicate this test for other dependent variables from our main analyses and reach similar conclusion.

assets and analysts' long-term forecast of sales as alternative measures of firm value, and find similar results. Overall, the evidence suggests that stricter EPA regulations are associated with an increase in firm value.

In Panel B, we further investigate whether regulatory intensity strengthens the positive relationship between EPA regulation restrictions and firm value. First, we examine whether firms located in states with more EPA regulatory activities experience a larger valuation increase. Prior studies have shown that greater county regulatory oversight is associated with a larger improvement in air quality (e.g., Henderson 1996, Choy *et al.* 2021). Therefore, in states where the EPA conducts more regulation and has a stronger presence, firms' decision-making may be more affected by agency regulations. To capture the level of state EPA oversight, we construct a variable, $HighEnforcementRank$, that equals one if the state has above median EPA enforcement actions in a year, and zero otherwise. Consistent with this view, we find a positive and significant coefficient estimate of the interaction between $PostEPA$ and $HighEnforcementRank$. Second, we use the budgets of the state EPAs as another proxy for regulatory intensity. We construct a variable, $HighEPABudget$, that equals one if the EPA has above cross-section median annual budgets in a year, and zero otherwise. In line with the regulatory intensity strengthening the effect of EPA regulation restrictions on firm value, we show a significantly positive coefficient estimate of the interaction between $PostEPA$ and $HighEPABudget$.

4.4 EPA Regulations and Firm Innovation

Next we examine the relationship between EPA regulations and future firm innovation. We use the patent database containing annual patent filing information for U.S. firms developed by Kogan *et al.* (2017) to identify firms' total innovations. We also identify firms' green innovations, proxied by the number of patent filings containing environmentally-related technologies following the OECD-proposed classification strategy (Haščič and Migotto 2015). Since innovation is realized over time and a typical investment plan involves a two-to-three-year implementation window (e.g., Brooks 2000, Atanassov 2013), we look at firms' three-year-ahead total patent filings and green patent filings following an increase in EPA regulation restrictions.

Table 5 presents the results of regressing future firm innovations on the $PostEPA$ variable. In columns (1) and (2), we find that regulated firms file more patents after three years have elapsed from the year of a large increase in regulation restrictions. Firms that experience large EPA restriction changes have 2.1% higher total patent filings and 5.7% higher patent citations than control firms. Moreover, in columns (3) and (4), we find that firms obtain more green patents after three years have elapsed, reflecting the length of time required to develop innovative projects. Treatment firms have 0.7% higher number of green patents and 1.6% higher number of green patent citations than control firms.[29] These results suggest that both the quantity and quality of firms' innovation output increase following implementation of stricter EPA regulations.

We further show that the value increases following an increase in EPA regulation restrictions is driven by shareholders' expectation of future firm innovation. In Table 6, we regress the number of three-year-ahead green patent filings and green patent citations on the interaction between $PostEPA$ and Q (or an indicator of large changes in Q), and we find that the interaction term is positive and significant, suggesting that firms that experience larger value increases are indeed those firms that innovate more. Collectively, the evidence suggest that innovation could be one of the channels that explain the value increase following an increase in EPA regulation restrictions.

4.5 EPA Regulations and Investment Efficiency

If the new innovations are value-enhancing, we should expect to find an increased efficiency of investment and innovation subsequent to EPA regulations. Therefore, we test the relationship between EPA regulations and investment efficiency in this subsection. We use two measures to capture investment efficiency. The first one is $FutSaletoR\&D$, which is the ratio of three-year ahead sales over R&D in the current year. The second one is $invEffiency$, which is the measure of capital expenditure investment efficiency. The results are documented in Table 7.We find that subsequent to stricter EPA regulations, firms' investment efficiency increases. Most of the significant improvements occur three or more years after large increases in EPA regulation restrictions, which is consistent with the innovation results documented above and the view that it takes time for firms to conduct innovations. Taken together, these results are consistent with the mechanism that EPA regulations induce value-enhancing green investments.

[29] In untabulated results, we also find that the value of firms' patents rises after a large increase in EPA regulation restrictions, consistent with the view that green innovation becoming more important following stricter environmental regulations.

4.6 EPA Regulations, Firm Valuation, and Corporate Governance

Our results thus far indicate that stricter EPA regulations are associated with subsequent appreciation in firm value and increases in value-enhancing investments, evidencing a disciplinary effect. A significant research stream suggests that firms with weak corporate governance and managerial myopia may benefit from alternative governance mechanisms (e.g., Edmans 2009), such as regulations. Guided by this line of reasoning, we hypothesize that the increase in firm value will be more pronounced in firms subject to higher threats of weak corporate governance and managerial myopia. Following prior literature, we use three measures to identify firms with weak corporate governance. The first measure is based on firms' leadership structure. Prior studies show that if the CEO of a firm also serves as the chairman of the board, the firm suffers more from weak governance due to the reduced incentive of the board to exert effort to monitor the management team (Karpoff *et al.* 2008). For the second measure, we surmise that firms with higher percentages of non-independent directors will have potentially weaker governance, since prior studies show that board oversight is compromised when its independence decreases (e.g., Dey 2008). To identify firms with managerial myopia, we use three common measures found in the literature. First, we use the accrual earnings management measure based on the modified Jones model in Dechow *et al.* (1995) to proxy for firms' agency issues and incentive to manipulate earnings to meet short-term targets. Prior literature shows that firms with high abnormal discretionary accruals are more likely to have agency problems (e.g., Cohen *et al.* 2008). Second, we identify firms that meet or narrowly beat analysts' earnings forecast consensus in the last fiscal year, as these firms tend to face greater pressure to meet short-term earnings targets (e.g., Keung *et al.* 2010) and are thus more vulnerable to managerial myopia. Third, we identify firms with larger percentages of transient institutional investors, since this investor type tends to be more focused on short-term gains and to invest more heavily in firms with greater expected near-term earnings, which could induce managerial myopia (Bushee 1998).

Table 8 presents the results of regressing firms' future Tobin's Q on the interaction of $PostEPA$ and measures of weak governance or managerial myopia. We find consistent evidence that firms with weak governance, or firms with myopic managers, experience significantly higher increases in firm value following stricter EPA regulations. In columns (1) to (3), we find that the increase in firm value is larger in firms whose CEOs are also the chairmen of the board, have higher percentages of non-independent directors, or have low MSCI KLD governance score. In columns (4) to (6), we find that the increase in firm value is greater when firms have earnings management incentives, proxied by high levels of abnormal discretionary accruals, have recently narrowly beat or met analysts' earnings forecast consensus, or when firms have more transient institutional investors. Overall, our results support the hypothesis that EPA regulations can serve as an external governance mechanism and may benefit firms by overcoming internal governance issues.

5 Additional Analyses

5.1 Effects of Financial Constraints

So far, our results suggest that stricter EPA regulations can serve as a governance mechanism to induce more value-enhancing green investments and innovations, especially for firms that are subject to managerial myopia. However, prior studies also find that financial resources are crucial for firms to invest and innovate (Cyert *et al.* 1963, Nohria and Gulati 1996, Allen *et al.* 2021). As a result, we explicitly test whether firms' financial constraint affects the role of EPA regulations. Following Xu and Kim (2022), we use two text-based financial-constraint measures developed by Bodnaruk *et al.* (2015) and Hoberg and Maksimovic (2015), which are shown to better capture firms' financial constraints over other conventional accounting-based measures, such as future dividend omissions and pension underfunding. Bodnaruk *et al.* (2015) measures the occurrences of financial constraint-related words in firms' 10-K filings, such as "required", "obligations", "imposed", and so on. . Hoberg and Maksimovic (2015) use the discussion in the MD&A section of 10-K and evaluate financial constraints by counting instances of constraints in raising capital. Following Xu and Kim (2022), we also use debt-market constraint measure that can capture firms' liquidity problems.

Table 9 presents the effects of firms' financial constraints on R&D investment, green innovation, and firm values. Consistent with our expectation, we find that more financially constrained firms experience lower increase in firm values after large increases in EPA regulation restrictions. These firms also invested less in R&D and generate fewer green patents in the future. The results are consistent with the view that the shareholders are aware of the lack of financial resources for firms to undertake value-enhancing green projects.

5.2 Decomposition of EPA Index

Given the EPA's broad scope, additional heterogeneous effects may be induced by different types of regulations (Greenstone *et al.* 2012). To understand the nature of these differences, we classify regulation content into topics using the Latent Dirichlet Allocation (LDA) analyses developed in (Blei *et al.* 2003). LDA is considered to be an objective instrument of topic identification, where a topic represents a group of words that frequently appear together in the text (Lowry *et al.* 2020). Importantly, LDA analysis treats each text document as a distribution over topics and provides an estimate of each topic's importance in the text. Because our EPA Index is based on each CFR part, we conduct LDA analyses using the part-level text in CFR-40 since 1996 and obtain the relative importance of each topic for the part text.[30] Although the algorithm automatically detects clusters of topic words, it requires one human input – the number of topics. To choose the number of topics, we follow a standard data-driven approach and use coherence values to select the optimal topic number (Röder *et al.* 2015). The estimation process shows that the optimal number of topics is fourteen. For each topic, we assign a label based on its keywords.[31]

Our goal is to examine the valuation effect of different EPA regulations. The LDA analysis returns the relative importance of each of the 14 topics in each part text, allowing us to calculate industry-part regulation restrictions corresponding to each topic. We then follow the same procedure as that employed to construct the industry EPA Index and obtain 14 topic-specific EPA indices for each six-digit NAICS industry, denoted as $EPA^{Ind}_{Topic_i}(i \in \{1, 2, ..., 14\})$. Because the text data in the early sample period is incomplete and not well structured, resulting in many missing parts, we use the decomposed EPA Index for the period after 2000.

We repeat our tests on firm values using changes in the topic-specific indices, and present the results in Appendix Table OA.1. We find that increases in EPA regulations on topics 7, 10, and 13, corresponding to "Air quality implementation plan," "Hazardous effect," and "Wastewater pretreatment technology," respectively, are positively and significantly associated with firm valuation. Moreover, the largest positive effect is associated with regulations for "Wastewater pretreatment

[30] We only have access to the CFR electronic text after 1996.

[31] In the Online Appendix, we list the 14 topics and their top keywords. The words are ordered by their relative weight in each topic, with the first word having the greatest weight. To verify that the label is meaningful, we also check the CFR parts where the topic is most relevant. For example, Topic 1 (Fuel and Gas Refinery) is found to be most relevant for CFR-40 part 80 titled "Regulation of fuels and fuel additives." We include more details about the LDA analyses and additional tests in the Online Appendix.

technology," which directly relates to technology development. At the same time, we find that regulations related to topic 2 ("Gas emission") and topic 14 ("Cost and administrative") are significantly and negatively associated with firm valuation. Overall, these results evidence the important heterogeneous effects of different EPA regulations on firms.

5.3 Alternative Channels

In this paper, we focus on how EPA regulations function as an external governance mechanism by disciplining firms and creating value. However, other factors may underlie the impact of environmental regulations on firm value and are not mutually exclusive from the disciplinary effect of EPA regulations. In this section, we discuss several of these mechanisms, including: (1) the disproportionate regulatory burden borne by small firms, which subsequently benefits larger firms; (2) greater investor attention to green companies; (3) consumer preference for environmental-friendly products; and (4) finalized regulations that reduced regulatory uncertainties.

5.3.1 Disproportional Regulatory Burden

One plausible explanation for the observed, on average, increase in valuation following stricter EPA regulations is that regulatory burdens may drive out smaller firms to the benefit of large corporations, which may be induced by small firms' lack of economies of scale to handle the fixed-cost component of compliance (Brock and Evans 1985) or large firms' lobby activities (Salop and Scheffman 1983). Prior literature has shown that regulations, in general, can have differential impacts on firms of different sizes (e.g., Chittenden *et al.* 2002, Chhaochharia and Grinstein 2007) and can be particularly costly for small companies (e.g., Crain and Crain 2005, Breuer *et al.* 2022, Wu 2021). To test the disproportional regulatory burden channel, we conduct several analyses. First, we study whether the valuation effect is stronger for larger companies. In Column (1) of Table 11, we repeat our main analyses of firm valuation by interacting $PostEPA$ with an indicator for firms with sizes ranked above the sample median by year. We do not find evidence of the regulations' differential effect on firm valuation for large versus small firms. In untabulated results, we investigate the likelihood that a firm exits the market following stricter EPA regulations. If regulatory burdens drive out some firms, we should expect to see an increase in firm exits following an increase in EPA regulation restrictions, but our results do not evidence a greater likelihood of firm exits over the four-year period subsequent to such increases.

5.3.2 Investor Attention

Prior studies have shown that investor' attention to green firms (e.g., Hong and Kacperczyk 2009, Krueger *et al.* 2020) can lead to increased investor demand and a subsequent boost in valuation. Our previous results suggest that stricter EPA regulations are associated with a significant reduction in firm pollution. If investor attention drives the increase in firm valuation, we would expect the positive relationship between EPA regulations and firm valuation to be stronger when investors pay more attention to ESG-related topics. We use the change in the Google Search Volume Index ($\triangle SVI$) for the keyword "ESG" to measure shifts in investor attention following prior literature (e.g., Da *et al.* 2011).[32] Column (2) of Table 11 presents the results of the relationship between EPA regulations and firm valuation conditional on investor attention ($\triangle SVI$). We do not find evidence to support the investor attention channel.

5.3.3 Consumer Demand

Next, we investigate whether consumer preference for green products is driving the positive relationship between EPA regulation restrictions and firm valuation. If so, we would expect to find a larger increase in firm value following an increase in EPA regulation restrictions among consumer-oriented industries, such as the consumer durables and consumer nondurables industries, since these industries rely heavily on consumers in their daily operations, and thus consumer purchasing behaviors may strongly affect financial performance and firm value. In Column (3) of Table 11, we find that firms in consumer-facing industries are not significantly more affected by changes in EPA regulation restrictions. Thus, we do not find strong evidence to support the consumer demand explanation.

5.3.4 Resolution of Regulatory Uncertainty

Lastly, we investigate whether the observed positive association between EPA regulations and firm value is driven by the resolution of regulatory uncertainties. We use the firm-level political

[32] In untabulated results, we also use the number of analysts covering a firm as an alternative measure of investor attention. We do not find evidence to suggest that firms with greater analyst coverage experience larger increases in firm valuation following stricter EPA regulations.

risks index relating to environmental issues developed by Hassan *et al.* (2019) as a proxy for firms' environmentally-related political uncertainties. We expect firms facing high environmental policy risks to experience a larger rise in value following an increase in EPA regulation restrictions. Column (4) of Table 11 presents the results. We do not find evidence that the resolution of regulatory uncertainties underpins the positive relationship between EPA regulation restrictions and firm valuation.

Overall, we do not find strong support for any of the proposed alternative channels to explain the positive relationship between EPA regulations and firm value in our sample.

5.4 Endogeneity and Robustness Analyses

We conduct additional analyses to address potential endogeneity concerns. First, our generalized difference-in-differences research design relies on an important identification assumption, i.e., that treated and control firms share parallel trends before the treatment. It's possible that EPA regulations may target firms with more innovative activities or higher value, in which case the observed results would be driven by reverse causality, evidenced by a trend of increasing innovation before changes in EPA regulations. To test the parallel trend assumption and check for preexisting trends, we follow Bertrand and Mullainathan (2003) and examine whether treatment firms (i.e., firms that experienced a large EPA regulation change in year t) and control firms (i.e., firms that did not experience a large EPA regulation change) share similar trends in firm outcomes before large regulatory changes. We regress firm outcomes on $Before^{-1or-2}$ that indicates two years or one year before the year of a large EPA regulation restriction change, $Current$ that indicates the year of the large change, $After^{1or2}$ ($After^{3or4}$) that indicates 1 or 2 (3 or 4) years after the year of the large change, and $After^{5+}$ that indicates five or more years after the year of the large change. The coefficient on $Before^{-1or-2}$ indicates whether there is a relation between the outcome variable and EPA regulations prior to a large change. A positive coefficient would indicate that the increase in innovation or value preceded the EPA regulation changes. In Table 10, the coefficient on $Before^{-1or-2}$ is statistically insignificant in all analyses, and thus we do not find any significant differences in the number of green patents, patent citations, Tobin's Q, or R&D intensity between the treatment and control firms in the years leading up to the large regulatory change. The significant and positive associations between EPA regulations and firm innovation and R&D only show up *after* large regulatory changes. In particular, the effect on green patents is only significant after a three-year period following a large EPA regulation change, which is intuitive because the change in innovative behavior takes longer to show its impact (e.g., patent filing and citation) than other investments after regulation changes. For firm value, the coefficients on $Current$ and $After^{1or2}$ are positive and statistically significant, suggesting that investors incorporate the effect of EPA regulation changes into stock prices immediately after (but not before) implementation and that the effect lingers over subsequent years.

It is possible that concurrent non-EPA regulations, such as those issued by the Securities and Exchange Commission, may confound our findings. Our previous results suggest that the effects of EPA regulations on firm valuation are more pronounced when the treatment effect is expected to be greater. If another regulatory type drives the results, it should affect firm value in a manner consistent with our cross-sectional results (e.g., stronger effects for firms with high EPA regulatory intensity). Although this effect is unlikely, we address the broader concern of concurrent regulations by directly controlling for all non-EPA regulations in our tests. Specifically, we construct an industry-year measure of changes in all non-EPA regulation restrictions using the same method employed for the EPA Index, and we create the variable $PostNonEPA$ for the periods when an industry experiences large changes in non-EPA regulations. In the Online Appendix Table OA.3, we find that $PostEPA$ continues to be significantly associated with an increase in firm value after controlling for the non-EPA regulations index and that the $PostNonEPA$ measure is not associated with value, suggesting that the positive association between EPA regulation and firm valuation is unlikely to be driven by concurrent non-environmental regulations.

Next, to mitigate concerns that firms' existing environmental and social practices are associated with either the EPA's propensity to implement a specific regulation or with firm value, we control for prior E&S performance using the MSCI KLD index pertaining to environmental and social aspects (i.e., environment, community, diversity, employee relations, and human rights). Due to its extensive coverage of firms and time periods, the MSCI KLD index is the most widely-used measure of firms' ESG quality in a large body of literature (e.g., Godfrey *et al.* 2009). In the Online Appendix Table OA.4, we find that our results still hold after controlling for the MSCI KLD index.

We also conduct additional robustness tests for our main results. First, we use the changes in

EPA Index and examine their effect on the main outcome variables. The relationships between the EPA Index changes and firm outcomes are consistent with our main results using $PostEPA$. Second, the results are robust to an alternative measure of the EPA Index using the less granular restriction word counts in McLaughlin and Sherouse (2018). Third, we apply alternative model specifications, including using different windows for the $PostEPA$ variable and excluding financial firms. All our inferences remain the same. Fourth, although our previous analyses suggest parallel trends between the treatment and control firms prior to large EPA regulation restriction changes, there could still be concern about business operation dissimilarities among treatment and control groups in our generalized difference-in-differences tests. To further strengthen the tests, we use an alternative control group, composed of firms that do not experience large changes in EPA restrictions but have the same four-digit NAICS code as the treatment firms. We conjecture that firms in the same four-digit NAICS industries are more likely to share similar growth opportunities and economic trends. The inferences remain economically and statistically consistent with the main results.

6 Conclusion

In this paper, we attempt to understand the overall effects of environmental regulations on firm value and innovative strategies. Over the past several decades, the EPA has implemented hundreds of overlapping regulations, making it challenging to identify the effect of a given individual rule. We construct a novel measure of the total restrictions of EPA regulations based on the universe of EPA rules from 1974 to 2019 and their machine-learned relevance to each industry. This measure captures all effective EPA regulations for a given industry at any given time. Our approach is flexible and tractable, allowing us to examine the average effect of EPA regulation restrictions without relying on any individual rules.

By adopting a difference-in-differences analysis around large changes in the degree of EPA restrictiveness at the industry level, we find that stricter EPA regulations are associated with an improvement in firm value. Investigating the potential underlying mechanism, we find that stricter EPA regulations induce green innovations and increase the marginal performance of R&D in regulated firms, reflecting an increase in innovation incentives. Moreover, the positive valuation effect is more pronounced for firms with myopic managers and weak shareholder monitoring. Collectively, our findings are consistent with the idea that stricter environmental regulations can serve as an external governance mechanism to induce value-enhancing green investment.

Overall, our findings contribute to the current policy debate about the economic effect of EPA regulations. The Supreme Court's recent issuance of a ruling limiting the EPA's authority to set climate standards for power plants is considered a significant setback to the broader adoption of environmental regulations. Proponents of curtailing EPA authority have alleged that the agency's regulations may impose excessive burdens on firms. However, our findings suggest an alternative view. Our results document that effectively-designed EPA regulations can promote innovations that ultimately benefit firms, a consideration that could help guide future policymaking.

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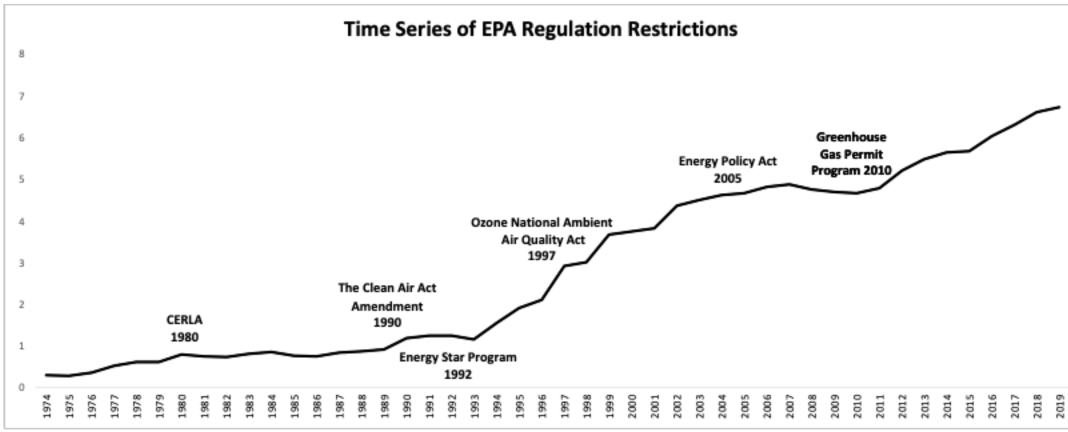
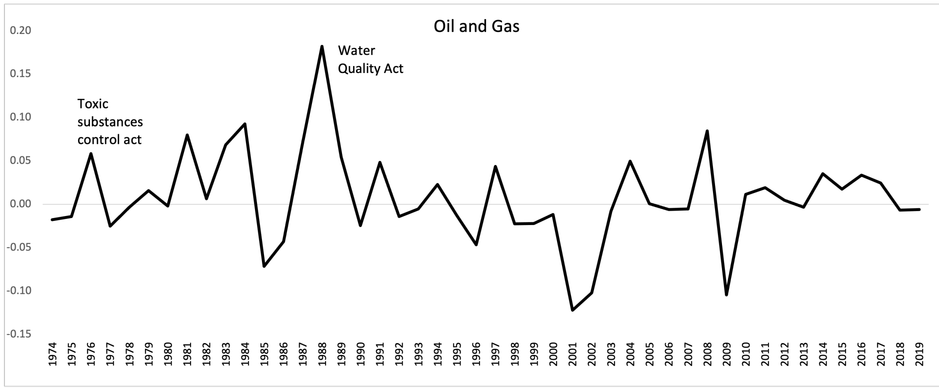
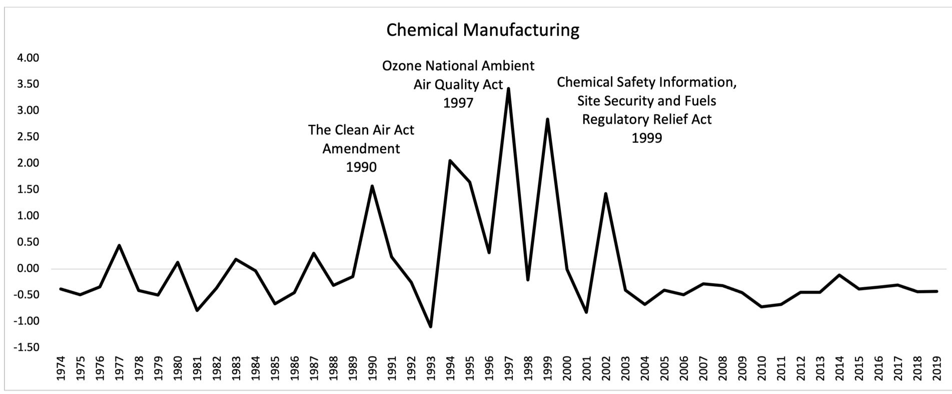
Figure 1: Time-Series of EPA Regulation Restriction Level



This graph presents the annual average of the stock of EPA regulation restrictions across all six-digit NAICS industries between 1974 and 2019. The EPA regulations are the total effective restrictions imposed on each industry each year, calculated as $EPAIndex^{Ind}$ in Model (2).

Figure 2: Time-Series of Changes in EPA Restrictions for Sample Industries





This figure presents the annual averages of the standardized changes in EPA indexes within selected representative industry groups between 1974 and 2019. The EPA Index is the total restrictions of EPA regulations for each six-digit NAICS code industry in each year ($EPAIndex^{Ind}$). We further standardize the changes in the EPA Index at the industry level to have a mean of zero and a standard deviation of one in this figure. The top graph is for the Oil and Gas industry group (NAICS code of 211), and the bottom graph is for the Chemical Manufacturing industry group (NAICS code 325).

Table 1: EPA Index by NAICS Sector

NAICS Sector	NAICS Sector Name
31-33	Manufacturing
44-45	Retail Trade
56	Administrative and Support and Waste Management and Remediation Services
11	Agriculture, Forestry, Fishing and Hunting
22	Utilities
21	Mining, Quarrying, and Oil and Gas Extraction
48-49	Transportation and Warehousing
54	Professional, Scientific, and Technical Services
42	Wholesale Trade
61	Educational Services
62	Health Care and Social Assistance
23	Construction
51	Information
72	Accommodation and Food Services Additionally, we use market capitalization scaled by lag total assets
71	Arts, Entertainment, and Recreation
52	Finance and Insurance
53	Real Estate and Rental and Leasing
81	Other Services (except Public Administration)

Notes: This table presents the mean EPA Index for each NAICS sector during our sample period of 1974 to 2019. The sectors are ranked by their average EPA Index. The EPA Index is the total restrictions of EPA regulations for each six-digit NAICS code industry in each year.

Table 2: Summary Statistics

Panel A. Main Sample					
Stats	Mean	Median	SD	p25	p75
Q	1.645	1.023	2.783	0.658	1.730
$\triangle EPA^{Ind}$	0.046	-0.031	0.903	-0.332	0.233
$PostEPA$	0.046	0.000	0.364	0.000	0.000
$Size$	5.843	5.755	2.228	4.202	7.359
$SG\&A$	0.299	0.199	0.593	0.067	0.346
$R\&D$	0.137	0.000	0.755	0.000	0.007
$Leverage$	2.577	1.109	5.161	0.447	2.634
ROA	-0.006	0.007	0.100	-0.001	0.019
$Cash$	0.047	0.001	0.117	0.000	0.029
IO	0.396	0.337	0.313	0.109	0.655
HHI	0.285	0.258	0.094	0.198	0.395
$EnvLobbyAmt$	0.440	2.375	0.000	0.000	0.000
$IndSalesGrowth$	0.097	0.067	0.392	-0.013	0.147
$lnTotalPatent_{t+3}$	0.428	0.000	1.102	0.000	0.000
$lnTotalCitation_{t+3}$	1.081	0.000	2.130	0.000	0.000
$lnGreenPatent_{t+3}$	0.031	0.000	0.247	0.000	0.000
$lnGreenCitations_{t+3}$	0.082	0.000	0.564	0.000	0.000
$HighEnforcementRank$	0.757	1.000	0.429	1.000	1.000
$HighEPABudget$	0.558	1.000	0.497	0.000	1.000
$\triangle SVI$	0.022	-0.038	0.531	-0.357	0.316
$DualCEO$	0.213	0.410	0.000	0.000	0.000
$BadGovScore$	0.159	0.651	0.000	0.000	0.000
$DisAccrual$	0.554	0.091	2.090	0.033	0.273
$\%NonIndDirector$	0.133	0.091	0.153	0.000	0.214
$NarrowBeat$	0.068	0.000	0.252	0.000	0.000
$TransInvestor$	0.450	0.390	0.448	0.157	0.697
$ConsumerFacing$	0.134	0.140	0.128	0.165	0.056
$EPU\_FirmEnvRisk$	6.693	7.329	2.587	6.139	8.258
$10KConstraint$	0.480	0.500	0.000	0.000	1.000
$DebtConstraint$	0.004	0.058	-0.036	-0.001	0.040
$FutSalestoR\&D$	86.913	230.522	6.622	20.648	63.171
$InvEfficiency$	0.051	0.220	0.000	0.000	0.000
Panel B. Facility-Level Sample					
Stats	Mean	Median	SD	p25	p75
$lnTRI_{t+1}$	6.880	7.198	3.721	4.715	9.684
$PostEPA$	0.097	0.000	0.440	0.000	0.000
$Size$	7.954	8.300	2.437	6.826	9.642
$SG\&A$	0.140	0.128	0.165	0.056	0.182
$R\&D$	0.018	0.003	0.140	0.000	0.025
$Leverage$	0.642	0.651	0.235	0.528	0.751
ROA	0.039	0.042	0.096	0.015	0.074
$Cash$	0.037	0.001	0.059	0.000	0.061
IO	0.644	0.691	0.263	0.484	0.842
$IndSalesGrowth$	0.087	0.049	0.418	-0.026	0.130

This table presents the summary statistics of variables used in different samples in this study. Panel A presents the univariate statistics for the main Compustat sample. Panel B presents the univariate statistics for the facility-level sample containing toxic release inventory data. Please refer to Appendix A for detailed variable definitions and information about their construction.

Table 3: EPA Index and Pollution Reduction

VARIABLES	(1) $lnTRI_{t+1}$	(2) $lnTRI_{t+1}$
PostEPA	-0.082***	-0.067**
	(0.017)	(0.027)
Size		-0.017
		(0.023)
SG&A		-0.708***
		(0.241)
R&D		-1.294**
		(0.549)
Leverage		0.406***
		(0.110)
ROA		0.632***
		(0.170)
Cash		1.275***
		(0.258)
IO		0.391***
		(0.081)
IndSalesGrowth		-0.036
		(0.035)
Constant	6.806***	6.052***
	(0.006)	(0.199)
Observations	146,823	146,823
Chemical-Year FE	YES	YES
Facility-Chemical FE	YES	YES
Adj.R-squared	0.407	0.444

This table presents the results of regressing firms' facility-level total toxic substance release on the $PostEPA$ variable. $lnTRI_{t+1}$ is the natural logarithm of the total amount of future one-year toxic chemical releases in tons at the facility level. $PostEPA$ is a variable that equals 1 (-1) for the four-year periods since the year when a six-digit NAICS industry experiences a larger than (smaller than) two standard deviation increase (decrease) in the level of EPA regulation restrictions relative to the industry mean, and zero otherwise. Control variables include firm size, SG&A expenditure intensity, R&D expenditure intensity, firm leverage, return-on-asset, cash balance, institutional ownership, and industry sales growth. All regressions include facility-chemical fixed effects and chemical-year fixed effects. Standard errors are clustered at the firm level and presented in parentheses below the coefficients. All continuous variables are winsorized at the top and bottom 1% levels. ***, **, * indicate statistical significance at 1%, 5%, and 10%, respectively. Variable definitions are included in Appendix A.

Table 4: EPA Index and Firm Valuation

Panel A. EPA Index and Firm Valuation	(1)	(2)	(3)
VARIABLES	Q_{t+1}	Q_{t+1}	Q_{t+1}
PostEPA	0.157***	0.157***	0.153***
	(0.055)	(0.057)	(0.050)
Size		-0.624***	-0.748***
		(0.080)	(0.094)
SG&A		-0.003	-0.009
		(0.067)	(0.099)
R&D		-0.064	-0.110**
		(0.046)	(0.049)
Leverage		-0.001	-0.001
		(0.002)	(0.002)
ROA		-2.738***	-3.490***
		(0.638)	(0.688)
Cash		0.733**	0.714***
		(0.291)	(0.230)
IO		1.318***	1.140***
		(0.180)	(0.202)
IndSalesGrowth		0.040*	-0.021
		(0.024)	(0.031)
HHI			0.071
			(0.195)
EnvLobbyAmt			-0.004
			(0.004)
Constant	1.553***	4.673***	5.820***
	(0.003)	(0.430)	(0.552)
Observations	107,169	107,169	107,169
Firm&Year FE	YES	YES	YES
Adj.R-squared	0.550	0.569	0.632

Panel B. EPA Index and Regulatory Intensity	(1)	(2)	(3)	(4)
VARIABLES	Q_{t+1}	Q_{t+1}	Q_{t+1}	Q_{t+1}
PostEPA× HighEnforcementRank	0.135**	0.126**		
	(0.053)	(0.052)		
PostEPA× HighEPABudget			0.268**	0.263**
			(0.123)	(0.118)
Control	NO	YES	NO	YES
Observations	107,169	107,169	107,169	107,169
Firm&Year FE	YES	YES	YES	YES
Adj.R-squared	0.549	0.564	0.550	0.565

This table presents the results of regressing firms' valuation on the $PostEPA$ variable. Q is Tobin's Q, measured at the end of the fiscal quarter immediately following July.$PostEPA$ is a variable that equals 1 (-1) for the four-year periods since the year when a six-digit NAICS industry experiences a larger than (smaller than) two standard deviation increase (decrease) in the level of EPA regulation restrictions relative to the industry mean, and zero otherwise. Control variables are measured at the end of the last fiscal quarter, including firm size, SG&A expense intensity, R&D expenditure intensity, firm leverage, return-on-assets, cash, institutional ownership, the industry sales Herfindahl-Hirschman Index of the 6-digit NAICS code that the firm is in, and the total lobby spending that are broadly related to environmental regulation. $HighEnforcementRank$ is an indicator that equals 1 if the state has above median EPA enforcement actions in the year. $HighEPABudget$ is an indicator that equals 1 if the EPA has above cross-section median annual budgets at year t, and zero otherwise. All regressions include firm fixed effects and year fixed effects. Standard errors are clustered at the six-digit NAICS industry level and presented in parentheses below the coefficients. All continuous variables are winsorized at the top and bottom 1% levels. ***, **, * indicate statistical significance at 1%, 5%, and 10%, respectively. Variable definitions are included in Appendix A.

Table 5: EPA Index and Future Innovation

VARIABLES	(1) $lnTotalPatent_{t+3}$	(2) $lnTotalCitations_{t+3}$	(3) $lnGreenPatent_{t+3}$	(4) $lnGreenCitations_{t+3}$
PostEPA	0.021	0.057**	0.007**	0.016**
	(0.014)	(0.026)	(0.003)	(0.008)
Size	0.126***	0.212***	0.008***	0.019***
	(0.027)	(0.037)	(0.003)	(0.007)
SG&A	0.003	0.018	0.000	0.000
	(0.007)	(0.016)	(0.001)	(0.003)
R&D	0.017***	0.017	-0.001	-0.000
	(0.006)	(0.013)	(0.001)	(0.005)
Leverage	-0.001	-0.005***	0.000	-0.001
	(0.001)	(0.002)	(0.000)	(0.001)
ROA	-0.071**	-0.182**	-0.005	-0.016
	(0.029)	(0.083)	(0.005)	(0.015)
Cash	0.027	-0.481***	-0.010	-0.016
	(0.055)	(0.160)	(0.009)	(0.036)
IO	0.065***	0.215***	0.001	0.033
	(0.024)	(0.071)	(0.007)	(0.024)
IndSalesGrowth	0.001	-0.013	-0.001	-0.007**
	(0.004)	(0.011)	(0.001)	(0.003)
Constant	-0.363**	-0.295	-0.021	-0.055
	(0.157)	(0.228)	(0.014)	(0.042)
Observations	107,169	107,169	107,169	107,169
Year FE	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Adj.R-squared	0.735	0.786	0.566	0.505

This table presents the results of regressing firms' future total innovation and green innovation on $PostEPA$. $lnTotalPatent_{t+3}$ is the natural log of one plus the total number of patent filings in year t+3. $lnGreenPatent_{t+3}$ is the number of green patents in year t+3 that are classified as containing environmental-related technologies according to the OECD proposed methodology. $PostEPA$ is a variable that equals 1 (-1) for the four-year periods since the year when a six-digit NAICS industry experiences a larger than (smaller than) two standard deviation increase (decrease) in the level of EPA regulation restrictions relative to the industry mean, and zero otherwise. Control variables include firm size, SG&A expense intensity, R&D expenditure intensity, firm leverage, return-on-assets, cash, institutional ownership, and industry-level sales growth. All regressions include firm and year fixed effects. Standard errors are clustered at the six-digit NAICS industry level and presented in parentheses below the coefficients. All continuous variables are winsorized at the top and bottom 1% levels. ***, **, * indicate statistical significance at 1%, 5%, and 10%, respectively. Variable definitions are included in Appendix A.

Table 6: EPA Index, Firm Value, and Future Innovation

VARIABLES	(1) $lnGreenPatent_{t+3}$	(2) $lnGreenPatent_{t+3}$	(3) $lnGreenPatent_{t+3}$	(4) $lnGreenCitations_{t+3}$
PostEPA	0.002	0.002	0.001	0.002
	(0.004)	(0.005)	(0.008)	(0.009)
Q	-0.000		0.001	
	(0.000)		(0.001)	
PostEPA×Q	0.000*		0.002**	
	(0.000)		(0.001)	
High△Q		-0.002***		0.002*
		(0.001)		(0.001)
PostEPA×△Q		0.003*		0.007*
		(0.002)		(0.004)
Size			0.034***	0.033***
			(0.008)	(0.008)
SG&A			-0.001	-0.000
			(0.002)	(0.002)
R&D			0.003	0.003
			(0.003)	(0.003)
Leverage			-0.000	-0.000
			(0.000)	(0.000)
ROA			-0.005	-0.009
			(0.006)	(0.006)
Cash			0.028	0.029
			(0.019)	(0.019)
IO			-0.008	-0.008
			(0.011)	(0.011)
IndSalesGrowth			0.002*	0.002*
			(0.001)	(0.001)
Constant	0.058***	0.063***	-0.116**	-0.112**
	(0.000)	(0.000)	(0.046)	(0.046)
Observations	318,545	289,111	137,699	135,607
Year FE	YES	YES	YES	YES
Ind FE	YES	YES	YES	YES
Adj.R-squared	0.732	0.736	0.761	0.762

This table presents the results of regressing firms' future total innovation and green innovation on $PostEPA$ conditional on the value increases in response to the regulation restrictions increase. $lnGreenPatent_{t+3}$ is the number of green patents in year t+3 that are classified as containing environmental-related technologies according to the OECD proposed methodology. $lnGreenCitation_{t+3}$ is the number of green patents citations in year t+3. $PostEPA$ is a variable that equals 1 (-1) for the four-year periods since the year when a six-digit NAICS industry experiences a larger than (smaller than) two standard deviation increase (decrease) in the level of EPA regulation restrictions relative to the industry mean, and zero otherwise. Q is Tobin's Q, measured at the end of the fiscal quarter immediately following July. $High\triangle Q$ is an indicator variable that equals one if the changes in Q between the current quarter and the previous quarter is ranked above the smaple median, and zero otherwise. Control variables include firm size, SG&A expense intensity, R&D expenditure intensity, firm leverage, return-on-assets, cash, institutional ownership, and industry-level sales growth. All regressions include firm and year fixed effects. Standard errors are clustered at the six-digit NAICS industry level and presented in parentheses below the coefficients. All continuous variables are winsorized at the top and bottom 1% levels. ***, **, * indicate statistical significance at 1%, 5%, and 10%, respectively. Variable definitions are included in Appendix A.

Table 7: EPA Index and Investment Efficiency

	(1)	(2)
VARIABLES	$FutSalestoR\&D$	$InvEfficency_t$
Before1or2	0.431	0.007
	(4.883)	(0.011)
Current	2.688	-0.014
	(4.274)	(0.011)
After1or2	6.544	-0.003
	(4.352)	(0.011)
After3or4	18.169	0.020**
	(14.429)	(0.009)
After5	17.290*	0.015*
	(9.736)	(0.009)
Size	-23.126***	-0.060***
	(4.024)	(0.004)
SG&A	-3.892***	-0.005
	(1.380)	(0.003)
R&D	-1.704***	0.001
	(0.501)	(0.003)
Leverage	-0.032	0.001*
	(0.237)	(0.000)
ROA	27.911*	0.037
	(14.866)	(0.026)
Cash	6.998	-0.181***
	(9.905)	(0.047)
IO	6.941	0.129***
	(8.627)	(0.014)
IndSalesGrowth	3.304	-0.007*
	(5.471)	(0.004)
Constant	204.671***	5.295***
	(22.638)	(0.786)
Observations	26,407	107,169
Firm & Year FE	YES	YES
Industry & Year FE	NO	NO
Adj.R-squared	0.735	0.632

This table presents the results of regressing firms' future total innovation and green innovation on $PostEPA$. $FutSalestoR\&D_{t1}$is the ratio of three-year ahead sales over R&D at year t. $InvEfficency_t$ is the measure of capital investment efficiency as used in Goodman *et al.* (2014), which is an indicator that equals one if a firm has an unexpected investment level below the median of the distribution of unexpected investment, and zero otherwise. $Before^{-1or-2}$ indicates two years or one year before the year of a large EPA regulation restriction change, $Current$ that indicates the year of the large change, $After^{1or2}$ ($After^{3or4}$) is 1 or 2 (3 or 4) years after the year of the large change, and $After^{5+}$ is five or more years after the year of the large change. Control variables include firm size, SG&A expense intensity, R&D expenditure intensity, firm leverage, return-on-assets, cash, institutional ownership, and industry-level sales growth. All regressions include firm and year fixed effects. Standard errors are clustered at the six-digit NAICS industry level and presented in parentheses below the coefficients. All continuous variables are winsorized at the top and bottom 1% levels. ***, **, * indicate statistical significance at 1%, 5%, and 10%, respectively. Variable definitions are included in Appendix A.

Table 8: EPA Index, Firm Valuation, and Governance Weakness

VARIABLES	(1) Q_{t+1}	(2) Q_{t+1}	(3) Q_{t+1}	(3) Q_{t+1}	(4) Q_{t+1}	(5) Q_{t+1}
PostEPA× DualCEO	0.173**					
	(0.085)					
PostEPA × %NonIndDirector		0.505**				
		(0.248)				
PostEPA × BadGovScore			0.181***			
			(0.048)			
PostEPA × DisAccrual				0.815***		
				(0.279)		
PostEPA × NarrowBeat					0.249***	
					(0.074)	
PostEPA ×TransInvestor						0.261***
						(0.093)
DualCEO	0.053**					
	(0.024)					
%NonIndDirector		-0.512***				
		(0.101)				
BadGovScore			-0.009			
			(0.016)			
DisAccrual				0.998***		
				(0.095)		
NarrowBeat					0.149***	
					(0.023)	
TransInvestor						0.006
						(0.025)
PostEPA	0.110**	0.127*	0.107	0.123**	0.130**	0.061
	(0.056)	(0.068)	(0.065)	(0.056)	(0.062)	(0.063)
Observations	107,169	45,782	23,644	107,169	107,169	107,169
Controls	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Adj.R-squared	0.582	0.580	0.676	0.566	0.582	0.622

This table presents the results of regressing firms' valuation on $PostEPA$, conditional on measures of weak governance and managerial myopia. Q is Tobin's Q, measured at the end of the fiscal quarter immediately following July. $PostEPA$ is a variable that equals 1 (-1) for the four-year periods since the year when a six-digit NAICS industry experiences a larger than (smaller than) two standard deviation increase (decrease) in the level of EPA regulation restrictions relative to the industry mean, and zero otherwise. $DualCEO$ is an indicator that equals 1 if the CEO of the firm is also the chairman of the board, and 0 otherwise. $\%NonIndDirector$ is one minus the percentage of independent directors over total number of directors. $BadGovScore$ is an indicator variable that equals one (zero) if the MSCI KLD governance score is below (over and above) sample median of a given year. $DisAccrual$ is the value of firms' discretionary accruals calculated following the modified Jones model by Dechow et al., (1995). $NonIndDirector$ is the percentage of non-independent firm directors, calculated as one minus the percentage of independent directors (BoardEx). $NarrowBeat$ is an indicator that equals one if the firm meets or beats the analysts' mean consensus forecast by less than one cent in the most recent fiscal year, and zero otherwise. $Transinvestor$ is the percentage of transient investors calculated following Bushee (1998). Control variables include firm size, SG&A expense intensity, R&D expenditure intensity, firm leverage, return-on-assets, cash, institutional ownership, and industry-level sales growth. All regressions include firm and year fixed effects. Standard errors are clustered at the six-digit NAICS industry level and presented in parentheses below the coefficients. All continuous variables are winsorized at the top and bottom 1% levels. ***, **, * indicate statistical significance at 1%, 5%, and 10%, respectively. Variable definitions are included in Appendix A.

Table 9: EPA Index, Green Investment, and Financial Constraint

VARIABLES	(1) Q_{t+1}	(2) $R\&D_{t+1}$	(3) $lnGreenPatent_{t+3}$	(4) Q_{t+1}	(5) $R\&D_{t+1}$	(6) $lnGreenPatent_{t+3}$
PostEPA	0.570***	-0.008	0.023	0.434***	0.039*	0.005
	(0.194)	(0.014)	(0.015)	(0.119)	(0.023)	(0.003)
PostEPA×10KConstraint	-0.024**	-0.004	-0.012**			
	(0.011)	(0.070)	(0.006)			
10KConstraint	-0.016*	0.853***	-0.018**			
	(0.008)	(0.191)	(0.008)			
PostEPA×DebtConstraint				-5.789***	-0.461*	-0.087*
				(1.846)	(0.263)	(0.048)
DebtConstraint				-0.067	0.022	-0.005
				(0.294)	(0.049)	(0.017)
Constant	0.043***	1.480***	0.024***	7.180***	0.150***	0.013
	(0.004)	(0.021)	(0.001)	(0.770)	(0.035)	(0.012)
Observations	40,826	40,826	40,826	30,274	30,274	30,274
Controls	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Adj.R-squared	0.681	0.537	0.626	0.509	0.753	0.629

This table presents the results of regressing firms' valuation, R&D intensity, and future green innovation on $PostEPA$, conditional on measures of financial constraint. Q is Tobin's Q, measured at the end of the fiscal quarter immediately following July. $R\&D_{t+1}$ is R&D expenditures over total sales in year $t+1$. $lnGreenPatent_{t+3}$ is the number of green patents in year t+3 that are classified as containing environmental-related technologies according to the OECD proposed methodology. $10Kconstraint$ is an indicator that equals 1 (0) if the percentage of the number of financial constraint words in firm's 10K filing is ranked above (below) the median of the sample in year t. $DebtConstraint$ is the Hoberg and Maksimovic (2014) measure of debt-market constraint. $PostEPA$ is a variable that equals 1 (-1) for the four-year periods since the year when a six-digit NAICS industry experiences a larger than (smaller than) two standard deviation increase (decrease) in the level of EPA regulation restrictions relative to the industry mean, and zero otherwise. Control variables include firm size, SG&A expense intensity, R&D expenditure intensity, firm leverage, return-on-assets, cash, institutional ownership, and industry-level sales growth. The coefficient estimates of the control variables, the variables used to interact with the $PostEPA$, $PostEPA$ alone, and constants are included in all models. All regressions include firm and year fixed effects. Standard errors are clustered at the six-digit NAICS industry level and presented in parentheses below the coefficients. All continuous variables are winsorized at the top and bottom 1% levels. ***, **, * indicate statistical significance at 1%, 5%, and 10%, respectively. Variable definitions are included in Appendix A.

Table 10: EPA Regulation and Firms: Dynamics

	(1)	(2)	(3)	(4)
VARIABLES	$lnGreenPatent_t$	$lnGreenCitations_t$	Q_t	$R\&D_t$
$Before^{-1or-2}$	0.001	0.016	0.020	0.028
	(0.005)	(0.011)	(0.041)	(0.022)
Current	-0.001	0.011	0.107**	0.007
	(0.004)	(0.008)	(0.044)	(0.014)
$After^{1or2}$	0.004	0.018**	0.264***	0.018*
	(0.004)	(0.009)	(0.089)	(0.011)
$After^{3or4}$	0.006*	0.013*	0.089	0.023*
	(0.003)	(0.008)	(0.055)	(0.012)
$After^{5+}$	-0.008	0.008	0.131	-0.029*
	(0.006)	(0.011)	(0.099)	(0.015)
Size	0.010***	0.022***	-0.715***	-0.002
	(0.002)	(0.005)	(0.136)	(0.002)
SG&A	0.000	0.001	0.019	-0.013
	(0.001)	(0.002)	(0.056)	(0.009)
R&D	0.000	-0.004*	-0.008	0.618***
	(0.001)	(0.002)	(0.061)	(0.014)
Leverage	0.000	0.000	0.000	-0.000
	(0.000)	(0.000)	(0.003)	(0.000)
ROA	-0.012***	-0.038***	-2.438***	-0.028
	(0.005)	(0.010)	(0.569)	(0.050)
Cash	0.003	0.014	1.460**	0.001
	(0.007)	(0.020)	(0.667)	(0.031)
IO	-0.007	0.032**	1.176***	0.006
	(0.008)	(0.014)	(0.153)	(0.011)
IndSalesGrowth	0.000	-0.002	0.050**	-0.002**
	(0.001)	(0.002)	(0.020)	(0.001)
Constant	-0.018	-0.095***	5.295***	-0.008
	(0.014)	(0.031)	(0.786)	(0.022)
Observations	107,169	107,169	107,169	107,169
Year FE	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Adj.R-squared	0.633	0.511	0.632	0.849

This table presents the results relating firm outcomes to EPA regulations. $lnGreenPatent_t$ is the number of "green" patents in year t that are classified as containing environmental-related technologies according to the OECD proposed methodology. $lnGreenCitations_{t+3}$ is the number of citations of green patents year t. Q is Tobin's Q. $Before^{-1or-2}$, $Current$, $After^{1or2}$, $After^{3or4}$, $After^{5+}$ are indicators of t-1 or t-2, t, t+1 or t+2, t+3 or t+4, and t+5 and beyond, respectively, where year t is the year of the large EPA regulation restrictions change. Control variables include firm size, SG&A expense intensity, R&D expenditure intensity, firm leverage, return-on-assets, cash, institutional ownership, and industry-level sales growth. All regressions include firm and year fixed effects. Standard errors are clustered at the six-digit NAICS industry level and presented in parentheses below the coefficients. All continuous variables are winsorized at the top and bottom 1% levels. ***, **, * indicate statistical significance at 1%, 5%, and 10%, respectively. Variable definitions are included in Appendix A.

Table 11: EPA Index, Firm Valuation, and Alternative Channels

VARIABLES	(1) Q_{t+1}	(2) Q_{t+1}	(3) Q_{t+1}	(4) Q_{t+1}
PostEPA $\times$BigFirm	0.060			
	(0.051)			
PostEPA $\times\triangle SVI$		0.093		
		(0.093)		
PostEPA $\times$ConsumerFacing			-0.107	
			(0.066)	
PostEPA $\times$EPU FirmEnvRisk				-0.006
				(0.006)
Control and main effects	YES	YES	YES	YES
Observations	107,169	107,169	107,169	32,910
Year FE	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Adj.R-squared	0.568	0.703	0.568	0.655

This table presents the results of regressing firms' valuation on the $PostEPA$, conditional on several alternative drivers of firm valuations. Q is Tobin's Q, measured at the end of the fiscal quarter immediately following July. $PostEPA$ is a variable that equals 1 (-1) for the four-year periods since the year when a six-digit NAICS industry experiences a larger than (smaller than) two standard deviation increase (decrease) in the level of EPA regulation restrictions relative to the industry mean, and zero otherwise. $\triangle SVI$ is the percentage change in the Google Search Volume Index for the keyword "ESG" at the end of calendar year t-1. ConsumerFacing is an indicator that equals 1 if the firm is in a consumer-facing industry, which includes the consumer durable, consumer nondurable, and the retail and wholesale industry according to Fama and French 12 industry classification. $EPUFirmEnvRisk$ is the firm-level economic policy uncertainty index relating to environmental risk. Control variables include firm size, SG&A expense intensity, R&D expenditure intensity, firm leverage, return-on-assets, cash, institutional ownership, and industry-level sales growth. The coefficient estimates of the control variables, the variables used to interact with the $PostEPA$, $PostEPA$ alone, and constants are included in all models. All regressions include firm and year fixed effects. Standard errors are clustered at the six-digit NAICS industry level and presented in parentheses below the coefficients. All continuous variables are winsorized at the top and bottom 1% levels. ***, **, * indicate statistical significance at 1%, 5%, and 10%, respectively. Variable definitions are included in Appendix A.

Appendix A: Variable Definitions

Variable	Description (Source)
Q	Tobin's Q, defined as the market value of equity plus book value of short- and long-term debt (Compustat DLC + DLTT) scaled by total assets, measured at the end of the fiscal quarter q immediately following July of year t, where year t is the year when the level of EPA regulations restrictions is constructed.
EPA Index	The total EPA regulatory restrictions imposed on each six-digit NAICS code industry.
$PostEPA$	A variable that equals 1 (-1) for the years t to t+4, where year t is the year when where year t marks the year when industry j experiences a larger than two-standard-deviation increase (decrease) in the EPA Index relative to the average increase (decrease) in industry j, and zero otherwise.
$Size$	Firms' market value of equity (Compustat).
$SG\&A$	Firms' SG&A intensity, calculated as total selling, general, and administrative expenditures over total sales (Compustat).
$R\&D$	Firms' R&D intensity, calculated as total research and development expenditures over total sales (Compustat).
$Leverage$	Firms' leverage, calculated as total debt over total stockholders' equity (Compustat).
ROA	Firms' return-on-assets, calculated as net income over the weighted average of firms' current and previous years' total assets (Compustat).
$Cash$	Firms' total cash scaled by lagged total assets (Compustat).
IO	Firms' institutional ownership, calculated as shares held by institutional investors as a percentage of total shares outstanding (Thomson/Refinitiv).
HHI	The industry sales Herfindahl-Hirschman Index of the 6-digit NAICS code that the firm is in (Compustat).
$EnvLobbyAmt$	Total spending of lobby that are broadly related to environmental regulation (https://www.lobbyview.org/).
$IndSalesGrowth$	Growth in industry sales computed as the change in total sales of firms operating in the industry scaled by beginning total industry sales. Industries are defined using six-digit NAICS classifications (Compustat).
$lnTRI_{t+1}$	The natural log of the total amount of toxic chemical release in tons at the facility level (TRI website, https://enviro.epa.gov/facts/tri).
$lnTotalPatent_{t+3}$	The natural log of one plus the total number of patents filed by the firm, measured at the end of the calendar year t+3, where year t is the year when the EPA Index is constructed (Kogan *et al.* (2017) patent dataset, https://github.com/KPSS2017/Technological-Innovation-Resource-Allocation-and-Growth-Extended-Data).
$lnTotalCitation_{t+3}$	The natural log of one plus the citations of a firm's patents measured at the end of the calendar year t+3, where year t is the year when the EPA Index is constructed (Kogan *et al.* (2017) patent dataset, https://github.com/KPSS2017/Technological-Innovation-Resource-Allocation-and-Growth-Extended-Data).
$lnGreenPatent_{t+3}$	The natural log of one plus the total number of green patents filed by the firm, measured at the end of the calendar year t+3, where year t is the year when the EPA Index is constructed. Green patents are those with environmental-related technology, classified based on the OECD's proposal as shown in Haščič and Migotto (2015).
$lnGreenCitation_{t+3}$	The natural log of one plus the total citations of green patents of a firm's green patents, measured at the end of the calendar year t+3, where year t is the year when the EPA Index is constructed.

Appendix A (Continued)

Variable	Description
$HighEnforcementRank$	An indicator variable that equals 1 if firm headquarters are located in a state with above median enforcement actions by the EPA, measured at the end of the calendar year t-1, and zero otherwise (EPA Enforcement and Compliance History Online, https://echo.epa.gov/).
$HighEPABudget$	An indicator variable if year t is the year when the EPA has above median annual budgets across the full sample, and zero otherwise (The EPA's website, https://www.epa.gov/planandbudget/budget).
$FutSalesRD$	The ratio of three-year ahead sales over R&D at year *t*
$InvEfficency$	The measure of capital investment efficiency as used in Goodman *et al.* (2014), which is an indicator that equals one if a firm has an unexpected investment level below the median of the distribution of unexpected investment, and zero otherwise.
$DualCEO$	An indicator that equals 1 if the CEO of the firm is also the chairman of the board, and 0 otherwise (ExecuComp).
$DisAccrual$	The value of firms' discretionary accruals calculated following the modified Jones model by Dechow *et al.* (1995) (Compustat).
$\%NonIndDirector$	The percentage of non-independent firm directors, calculated as one minus the percentage of independent directors, available since the year 1998 (BoardEx).
$BadGovScore$	An indicator variable that equals one (zero) if the MSCI KLD governance score is below (over and above) sample median of a given year, available from year 1990 to 2016 (MSCI KLD).
$NarrowBeat$	An indicator that equals one if the firm meet or beat the analysts' mean consensus forecast by less than one cent in the most recent fiscal year, and zero otherwise (I/B/E/S).
$TransInvestor$	The percentage of transient investors calculated following Bushee (1998) (Brian Bushee's website, https://accounting-faculty.wharton.upenn.edu/bushee/).
$10KConstraint$	An indicator that equals 1 (0) if the percentage of the number of financial constraint words in firm's 10K filing is ranked above (below) the median of the sample in year t.
$DebtConstraint$	The Hoberg and Maksimovic (2015) measure of debt-market constraint.
$\triangle SVI$	The percentage changes in the state-level Google Search Volume Index for the keyword "ESG" of year t, where firms' headquarters are located (Google Trend, https://trends.google.com/trends/?geo=US).
$ConsumerFacing$	An indicator variable that equals one if the industry the firm belongs to is in the consumer-facing industries based on Fama and French 12-industry classification, including the consumer nondurable, consumer durable, wholesale and retail, and healthcare industries (Compustat).
$EPU\_FirmEnvRisk$	The firm-level environmentally-related economic political risks developed by Hassan *et al.* (2019) (The Economic Policy Uncertainty website-Firm-level Political Risk, https://www.policyuncertainty.com/firm_pr.html).

ONLINE APPENDIX

"Going Green: The Effect of Environmental Regulations on Firms"

This appendix provides descriptive information and supplemental analyses that are not presented in the paper.

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ONLINE APPENDIX A: Topic Modeling

LDA analysis is performed with gensim package in Python. To prepare for the LDA analysis, we take the following steps:

- Use the CFR Title 40 text for EPA regulations from 1996 to 2020 and extract parts from each file to create a data frame.[33]
- Replace non-alphabetical characters with empty strings and lowercase remaining words.
- Tokenize the text by converting a document to its atomic elements.
- Remove stopwords (English words) and additional terms that are meaningless, such as "fr", "section", "use", and "paragraph".
- Remove punctuation and lemmatize the words. Words that have fewer than three characters are removed.
- Generate the set of bigrams (pairs of two words) frequently occurring in the document.
- Filter out tokens that appear in less than 10 documents (absolute number) or more than 0.5 documents (fraction of total corpus size). The unique set of terms is the corpus vocabulary.
- Create the term dictionary of the corpus, where every unique term is assigned an index.
- Convert the list of documents/parts (corpus) into Document-Term Matrix using the dictionary prepared above. Thus, for each document, we create a dictionary reporting how many words and how many times those words appear.

To select the number of topics, we estimate a variety of models with different numbers of topics and select the model specification that has the highest coherence value. The estimation suggests a 14-topic model.

[33] Raw text data is from https://www.govinfo.gov/bulkdata/CFR

EPA Regulations Topics		
Topic number	**Topic Name**	**Topic Top Keywords**
Category A	**Air quality**	
Topic 1	Fuel and Gas Refinery	fuel, gasoline, refiner, volume, importer, refinery, sulfur, diesel, baseline, import
Topic 2	Gas emission	emission, gas, operator, rate, concentration, owners, flow, fuel, calibration, calculate
Topic 3	Air quality control regional	county, line, township, range, north, refrigerant, east, west, south, AQCR
Topic 4	Engine emission	engine, emission, vehicle, manufacturer, fuel, model, family, exhaust, credit, locomotive
Topic 5	Ozone and NOx CAIR	NOx, CAIR, allowance, account, emission, ozone_season, creek, opt-in, owner, operator
Topic 6	Gaseous calibration standards	concentration, flow, measurement, filter, calibration, gas, sampler, laboratory, rate, calculate
Topic 7	Air quality implementation plan	emission, rule, revision, county, department, implementation, adopt, SIP, pollution, November
Topic 8	Substance release recordkeeping	substance, recordkeeping, release, manufacturer, manufacture, pmn, revocation_certain, factor, importer_processor, concentration
Category B	**Hazardous substance**	
Topic 9	Hazardous pollutants	emission, operator, owner, device, hap, organic, vent, coat, accord, gas
Topic 10	Hazardous effect	hazardous, operator, owner, tank, regional, disposal, storage, oil, closure, container
Topic 11	Toxic substance	study, substance, animal, dose, exposure, concentration, toxicity, species, chamber, weight
Topic 12	Pesticide control	pesticide, tolerance, residue, commodity, exemption, registration, byproduct, label, food, acid
Category C	**Wastewater**	
Topic 13	Wastewater pretreatment technology	pollutant, effluent, pound, wastewater, lead, oil, zinc, range, pretreatment, technology
Category D	**EPA administrative procedure**	
Topic 14	Cost and Administrative	cost, hear, project, regional, party, applicant, claim, fund, comment, administrative

Table OA.1: Firm Valuation and Sub-EPA Index Based on Topics

	Dependent variables: Q													
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
$\triangle EPA^{Ind}_{Topic}$	-0.004	-0.022***	0.011	-0.012	-0.006	-0.001	0.010**	0.003	-0.008	0.019**	-0.003	-0.009	0.020**	-0.018*
	(0.017)	(0.007)	(0.008)	(0.007)	(0.009)	(0.004)	(0.004)	(0.010)	(0.006)	(0.008)	(0.013)	(0.014)	(0.008)	(0.010)
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	91,931	91,931	91,931	91,931	91,931	91,931	91,931	91,931	91,931	91,931	91,931	91,931	91,931	91,931
Adj.R-squared	0.643	0.643	0.643	0.643	0.643	0.643	0.643	0.643	0.643	0.643	0.643	0.643	0.643	0.643

This table presents the results of regressing firms' valuation on changes in the sub-EPA Index based on topics, $\triangle EPA^{Ind}_{Topic}$. Q is Tobin's Q, measured at the end of the fiscal quarter immediately following July. $\triangle EPA^{Ind}_{Topic}$ is the standardized changes in EPA regulatory restrictions imposed on each six-digit NAICS code industry for each of the 14 identified topics. The topic number is indicated by the column number. Control variables include firm size, SG&A expense intensity, R&D expenditure intensity, firm leverage, return-on-assets, cash, institutional ownership, and industry-level sales growth. The coefficient estimates of control variables and constants are included in all models. All regressions include firm and year fixed effects. Standard errors are clustered at the six-digit NAICS industry level and presented in parentheses below the coefficients. All continuous variables are winsorized at the top and bottom 1% levels. ***, **, * indicate statistical significance at 1%, 5%, and 10%, respectively. Variable definitions are included in Appendix A.

Table OA.2: EPA Index and Firm Valuation Conditional on Prior EPA Regulations

	(1)	(2)
	full	full
VARIABLES	Q	Q
PostEPA×LowEPA	0.078**	0.065**
	(0.038)	(0.032)
PostEPA	0.121***	0.186***
	(0.033)	(0.028)
LowEPA	0.003	-0.038***
	(0.016)	(0.011)
Size		-0.724***
		(0.059)
SG&A		0.014
		(0.060)
R&D		-0.009
		(0.054)
Leverage		0.000
		(0.002)
ROA		-2.350***
		(0.511)
Cash		1.417***
		(0.418)
IO		1.174***
		(0.077)
IndSalesGrowth		0.052***
		(0.016)
Constant	2.127***	5.302***
	(0.010)	(0.338)
Observations	106,947	106,947
Year FE	YES	YES
Firm FE	YES	YES
Adj.R-squared	0.551	0.630

This table presents the results of regressing firms' valuation on $PostEPA$ variable, conditional on the level of prior EPA regulations. Q is Tobin's Q, measured at the end of the fiscal quarter immediately following July. $PostEPA$ is a variable that equals 1 (-1) for the four-year periods since the year when a six-digit NAIC industry experiences a larger than (smaller than) two standard deviation increase (decrease) in the level of EPA regulation restrictions relative to industry mean, and zero otherwise. LowEPA is an indicator variable that equals 1 if the previous level of aggregate EPA regulations of a firm is below the sample median of a given year, and zero otherwise. Control variables include firm size, SG&A expense intensity, R&D expenditure intensity, firm leverage, return-on-assets, cash, institutional ownership, and industry-level sales growth. All regressions include firm and year fixed effects. Standard errors are clustered at the six-digit NAICS industry level and presented in parentheses below the coefficients. All continuous variables are winsorized at the top and bottom 1% levels. ***, **, * indicate statistical significance at 1%, 5%, and 10%, respectively. Variable definitions are included in Appendix A.

Table OA.3: EPA Index and Firm Valuation Controlling for non-EPA Regulations

	(1)	(2)
	full	full
VARIABLES	Q	Q
PostEPA	0.271***	
	(0.014)	
PostIncrease		0.209**
		(0.043)
PostDecrease		-0.011
		(0.045)
non-EPA	-0.015	-0.013
	(0.010)	(0.010)
Size	-0.651***	-0.761***
	(0.084)	(0.146)
SG&A	-0.014	0.008
	(0.070)	(0.059)
R&D	-0.056	0.010
	(0.051)	(0.068)
Leverage	-0.000	0.001
	(0.002)	(0.003)
ROA	-2.720***	-2.415***
	(0.684)	(0.599)
Cash	0.678**	1.527**
	(0.308)	(0.746)
IO	1.485***	1.325***
	(0.191)	(0.170)
IndSalesGrowth	0.054**	0.057***
	(0.023)	(0.020)
Constant	4.683***	5.312***
	(0.432)	(0.784)
Observations	107,169	107,169
Year FE	YES	YES
Firm FE	YES	YES
Adj.R-squared	0.556	0.623

This table presents the results of regressing firms' valuation on the *PostEPA* variable, controlling for non-EPA regulations. Q is Tobin's Q, measured at the end of the fiscal quarter immediately following July. *PostEPA* is a variable that equals 1 (-1) for the four-year periods since the year when a six-digit NAICS industry experiences a larger than (smaller than) two standard deviation increase (decrease) in the level of EPA regulation restrictions relative to the industry mean, and zero otherwise. *PostIncrease* (*PostDecrease*) is a variable that equals 1 if *PostEPA* equals 1 (-1), and equals zero otherwise. Control variables include firm size, SG&A expense intensity, R&D expenditure intensity, firm leverage, return-on-assets, cash, institutional ownership, and industry-level sales growth. All regressions include firm and year fixed effects. Standard errors are clustered at the six-digit NAICS industry level and presented in parentheses below the coefficients. All continuous variables are winsorized at the top and bottom 1% levels. ***, **, * indicate statistical significance at 1%, 5%, and 10%, respectively. Variable definitions are included in Appendix A.

Table OA.4: EPA Index and Firm Valuation Controlling for Prior E&S Ratings

	(1)	(2)
	full	full
VARIABLES	Q	Q
PostEPA	0.163**	
	(0.079)	
PostIncrease		0.293**
		(0.123)
PostDecrease		-0.112
		(0.082)
lagKLDIndex	-0.023**	-0.019**
	(0.010)	(0.008)
Size	-0.671***	-0.638***
	(0.075)	(0.065)
SG&A	-0.053	-0.165
	(0.072)	(0.123)
R&D	-0.004	0.019
	(0.116)	(0.119)
Leverage	-0.000	-0.002
	(0.003)	(0.002)
ROA	2.436***	2.770***
	(0.918)	(0.790)
Cash	0.328	0.243
	(0.247)	(0.224)
IO	0.760***	0.725***
	(0.219)	(0.187)
IndSalesGrowth	0.057*	0.032
	(0.034)	(0.032)
Constant	6.116***	5.941***
	(0.486)	(0.422)
Observations	28,946	28,946
Year FE	YES	YES
Firm FE	YES	YES
Adj.R-squared	0.671	0.674

This table presents the results of regressing firms' valuation on the *PostEPA* variable. Q is Tobin's Q, measured at the end of the fiscal quarter immediately following July. *PostEPA* is a variable that equals 1 (-1) for the four-year periods since the year when a six-digit NAICS industry experiences a larger than (smaller than) two standard deviation increase (decrease) in the level of EPA regulation restrictions relative to industry mean, and zero otherwise. *PostIncrease* (*PostDecrease*) is a variable that equals 1 if*PostEPA* equals 1 (-1), and equals zero otherwise. Control variables include firm size, SG&A expense intensity, R&D expenditure intensity, firm leverage, return-on-assets, cash, institutional ownership, and industry-level sales growth. All regressions include firm and year fixed effects. Standard errors are clustered at the six-digit NAICS industry level and presented in parentheses below the coefficients. All continuous variables are winsorized at the top and bottom 1% levels. ***, **, * indicate statistical significance at 1%, 5%, and 10%, respectively. Variable definitions are included in Appendix A.