Harnessing Renewable Portfolio Standards for Sustainable Futures: An Empirical Examination of Spillover Effects

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Abstract

Given the importance of managing industrial energy consumption, setting standards and making policies to encourage the use of renewable energy sources is critical to incentivize sustainable firm actions. Public policy designs must work in lockstep with firms' environmental policies if they are to play a vital role in mitigating greenhouse gas (GHG) emissions and facilitating a sustainable future. While research on policy impacts on firm behavior and the role of the supply chain in sustainability is growing, a critical understudied effect is the spillover effects of the rules on the supply chain partners and peer firms, especially those who do not come under the direct purview of environmental regulations. In this paper, we present a novel approach by integrating data from the Carbon Disclosure Project (CDP) and the Renewable Portfolio Standards (RPS), which are currently state-driven initiatives to incentivize electricity consumption generated through eligible renewable resources. We examine the causal effects of state-level policies on firm-level GHG emissions, particularly emphasizing the spillover effects of policies on unregulated firms in different markets. Our analysis, using a staggered difference-in-differences methodology, reveals an encouraging negative association between the introduction of the RPS and the volume of GHG emissions of unregulated firms across industries. Interestingly, we observe that firms headquartered in states with more conservative RPS targets and progressive milestone-based implementation strategies have significantly lower GHG emissions when compared to firms headquartered in states with more aggressive targets and states with long-term absolute implementation targets. Our findings have significant implications for developing environmental regulations and public policies aimed at GHG emissions.

Keywords: Environmental regulations, GHG emissions, Renewable Portfolio Standards, Staggered difference-in-differences methodology, Spillover effects.

1 INTRODUCTION

Climate change poses substantial risks to the global economy (Bansal et al., 2017), and virtually all sectors of our society actively engage in efforts to promote environmental sustainability (Fischer et al., 2012). Policymakers have introduced a range of measures to reduce firms' emissions by increasing the use of renewable energy (Aflaki & Netessine, 2017; Albertini, 2014; Borenstein, 2012; Lima et al., 2020). In the US, this includes the traditional command and control system and the recent, more flexible policy tools such as market-based regulation, economic incentives, self-regulation, voluntarism, and information strategies (King & Lenox, 2001; Klassen & Whybark, 1999; Tuladhar et al., 2014; Weigelt & Shittu, 2016). The Renewable Portfolio Standard (RPS) is one such policy tool designed to increase the use of renewable energy sources for electricity generation (Carley & Browne, 2013). Since Rader and Norgaard (1996), it has been the subject of in-depth study, stemming from an Iowan renewable power goal established in 1983. The goal of the RPS is to increase the usage of renewable energy, such as solar, wind, and hydroelectric power, thereby reducing reliance on fossil fuels and mitigating adverse environmental impacts such as greenhouse gas emissions (Barbose et al., 2015; Barbose et al., 2016; Farooq et al., 2013). The mechanism typically involves setting legally binding targets for utilities to achieve a certain amount of their energy production from renewable sources by a specified date (Wiser et al., 2008).

While no federal RPS with uniform standards currently exists, 29 states have enacted their own RPS programs, and three states have adopted voluntary renewable energy goals. Most states differ in their choice of target requirements, the incentives they offer for compliance, the resources considered eligible under the requirements, and the option to obtain tradable renewable energy credits or certificates, among other design features (Barbose et al., 2016; Wiser et al., 2008). While 15 states have set a 100% clean energy target, five have set their targets at 50% and above. Across these states, the deadlines to meet the respective targets vary greatly. For instance, Connecticut has set a target of 100% with a deadline of 2040, while Illinois has a target of 50% for the same year. Appendix 1 summarizes the timeline and other attributes of state RPS implementations.

Numerous studies have shown that RPS policies have effectively driven the deployment of renewable energy technologies, such as wind, solar, and biomass (Wiser et al., 2011). This includes studies that show how RPS policies interact with other energy and environmental policies, such as federal tax incentives, cap-and-trade programs, and energy efficiency measures (Gao et al., 2023a). It has been found that states with RPS mandates tend to have higher shares of renewable energy in their electricity generation mix (Carley, 2009; Schmalensee, 2012). Research has also quantified certain environmental benefits of RPS, including reductions in carbon dioxide emissions and improved air quality (Kravchenko et al., 2023). It has further been demonstrated that the effectiveness of RPS in driving the growth of renewable energy varies with the stringency of the standards and the commitment of the state to enforce them (Solomon & Zhou, 2021; Zhou

& Solomon, 2020). One dimension unclear from this body is the spillover of RPS policies on unregulated partner/supply chain firms in different industries that could significantly impact environmental outcomes. Does introducing RPS indirectly result in improved environmental performance of firms that do not directly fall under the purview of the state's RPS? If yes, by how much do their emissions fall? Does the RPS design, specifically the level of stringency (aggressive vs. conservative targets) and implementation strategy (progressive milestone-based vs. long-term absolutes) stipulated under the RPS, impact the environmental performance of the unregulated firm? In this study, we aim to answer these questions empirically.

Scholarly discourse on how policies impact firm emissions can contribute to strategies that enhance the resilience of businesses and economies against climate-induced shocks (Huang et al., 2022; Scott et al., 2016). By understanding how existing policies impact firms' emissions, governments can anticipate the effects of future regulations, ensuring they are effectively designed to achieve desired outcomes (Aragòn-Correa et al., 2020; Lucas et al., 2008). Modern investors increasingly value environmental stewardship. Through understanding the nexus between policy and emission outcomes, firms can better position themselves as responsible actors in the market, potentially gaining a competitive advantage (Issa & In'airat, 2023; Porter & Kramer, 2006; Quairel-Lanoizelée, 2011). As policies demand more transparency in emissions reporting, understanding the interplay between policy and firm behavior can assist in developing more effective and streamlined reporting mechanisms (Lee & Klassen, 2016; Quairel-Lanoizelée, 2011). With this study, we aim to deepen this understanding of the impact of environmental regulations on firm behavior.

For this study, we collate 3,629 observations representing 365 US public firms between 2007 and 2019. This data consists of emission amounts of US public firms participating in the Carbon Disclosure Project (CDP). This investor-led, nonprofit organization manages a worldwide disclosure system for environmentally sustainable initiatives of countries, cities, firms, and investors. We combine this data with firm-specific financial and operational characteristics, such as return on assets and the number of full-time employees, collected from the Compustat database at Wharton Research Data Services[1]. We further augment this data with the attributes of state-level RPS targets gathered from the Environmental Investigation Agency[2]. Using a staggered difference-in-differences research design consistent with a state-of-the-art methodological approach in management and applied economics literature (e.g., Beck et al., 2010; Lin et al., 2021; Manski & Pepper, 2018), we examine the effects of exogenous policy changes. Our focus is on the changes in the firm emission performance in response to the corresponding state's RPS implementation. A key strength of our research design is the incorporation of the fact that the RPS targets in different states were initiated at different points of time during our study period (see Appendix 1) while

[1] WRDS, https://wrds-www.wharton.upenn.edu
[2] EIA, https://eia-international.org

also controlling for firm heterogeneity. The geographic and temporal variation in entry allows us to tease out the effects of the state RPS initiatives on firm emission performance from macro trends. In addition, for methodological triangulation, we also employ an event-study design for an auxiliary analysis that examines the immediate short-term and consistent long-term effects of the RPS.

Our results first confirm the negative relationship between the implementation of RPS and firms' emissions, which aligns with previous studies in the literature on regulated firms responding to RPS policies (Gao et al., 2023b; Meng & Yu, 2023). Second, compared to the 85% reduction in GHG in the energy sector due to the RPS, the GHG reduction for the non-energy sector is 9%, which implies that the spillover effects of the RPS on the non-energy sector exist, even though the magnitude is not as high as that of the energy sector. These results contribute to practice and theory regarding estimations of spillover effects of the policy on the unregulated sector (Engl et al., 2021; Henriques et al., 2013). Further, by splitting the RPS states' implementations based on their stringency (aggressive vs. conservative) and target-setting strategies (progressive milestone-based targets vs. long-term absolute targets), we confirm that a more flexible RPS leads to a more significant reduction in GHG than a more aggressive policy design.

The remaining paper is divided into the following sections. Sections 2 and 3 situate our paper in the context of existing literature and introduces the hypotheses, respectively. Section 4 describes our key variables, while sections 5 and 6 lay down the empirical framework and results for this study. We discuss the findings and policy implications in section 7, and in section 8, we consider the scope for future research and make concluding remarks.

2 THEORETICAL BACKGROUND AND HYPOTHESES

2.1 Related Literature

2.1.1 Drivers of voluntary adoption of better environmental practices by firms

Our study relates to the management literature investigating the interrelationships between environmental regulation and firm behavior. Reid and Toffel (2009) found that public and private pressures, such as environmental regulations, shareholder resolutions, and social movements, drive firms' corporate disclosure posture, among other actions to address climate change. Their study provides empirical evidence of the direct and spillover effects of stakeholder actions and regulatory threats in terms of disclosure behavior. That is, they find that firms within an industry or within a state where other firms have been subjected to such internal and external pressures are more likely to publicly disclose information to NGOs such as the Carbon Disclosure Project (CDP). Driven by such factors, firms' Corporate Social Responsibility (CSR) actions that foster transparency have enabled researchers to better evaluate corporate environmental performance in recent years.

Prior research highlights that firms benefit from CSR practices in terms of their environmental performance, including implementations of management systems such as ISO 14000[3] certified processes (Cohen, 2000; Melnyk et al., 2003), voluntary Environmental, Social, and Governance (ESG) programs (Chen & Delmas, 2011; Li & Wu, 2020; Scott et al., 2022), and other operational management practices (Alt et al., 2015; King & Lenox, 2001; Klassen & Whybark, 1999; Park et al., 2022; Shafiq et al., 2014). In addition to such intra-firm levers, external factors, such as institutional pressure (Sarkis et al., 2010; Zhu & Sarkis, 2007) and regulations (Brulhart et al., 2019; Li & Ramanathan, 2018), have been found to play an important role in firm CSR decisions and performance. Flammer (2015) finds that a reduction in tariffs is associated with an increase in firms' engagement in CSR. Similarly, Porteous et al. (2015) propose an analytical model to demonstrate the effect of supply chain contracts on suppliers' environmental compliance. Most of this literature stream has predominantly focused on the institutional and intra-firm levers intended to achieve pro-environmental outcomes. Our paper contributes to the existing discussion on institutional pressure by identifying an understudied influential factor that could indirectly influence firm environmental performance: the spillover effect of regulatory pressure.

2.1.2 Impacts of public policy on corporate environmental performance

Operations management literature has recently seen a growing body of work employing analytical models to study the different impacts of policy designs in the context of climate change. For example, Kok et al. (2014) investigate the impacts of pricing policies (i.e., flat pricing vs. peak pricing) on carbon emissions in competing energy sources; Sunar and Plambeck (2016) propose an optimal policy regarding the emission tax imposed on the primary product to reduce emission and increase welfare; Fan et al. (2022) simultaneously model the impact of the cap-and-trade policy and the carbon tax policy on a firm's carbon emission and technology investment. While many analytical models have established the importance of considering the distinct impacts of policy forms and designs, empirical examinations of the impact of RPS designs on the carbon emissions of firms have been limited. Our paper contributes to this stream of literature by empirically examining the causal impact of state environmental policy on a firm's emissions and, more importantly, the emissions generated by non-regulated firms that are not compelled to act on specific environmental laws. To establish this causation, we leverage the exogenous shock of a multi-state implementation of a clean energy policy.

2.1.3 Evaluations of RPS

Specifically concerning RPS, much like the policy itself, the research on evaluating its effectiveness is evolving. Some of the earlier works were concerned with estimating the impact of the RPS to determine its success in promoting renewable energy (Barbose et al., 2015). More specifically, research also quantified

[3] https://www.iso.org/standards/popular/iso-14000-family

the state-level reduction in GHG after the introduction of RPS policies (Barbose et al., 2016; Eastin, 2014; Yi, 2015). However, a critical departure of our work is our focus on unregulated firms, while incorporating heterogeneity in the design features of RPS policies across states. Yin and Powers (2010) make an important contribution to the policy heterogeneity perspective, as they established that upon accounting for heterogeneity in policy design, specifically the different degrees of stringencies, significant impacts of RPS policies could be observed on the renewable energy capacity of states. It was also demonstrated that more stringent policy designs are associated with a higher deployment of renewable energy in a state (Fischlein & Smith, 2013; Shrimali & Kniefel, 2011; Yin & Powers, 2010). More recently, Anguelov and Dooley (2019) have found contrasting results, showing that states with relatively weaker RPS policies have higher renewable energy consumption. A majority of this work has been undertaken to evaluate the impact of energy policy. Our contribution to this literature stream is introducing an OM perspective surrounding firm behavior and spillover effects on unregulated firm behavior stemming from top-down, state-wide environmental policies.

Reid and Toffel (2009) have examined corporate disclosure behavior as a response to regulation and other competition concerns. OM literature on RPS and firm responses to top-down policy shocks is limited. Our study ties together the empirical literature on corporate environmental performance and impact evaluation studies on RPS. We investigate the impact of regulatory spillover on firm environmental performance, which reflects greater sustained pro-environmental dedication of firms compared to disclosure decisions. We also identify heterogeneity in how firms adapt their environmental performance in response to distinct designs of a regulatory policy. As such, our study is an expansion of previous works that have looked at the heterogeneity of RPS design features (Carley et al., 2019; Shrimali & Kniefel, 2011; Yin & Powers, 2010), its spillover effects (Fu et al., 2018; Wolverton et al., 2022) and, in general, the factors influencing improved environmental performance.

2.2 Hypothesis Development

While existing literature predominantly focuses on how firms respond to regulations by improving compliance behavior (Backer, 2007; Mani & Muthulingam, 2019; Stafford, 2002), we posit that those environmental regulations are likely to improve environmental performance among unregulated firms in the same institutional region as well. We predict that unregulated firms are likely to introduce strategic adjustments, such as revising their existing operational paradigms, adapting their operational strategies, and embracing practices that harmonize more closely with the anticipated regulatory requirements and public expectations.

One line of reasoning for this is that the prospect of enforcing environmental regulations that could potentially disrupt established operational practices tends to trigger parallel responses among firms within the same institutional field (Reid & Toffel, 2009). This institutional field can encompass a specific geographic area where firms operate under similar regulatory and environmental conditions (González-Benito & González-Benito, 2006). When firms within this shared institutional field witness their counterparts facing the specter of existing environmental regulations, they often perceive these regulations as signals reflecting public sentiments and emphasizing the environmental imperative (Morgan, 2007). Considering this, they may regard themselves as potential future targets of similar regulatory measures. This perception stems from recognizing that regulators tend to monitor public concerns and observe industrial trends when formulating new regulations (Majone, 1997). This collective perception of vulnerability prompts firms to interpret major environmental regulations as opportunities to align with evolving norms and frameworks that currently govern their operations within the industry. Consequently, these firms may opt to follow a path similar to that of their regulated counterparts by engaging in pro-environmental efforts (Reid & Toffel, 2009).

A second incentive for unregulated firms to adopt the regulatory standard not directly applicable to them is the competitive advantage they stand to gain over their peers. By taking such measures, these firms may not only proactively prepare for potential future regulation, but also seek to enhance their own environmental performance standards (Zhang et al., 2019), strengthen their environmental reputation (Brulhart et al., 2019; Zhao et al., 2020), and position themselves more effectively within the competitive market (Brulhart et al., 2019; Dai et al., 2017; Walker et al., 2014). Firms that proactively adopt pro-environment measures in their operations may even position themselves to support more stringent regulation, thereby increasing costs for their rivals (Fremeth & Shaver, 2014). In essence, such proactiveness is likely to signify a collective response to regulatory pressure as firms across the board recognize the importance of environmental responsibility and the consequences of falling short in this regard. Along these lines, we propose the following hypothesis:

Hypothesis 1 (H1): Enforcing environmental regulations (such as the RPS) within the institutional region leads to enhanced environmental performance for unregulated (indirect) firms.

While environmental enforcement is expected to deter violations and improve performance, prior research has discerned various conditions under which the effectiveness of regulatory deterrence varies. The efficacy of regulatory deterrence is contingent on facility characteristics and permit conditions (Earnhart, 2009; Gray & Shimshack, 2011; Johnson, 2020). These findings reveal the importance of identifying the conditions under which firms will and will not respond to regulatory threats and interventions. In this study, we delve into this contingency mechanism by specifically examining how the stringency (aggressive vs. conservative targets) and implementation strategy (progressive milestone-based vs. long-term absolute target setting) of regulatory targets act as moderating factors in deterrence effects.

Previous research has shown that a more stringent legal environment could generate costs exceeding the benefits, including both the direct costs of implementing the pro-environmental measures and any indirect negative effects due to more rigid corporate strategies, which may harm managerial initiatives and lead to relative interior performance (Bruno & Claessens, 2010). When environmental regulations are excessively aggressive, firms may perceive compliance as an insurmountable challenge, leading to noncompliance or even avoidance of the regulated activities. On the contrary, less stringent or conservatory environmental regulations allow firms to proactively explore and implement eco-friendly practices without the heavy burden of compliance costs and strict targets. These firms can serve as pioneers, demonstrating that adopting environmentally responsible practices is feasible and can yield substantial benefits. Peer firms in the same institutional region can observe these examples and recognize the positive outcomes, which may encourage them to voluntarily adopt similar practices to enhance their environmental performance. Therefore, less stringent but reasonable regulations can foster a culture of compliance and continuous improvement, ultimately strengthening the deterrence effect in environmental regulation. Prior research has proved that this holds true even in the context of RPS (Anguelov & Dooley, 2019). Thus, we hypothesize as follows:

Hypothesis 2 (H2): The effect of environmental regulations (such as the RPS) on firms' environmental performance is stronger when the regulatory targets are less stringent (more conservative).

As for the regulatory policymaking strategy, we expect that when the policymaker embraces a progressive milestone-based (PMB) target (as opposed to a long-term absolute [LTA] target), there is a cooperative mindset that firms take, which should lead to better near-term environmental outcomes. PMB target-setting strategy refers to a policy where consistent and persistent adjustments of environmental regulations and enforcement targets occur over time (Cook, 2002; Yuan & Zhang, 2020). It allows gradual and iterative changes to be made to regulatory requirements over time. This approach focuses on making small adjustments and refinements to existing policies rather than implementing drastic changes (Jänicke, 2008; Levin et al., 2012). Firms operating under the shadow of progressive and continuous regulatory adjustments are more likely to perceive the regulatory environment as responsive and adaptable (Yuan & Zhang, 2020). This perception, in turn, acts as a powerful deterrent, motivating unregulated firms to adopt and maintain higher environmental standards, implement robust compliance measures, and reduce the risk of environmental violations (e.g., Reid & Toffel, 2009). The sustained presence of regulatory targets and the expectation of long-term scrutiny create a culture of environmental responsibility and compliance within firms and regions, making it less likely that they will engage in environmentally harmful practices.

Moreover, a regulatory implementation strategy that allows for incremental improvements and gradual transitions to environmentally friendly practices, along with a gradual approach to regulation with continuous adjustments to regulatory targets, can lead to more sustainable, long-term changes in firms (Ngan, 2010; Schrettle et al., 2014). Such a strategy enables both regulated and unregulated firms to transition to environmentally friendly practices at a manageable and economically viable pace, resulting in more enduring improvements in environmental performance. Consequently, implementations of progressive milestone-based regulatory targets are likely to strengthen the overall effectiveness of regulatory deterrence significantly. This leads us to propose the following hypothesis:

Hypothesis 3 (H3): The effect of environmental regulations (such as the RPS) on environmental performance of unregulated firms is stronger when regulations are progressive milestone-based.

Our research framework is presented in Figure 2-1.

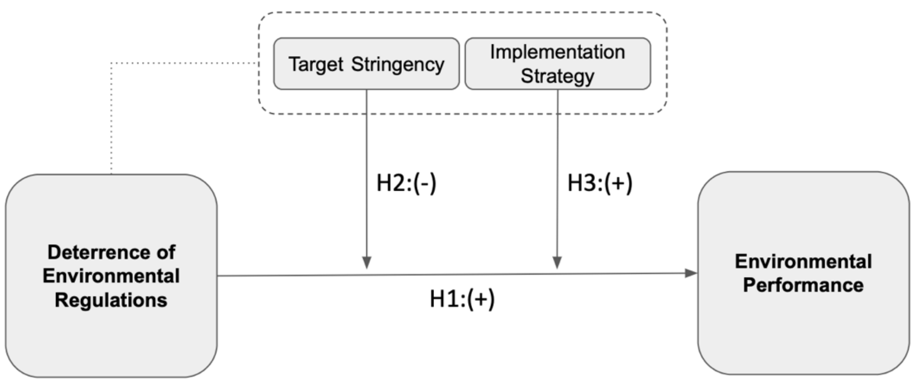


Figure 2-1: Research Framework

3 DATA DESCRIPTION

Through combining the firm environmental performance data from the CDP, an investor-led NGO that manages a worldwide disclosure system for the environmentally sustainable initiatives of countries, cities, firms, and investors, and financial performance data and other firm-level characteristics from the Compustat database, we identify 365 US public firms and compile a panel dataset of 3,629 observations between 2007 and 2019. We obtain the data on the RPS targets for each state from the official website of the EIA.

The primary dependent variable is the GHG emissions intensity of the firms. We compute emission intensity, which has been used as a key metric of firm emission outcomes in prior research (Bolay et al., 2022), by dividing the gross combined direct (or "scope 1") emissions and indirect (or "scope 2") emissions in metric tons of CO_2 of the firm[4] by the total number of employees. The main explanatory variable in this study is *RPS*, a binary variable indicating the RPS policy implementation at the state level. This variable takes on the value of one for a firm-year pair if the state where the firm is headquartered had its RPS policy implemented, and it equals zero otherwise. In order to test our hypotheses concerning the role of the design of RPS targets, we categorize our observations based on two characteristics. First, referring to Figure 3-1, we categorize the RPS policies based on the stringency of their initial targets (in the first year when the RPS target went into effect) as either "high" or "low." States with RPS targets below 10%[5]—deemed lower than average—are assigned a value of zero (implying conservative targets), while those with initial RPS targets exceeding 10%—thereby surpassing the average—are designated a value of one (implying aggressive targets). Second, we classify the states' RPS implementations into either *progressive milestone-based targets* (PMBT) or *long-term absolute targets* (LTAT) categories, as shown in Figure 3-2. The PBMT group compromises states with RPS targets that incrementally increase yearly (such as Minnesota), contrasting with their counterparts that update their targets on a long-term absolute basis (such as Texas). This split facilitates the evaluation of the long-term effects of RPS policy dynamics on trends in greenhouse gas emissions.

For our analysis, we also capture the characteristics of the firm for the following two reasons. First, controlling for firm characteristics enables the meaningful comparison of emissions across different firms. Without controlling for these characteristics, comparisons may be biased by intrinsic differences between firms rather than reflect the impact of their carbon emissions policies (Brannlund & Persson, 2012; Downar et al., 2021). Second, firm characteristics can act as confounding variables that influence both the implementation of certain practices and the level of emissions. For example, larger firms or those in certain industries might be more likely to implement sustainability practices and have higher absolute emissions levels (Hahn, 1989; Konar & Cohen, 1997; Lanoie et al., 2011). Controlling for such characteristics helps reduce confounding bias, ensuring that the observed effects are more likely to be caused by external policy rather than endogenous factors. Therefore, consistent with the previous research (Atif et al., 2023; Atif et al., 2019; Liu et al., 2014), we employ four variables as the control variables in our analysis: return on assets (*ROA*), market capitalization (*MC*), research and development (R&D) expense (*RD*), and firm age (*Age*).

[4] Direct emissions consist of those that come from activities that are controlled by the respondent firm (e.g., from manufacturing processes, consumption of fossil fuels in equipment, and generation of power in-house). Indirect emissions consist of those that arise from the firms' purchase of electricity from external sources.
[5] An RPS target indicates the percentage of electricity sourced from renewable resources.

Table 3-1: Descriptive Statistics

Variable	Description	Mean	Std. Dev.
GHG Emission intensity	Total GHG Emission/ Firm Size (Employee)	13.29	2.729
RPS	Renewable Portfolio Standards	0.727	0.446
Energy Sector	Classification based on SIC codes	0.048	0.215
RPS targets	A specified percentage of the electricity utilities sell comes from renewable resources	0.105	0.087
ROA	Return on assets	0.056	0.086
MC	Market capitalization	9.273	2.633
RD	R&D expense	12.291	151.292
Age	Firm's Age	147.432	343.900
N	3629		
Year	2007-2019		

4 EMPIRICAL FRAMEWORK

4.1 Staggered Difference-in-Differences

To identify the impacts on corporate GHG emissions before and after the implementation of the RPS policy, we leverage the start of the RPS policy as a quasi-experimental treatment and adopt a staggered difference-in-differences (DiD) methodology. Since around 28% of the states in our data do not have the RPS policy, and the point in time when the RPS policy is implemented varies by state, we can identify the effect of the implementation of RPS on firms' GHG emissions. We run the DiD analysis using an ordinary least squares (OLS) estimation with fixed effects. Our model specification for the DiD analysis is as follows:

$$GHG_{it} = \beta_0 + \beta_1 GHG_{it-1} + \beta_2 RPS_{it} + \beta_3 C_{it} + \mu_i + \eta_t + \epsilon_{it}$$

where GHG_{it} represents the GHG emission intensity of a firm i in a given year t. Since each firm's emission from the previous year will affect the emission in the current year, we use a dynamic model with GHG_{it-1} included in the regression to represent the firm's emissions intensity of last year. RPS_{it} represents the policy implementation, which equals to one if the state where the firm's headquarters are located had the RPS policy in year t. β_2 is the coefficient of interest that captures the effect of states' RPS implementations on firms' GHG emissions. C_{it} represents other control variables of the firm. ϵ_{it} is the random error term that follows an independent identical distribution. In this empirical analysis, standard errors are clustered at the state level. We also include fixed effects for the *firm* and *year* to account for firm heterogeneity and temporal time trends.

4.2 Parallel Trend Test

To examine the parallel trend assumption, we employ an event study approach that distinguishes between the policy's short- and long-term impacts. We use the implementation of RPS as the reference point, selecting years leading up to and following it for validation. This analysis aims to ensure that the difference in GHG emissions of firms before and after the start of the RPS policy is caused by the RPS policy itself, instead of some unobservable factors. Therefore, to screen the trends in the GHG emission levels of enterprises before and after the start of the pilot, as well as to clarify the policy effects of the pilot policy, we use the following model to test the parallel trends in the treatment and control groups before and after the policy:

$$GHG_{it} = \alpha + \sum_{n=-8}^{8} \beta_n RelativeRPS_{it}^{n} + \gamma C_{it} + \mu_i + \eta_t + \epsilon_{it}$$

where the variables $RelativeRPS_{it}$ is a relative year policy variable generated with reference to the year of RPS implementation, and $GrelativeRPS_{it}^{n}$ equals to one for firms included in the experiment, while GHG_{it}^{n} is always zero for not included firms. We set the year prior to RPS policy implementation as the base year for event analysis, and β_n is the regression coefficient relative to the base year. We define the other variables so as to remain consistent with the base regression model settings and cluster them at the state level. If the coefficient β_n is not significantly different from zero, it indicates that the common trend assumption is satisfied, and we can plot the estimated results of β_n at the 95% confidence interval.

5 EMPIRICAL RESULTS

5.1 Effect of RPS on Firm GHG Emission

Panel A in Table 5-1 presents a comprehensive analysis of the impact of RPS on GHG emission intensity. These analyses are significant based on the p-value of zero. The company-specific GHG emission intensity is shown in the first column and demonstrates a significant *decrease* of a factor of 0.908 (= exp[-0.0957]), or 9.12%, after implementing the RPS regulation. Furthermore, the company's GHG emission intensity decreased by a factor of 0.148 (= exp[-1.909]), or 85.2%, once the RPS policy was activated, according to the second column, which focuses on the energy sector.

Table 5-1: Effect of RPS on Firm GHG Emission Intensity

	Panel A			Panel B	
VARIABLES	(1) Whole Sample	(2) Energy Sector	(3) Non-Energy Sector	(4) Whole Sample	(5) Whole Sample
RPS	**-0.0957***	**-1.909****	**-0.0939****	**-0.211****	**-0.234*****
	(0.0560)	(0.832)	(0.0473)	(0.0847)	(0.0896)
RPS x Aggressive targets				**0.208***	
				(0.110)	
RPS x Long-term Absolute (LTA) targets					**0.227****
					(0.111)
Log (GHG_{t-1})	0.138***	0.104	0.353***	0.123***	0.121***
	(0.0237)	(0.0814)	(0.0274)	(0.0245)	(0.0245)
Constant	1.470	115.4***	3.837***	0.577	0.591
	(1.584)	(36.14)	(1.289)	(1.855)	(1.853)
Controls	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
Observations	2,435	124	2,311	2,024	2,024
Number of Firms	365	18	347	308	308
R-squared	0.96	0.503	0.984	0.96	0.96

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1. Robust standard clustering errors at the state level are reported in parentheses.

The coefficient for the non-energy sector (in the third column) shows a noteworthy decrease in the company's GHG emission intensity of 0.91 (= exp[-0.0939]), or 9%, after the implementation of the RPS. As a result, even if the policy is intended to benefit the energy industry, the RPS will significantly impact non-energy firms. This result supports our first hypothesis, which states that improved environmental performance for unregulated (indirect) enterprises results from institutional region-wide enforcement of environmental legislation. As shown in Table 5-1, we also observe that increased emissions intensity in the past year is associated with an increase in emission intensity levels of the current year, which is consistent with the findings in the previous literature (den Elzen et al., 2016; Yu et al., 2014).

Panel B of Table 5-1 presents the results of regressions for different policy types. The results in the fourth column demonstrate that the RPS policy reduces GHG emission intensity by a factor of 0.81 (= exp[-0.211]), or 19%, when the first year's target is relatively low (a target with a percentage of less than 10%). The RPS program could result in a trivial decrease of 0.3% (=1- exp[-0.211 + 0.208]) if the initial year's goal is set high, implying that firms are less likely to respond to the policy if it starts with a high target. This supports our second hypothesis that less stringent RPS goals are likely to have a greater impact on the environmental performance of firms. The fifth column suggests that when the RPS targets were set progressively on a milestone basis, GHG emission intensity decreased by a factor of 0.791 (= exp[-0.234]), or 20.9%. In contrast, when the RPS policy target design is progressive, firms' GHG emissions decrease by just 0.7% (=1- exp[-0.234 + 0.227]). This finding supports the third hypothesis that there is likely to be a stronger impact of RPS implementation on firms' environmental performance when the regulatory framework implements progressive milestone-based targets.

5.2 Extension: Examination of Firm-level Heterogeneity

Previous literature has demonstrated that firms' pro-environmental behavior varies across firms with different characteristics, such as the firm age (Patel et al., 2017) and the industry segment (Moser, 2015). Next, we perform a posthoc analysis to examine the heterogeneous effect of the RPS implantation on firm emission performance. In particular, we consider two variables, namely, *Age*, measured by calculating the number of years since the firm's establishment, and *Service*, which takes the value of one if the firm belongs to the service segment. We then include interaction terms, *RPS* x *Age* and *RPS* x *Service*, to capture the heterogeneity in firm emission performance following the implantation of RPS. We present estimation results in Table 5-2 and sequentially include the two variables (Columns 1-2) and the interaction terms (Columns 3-4). In Column 3, we observe a significant negative coefficient for the interaction term of RPS x Age, indicating the emission intensity of aged firms will decrease more than young firms after the adoption of the RPS. In Column 4, we observe a positive coefficient for the interaction term of RPS x Service, indicating the emission intensity of service firms will decrease less than non-service firms after the adoption of the RPS, but the effect is not significant.

Table 5-2: Effect of Firm Heterogeneities on GHG Emission Intensity

VARIABLES	(1) Emission Intensity	(2) Emission Intensity	(3) Emission Intensity	(4) Emission Intensity
RPS	**-0.0957***	**-0.0957***	**-0.0416**	**-0.175****
	(0.0560)	(0.0560)	(0.0617)	(0.0875)
Age	**0.253****	**0.253****	**0.251****	**0.251****
	(0.105)	(0.105)	(0.105)	(0.105)
Service		**-4.443*****	**-4.391*****	**-4.549*****
		(1.243)	(1.242)	(1.246)
RPS x Age			**-0.00235****	
			(0.00113)	
RPS x Service				**0.128**
				(0.108)
Log (GHG_{t-1})	0.138***	0.138***	0.137***	0.139***
	(0.0237)	(0.0237)	(0.0237)	(0.0237)
Constant	0.249	4.692***	4.652***	4.768***
	(1.368)	(0.553)	(0.553)	(0.557)
Controls	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	2,435	2,435	2,435	2,435
Number of ids	365	365	365	365
Adjusted R-squared	0.882	0.882	0.886	0.882

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1. Robust standard clustering errors at the state level are reported in parentheses. As the *Service* variable remains consistent within the panel and is collinear with firm-level fixed effects, one of the firm-specific dummies was automatically dropped from the estimation process.

5.3 Robustness Checks

5.3.1 Event study results

Figure 5-1 below shows the results of the event study. Before the base period, the estimates fluctuate up and down around zero, indicating that our dataset passes the parallel trend test. Before the implementation of the RPS policy, none of the GHG_{it}^{n} coefficients were significant, indicating that there was no significant difference in GHG emission intensity between the treatment and control groups. In comparison, after we implemented the RPS policy, there was a marginally significant reduction (p<0.1) in the level of GHG emission intensity of the firms. The policy's negative impact began to appear and maintained a continuous decrease in the long term. This observation indicates that firms would continuously pay attention to environmental protection and reduce their GHG emissions after the start of the policy of RPS targets. As a result, after the regulation is implemented, the intensity of GHG emissions decreases significantly.

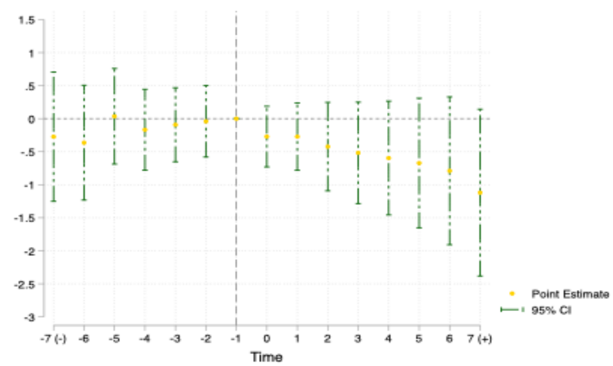


Figure 5-1: Event plot graph

5.3.2 Placebo test

In this study, we use a placebo test to identify the chance of the effect of the RPS policy and construct a "pseudo policy dummy variable" by randomly sampling 1,000 times using the placebo test according to the distribution of the policy variable RPS in the baseline regression and estimate this chance in the model to test the coefficient and p-value. Figure 5-2 shows the distribution of the estimated coefficients and p values of the pseudo policy dummy variables after 1,000 random samples. The above results fully demonstrate that most of the estimated coefficients in the 1,000 random samples are nonsignificant, and the city pilot has no significant effect in the randomly selected pseudo policy dummy variables. Therefore, we conclude that the estimates in the baseline regression were not derived by chance and thus passed the placebo test.

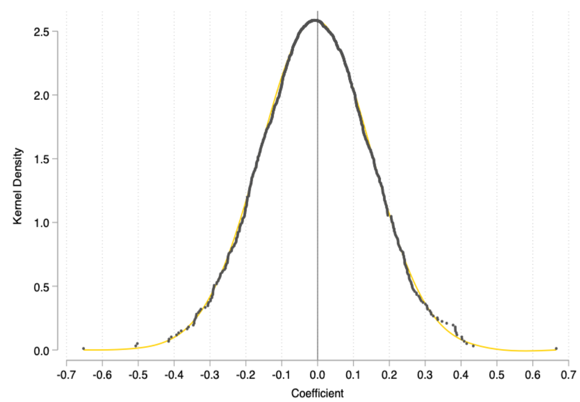


Figure 5-2: Distribution of Estimate Coefficients

6 Discussion of Results and Limitations

In recent years, the RPS has become a popular policy tool in the US to push for renewable energy, with several states adopting diverse policy designs and setting increasingly higher targets. However, scholarly debate persists on the suitability and effectiveness of stringent policy designs in influencing firm behavior and achieving policy goals. From a practitioner's perspective, established and robust empirical evidence on the effectiveness of these policy designs on environmental performance is limited. Our study intends to ameliorate these limitations.

The primary objective of this study was to examine the spillover effects of the RPS policy on emission levels of unregulated firms—that is, firms in the non-energy sector. We adopted a difference-in-differences design on a 13-year (2007-2019) panel data of 365 US public firms and mapped this sample with the state-level RPS targets. Our results indicate an overall decrease of 9.12% in the firm-level emissions with a decrease of 85% being observed in the energy industry. While the energy sector results are consistent with previous research on the efficacy of the RPS in reducing state-level emissions (Barbose et al., 2016; Eastin, 2014; Yi, 2015), our work highlights that in the non-energy supply chain partners, the introduction of the RPS policy is associated with a decrease of 9% in the firm emission intensity. This finding supports our first hypothesis that environmental regulations have spillover effects on unregulated firms within the institutional region. We further observe that this spillover effect is more significant for aged firms than young firms, and for firms in the production sector as compared to the service industry. In addition, we provide empirical evidence to support that the RPS policy is more effective in reducing emissions if a non-aggressive target (a target of less than 10 percent reduction) is set for the first year. This result suggests that less stringent regulatory goals have a greater indirect impact on the environmental performance of unregulated firms. Similarly, we show that continuous and gradual increments in RPS policy goals are more effective in reducing emissions than sudden, drastic, or severe increments in the targets.

Through our research, we continue the discourse on CSR by empirically establishing that firms are likely to adopt pro-environment behavior if their headquarters are located in a geographical region subjected to environmental regulations. This aligns with predictions from previous work in other contexts (e.g., Reid & Toffel, 2009). We augment this research by inspecting the effect of heterogeneity in policy design on voluntary firm behavior. This differentiates our findings from previous studies, which found higher stringency to be associated with higher deployment of renewable energy (Fischlein & Smith, 2013; Shrimali & Kniefel, 2011; Yin & Powers, 2010). Instead, our results are consistent with the evidence produced by Anguelov and Dooley (2019), wherein less stringent RPS policies were shown to be related to a higher consumption of renewable energy. However, the focus area of our study is different from all previous works, and to the best of our understanding, this is the first paper to systematically establish a causal link between the introduction of the RPS policy and the spillover effect on emissions.

While this study offers valuable insights into the interplay between public policy and firm-level sustainability practices, particularly within the context of GHG emissions, it is important to acknowledge certain limitations. While robust, reliance on data from the CDP and Compustat database is constrained by the scope of data availability, potentially leading to restricted implications to other sectors, such as private firms or non-profit organizations. In addition, while the findings contribute to the discourse on the effectiveness of RPS and firm behavior, the generalizability of these results needs to be established across different economic settings. While our study is limited to the US to examine state-specific effects, different regulatory environments outside the US, variances in cultural attitudes toward sustainability, and differences in energy consumption patterns could all influence the generalizability of our results.

7 SCOPE FOR FUTURE RESEARCH AND CONCLUDING REMARKS

Future research should aim to mitigate these limitations by incorporating a broader dataset, including international firm data, and considering alternative methodological approaches that can further refine the causal relationships between public policies and firm-level environmental outcomes. Finally, given that non-energy firms make up the majority of the samples in our dataset (and most empirical firm datasets), it is imperative that future research include clever and additional ways to assess the impacts of energy companies in the study samples. Environmental regulations have evolved from the older command and control systems to more flexible and innovative designs, implying that a better understanding of the incentives for compliance and better climate risk mitigation strategies are possible for firms. It is promising to see that the RPS has successfully leveraged the present regulatory and market climate to encourage firms to take voluntary cognizance of their environmental impacts. As discussed above, their regulatory impact exceeds what was originally anticipated, showcasing the underlying potential of policies as an effective tool for combating climate change. As states revise their RPS targets, we hope our study will aid an evolved understanding of different design options so policymakers can maximize their reach and benefits and achieve their goals.

We have made some important contributions to literature in our study. There is limited research in OM on RPS and firm responses to top-down policy shocks. Our study combines empirical literature on corporate environmental performance with policy literature on environmental governance, including RPS. We explore the effect of regulatory policy on firm environmental performance and, in the process, identify differences in how firms adjust their environmental performance in response to various designs of a regulatory policy. Further, we expand on previous works that have investigated the heterogeneity of RPS design features (Carley et al., 2019; Shrimali & Kniefel, 2011; Yin & Powers, 2010) and its spillover effects (Fu et al., 2018; Wolverton et al., 2022) by examining the behavior of unregulated firms in various industries.

Overall, our findings have three key implications for policymakers. First, policymakers need to be mindful of the fact that as they seek to influence the behavior of target firms by implementing policies, unforeseen strategic adjustments are also likely to be made by unregulated entities. Second, to align the RPS with its objectives, it would be beneficial to make informed design choices, especially regarding stringency (aggressiveness vs. conservativeness) and progressiveness of implementation targets (as opposed to setting long-term absolute targets). Finally, while conducting an impact evaluation of the RPS and studying the effectiveness of its designs, researchers and policymakers should account for the spillover effects of the policy to arrive at a more comprehensive measure of the outcome of the policy.

8 References

Aflaki, S., & Netessine, S. (2017). Strategic investment in renewable energy sources: The effect of supply intermittency. *Manufacturing & Service Operations Management*, *19*(3), 489-507.

Albertini, E. (2014). A descriptive analysis of environmental disclosure: A longitudinal study of French companies. *Journal of Business Ethics*, *121*(2), 233-254.

Alt, E., Díez-de-Castro, E.P., & Lloréns-Montes, F. J. (2015). Linking employee stakeholders to environmental performance: The role of proactive environmental strategies and shared vision. *Journal of Business Ethics*, *128*(1), 167-181. http://www.jstor.org/stable/24702860

Anguelov, N., & Dooley, W. F. (2019). Renewable portfolio standards and policy stringency: An assessment of implementation and outcomes. *Review of Policy Research*, *36*(2), 195-216. https://doi.org/https://doi.org/10.1111/ropr.12322

Aragòn-Correa, J. A., Marcus, A. A., & Vogel, D. (2020). The effects of mandatory and voluntary regulatory pressures on firms' environmental strategies: A review and recommendations for future research. *Academy of Management Annals*, *14*(1), 339-365.

Atif, M., Alam, M. S., & Islam, M. S. (2023). Firm-level energy and carbon performance: Does sustainable investment matter? *Business Strategy and the Environment*, *32*(4), 2275-2295. https://doi.org/https://doi.org/10.1002/bse.3248

Atif, M., Liu, B., & Huang, A. (2019). Does board gender diversity affect corporate cash holdings? *Journal of Business Finance & Accounting*, *46*(7-8), 1003-1029. https://doi.org/https://doi.org/10.1111/jbfa.12397

Backer, L. (2007). Engaging stakeholders in corporate environmental governance. *Business and Society Review*, *112*(1), 29-54. https://doi.org/https://doi.org/10.1111/j.1467-8594.2007.00285.x
Bansal, R., Ochoa, M., & Kiku, D. (2017). Climate change and growth risks. *NBER Working Paper Series.*
Barbose, G., Bird, L., Heeter, J., Flores-Espino, F., & Wiser, R. (2015). Costs and benefits of renewables portfolio standards in the United States. *Renewable and Sustainable Energy Reviews*, *52*, 523-533. https://doi.org/https://doi.org/10.1016/j.rser.2015.07.175
Barbose, G., Wiser, R., Heeter, J., Mai, T., Bird, L., Bolinger, M., Carpenter, A., Heath, G., Keyser, D., & Macknick, J. (2016). A retrospective analysis of benefits and impacts of US renewable portfolio standards. *Energy Policy*, *96*, 645-660.
Beck, T., Levine, R., & Levkov, A. (2010). Big bad banks? The winners and losers from bank deregulation in the United States. *The Journal of Finance*, *65*(5), 1637-1667. https://doi.org/https://doi.org/10.1111/j.1540-6261.2010.01589.x
Bolay, A.-F., Bjørn, A., Weber, O., & Margni, M. (2022). Prospective sectoral GHG benchmarks based on corporate climate mitigation targets. *Journal of Cleaner Production*, *376*, 134220. https://doi.org/https://doi.org/10.1016/j.jclepro.2022.134220
Borenstein, S. (2012). The private and public economics of renewable electricity generation. *Journal of Economic Perspectives*, *26*(1), 67-92. https://doi.org/10.1257/jep.26.1.67
Brannlund, R., & Persson, L. (2012). To tax, or not to tax: Preferences for climate policy attributes. *Climate Policy*, *12*(6), 704-721.
Brulhart, F., Gherra, S., & Quelin, B. V. (2019). Do stakeholder orientation and environmental proactivity impact firm profitability? *Journal of Business Ethics*, *158*(1), 25-46. https://doi.org/10.1007/s10551-017-3732-y
Bruno, V., & Claessens, S. (2010). Corporate governance and regulation: Can there be too much of a good thing? *Journal of Financial Intermediation*, *19*(4), 461-482. https://doi.org/https://doi.org/10.1016/j.jfi.2009.10.001
Carley, S. (2009). State renewable energy electricity policies: An empirical evaluation of effectiveness. *Energy Policy*, *37*(8), 3071-3081.
Carley, S., & Browne, T. R. (2013). Innovative US energy policy: A review of states' policy experiences. *Wiley Interdisciplinary Reviews: Energy and Environment*, *2*(5), 488-506.
Carley, S., Davies, L. L., Spence, D. B., & Zirogiannis, N. (2019). Author correction: Empirical evaluation of the stringency and design of renewable portfolio standards. *Nature Energy*, *4*(2), 167-168. https://doi.org/10.1038/s41560-019-0334-1
Chen, C.-M., & Delmas, M. (2011). Measuring corporate social performance: An efficiency perspective. *Production and Operations Management*, *20*(6), 789-804. https://doi.org/https://doi.org/10.1111/j.1937-5956.2010.01202.x
Cohen, M. (2000). Empirical research on the deterrent effect of environmental monitoring and enforcement. *Environmental Law Reporter*, *30*.
Cook, B. J. (2002). The politics of market-based environmental regulation: Continuity and change in air pollution control policy conflict. *Social Science Quarterly*, *83*(1), 156-166. https://doi.org/https://doi.org/10.1111/1540-6237.00076
Dai, J., Cantor, D. E., & Montabon, F. L. (2017). Examining corporate environmental proactivity and operational performance: A strategy-structure-capabilities-performance perspective within a green context. *International Journal of Production Economics*, *193*, 272-280. https://doi.org/https://doi.org/10.1016/j.ijpe.2017.07.023
den Elzen, M., Fekete, H., Höhne, N., Admiraal, A., Forsell, N., Hof, A. F., Olivier, J. G., Roelfsema, M., & van Soest, H. (2016). Greenhouse gas emissions from current and enhanced policies of China until 2030: Can emissions peak before 2030? *Energy Policy*, *89*, 224-236.
Downar, B., Ernstberger, J., Reichelstein, S., Schwenen, S., & Zaklan, A. (2021). The impact of carbon disclosure mandates on emissions and financial operating performance. *Review of Accounting Studies*, *26*(3), 1137-1175.

Earnhart, D. (2009). The influence of facility characteristics and permit conditions on the effectiveness of environmental regulatory deterrence. *Journal of Regulatory Economics*, *36*(3), 247-273. https://doi.org/10.1007/s11149-009-9095-2
Eastin, L. J. L. (2014). An assessment of the effectiveness of renewable portfolio standards in the United States. *The Electricity Journal*, *27*(7), 126-137. https://doi.org/https://doi.org/10.1016/j.tej.2014.07.010
Engl, F., Riedl, A., & Weber, R. (2021). spillover effects of institutions on cooperative behavior, preferences, and beliefs. *American Economic Journal: Microeconomics*, *13*(4), 261-299. https://doi.org/10.1257/mic.20180336
Fan, X., Chen, K., & Chen, Y.-J. (2022). Is price commitment a better solution to control carbon emissions and promote technology investment? *Management Science*, *69*. https://doi.org/10.1287/mnsc.2022.4365
Farooq, M. K., Kumar, S., & Shrestha, R. M. (2013). Energy, environmental and economic effects of renewable portfolio standards (RPS) in a developing country. *Energy Policy*, *62*, 989-1001.
Fischer, J., Dyball, R., Fazey, I., Gross, C., Dovers, S., Ehrlich, P. R., Brulle, R. J., Christensen, C., & Borden, R. J. (2012). Human behavior and sustainability. *Frontiers in Ecology and the Environment*, *10*(3), 153-160.
Fischlein, M., & Smith, T. M. (2013). Revisiting renewable portfolio standard effectiveness: Policy design and outcome specification matter. *Policy Sciences*, *46*(3), 277-310. http://www.jstor.org/stable/42636771
Flammer, C. (2015). Does product market competition foster corporate social responsibility? Evidence from trade liberalization. *Strategic Management Journal*, *36*(10), 1469-1485. https://doi.org/https://doi.org/10.1002/smj.2307
Fremeth, A. R., & Shaver, J. M. (2014). Strategic rationale for responding to extra-jurisdictional regulation: Evidence from firm adoption of renewable power in the US. *Strategic Management Journal*, *35*(5), 629-651. https://doi.org/https://doi.org/10.1002/smj.2118
Fu, W., Li, C., Ondrich, J., & Popp, D. (2018). Technological spillover effects of state renewable energy policy: Evidence from patent counts. *NBER Working Paper Series.*
Gao, Y., Zhao, C., & Zhang, J. (2023a). *Environmental regulation, smart meter adoption, and carbon emission: An interpretable machine learning approach*. Proceedings of the 24th Annual International Conference on Digital Government Research, Gdansk, Poland. https://doi.org/10.1145/3598469.3598531
Gao, Y., Zhao, C., & Zhang, J. (2023b). *Environmental regulation, smart meter adoption, and carbon emission: an interpretable machine learning approach.* Proceedings of the 24th Annual International Conference on Digital Government Research, Gdansk, Poland.
González-Benito, J., & González-Benito, Ó. (2006). A review of determinant factors of environmental proactivity. *Business Strategy and the Environment*, *15*(2), 87-102. https://doi.org/https://doi.org/10.1002/bse.450
Gray, W. B., & Shimshack, J. P. (2011). The effectiveness of environmental monitoring and enforcement: A review of the empirical evidence. *Review of Environmental Economics and Policy*, *5*(1), 3-24. https://doi.org/10.1093/reep/req017
Hahn, R. W. (1989). Economic prescriptions for environmental problems: How the patient followed the doctor's orders. *Journal of Economic Perspectives*, *3*(2), 95-114.
Henriques, I., Husted, B. W., & Montiel, I. (2013). Spillover effects of voluntary environmental programs on greenhouse gas emissions: Lessons from Mexico. *Journal of Policy Analysis and Management*, *32*(2), 296-322.
Huang, H. H., Kerstein, J., Wang, C., & Wu, F. (2022). Firm climate risk, risk management, and bank loan financing. *Strategic Management Journal*, *43*(13), 2849-2880.
Issa, A., & In'airat, M. (2023). From words to action: unpacking the real impact of sustainability initiatives on carbon emissions reduction. *Social Responsibility Journal, 20(3), 585-604*.

Jänicke, M. (2008). Ecological modernisation: New perspectives. *Journal of Cleaner Production*, *16*(5), 557-565. https://doi.org/https://doi.org/10.1016/j.jclepro.2007.02.011
Johnson, M. S. (2020). Regulation by shaming: Deterrence effects of publicizing violations of workplace safety and health laws. *American Economic Review*, *110*(6), 1866-1904. https://doi.org/10.1257/aer.20180501
King, A. A., & Lenox, M. J. (2001). Lean And green? An empirical examination of the relationship between lean production and environmental performance. *Production and Operations Management*, *10*(3), 244-256. https://doi.org/https://doi.org/10.1111/j.1937-5956.2001.tb00373.x
Klassen, R. D., & Whybark, D. C. (1999). Environmental management in operations: The selection of environmental technologies*. *Decision Sciences*, *30*(3), 601-631. https://doi.org/https://doi.org/10.1111/j.1540-5915.1999.tb00900.x
Kok, G., Shang, K., & Yucel, S. (2014). Impact of electricity pricing policy on renewable energy investments and carbon emissions. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2525940
Konar, S., & Cohen, M. A. (1997). Information as regulation: The effect of community right to know laws on toxic emissions. *Journal of Environmental Economics and Management*, *32*(1), 109-124.
Kravchenko, E., Wang, Y. C., & Ni, J. J. (2023). Effects of phase change material inclusion on reducing greenhouse gas emissions from soil in cold region. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-023-29675-3
Lanoie, P., Laurent-Lucchetti, J., Johnstone, N., & Ambec, S. (2011). Environmental policy, innovation and performance: New insights on the Porter hypothesis. *Journal of Economics & Management Strategy*, *20*(3), 803-842.
Lee, S. Y., & Klassen, R. D. (2016). Firms' response to climate change: The interplay of business uncertainty and organizational capabilities. *Business Strategy and the Environment*, *25*(8), 577-592.
Levin, K., Cashore, B., Bernstein, S., & Auld, G. (2012). Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate global climate change. *Policy Sciences*, *45*(2), 123-152. https://doi.org/10.1007/s11077-012-9151-0
Li, J., & Wu, D. (2020). Do corporate social responsibility engagements lead to real environmental, social, and governance impact? *Management Science*, *66(6)*, 2564-2588.
Li, R., & Ramanathan, R. (2018). Exploring the relationships between different types of environmental regulations and environmental performance: Evidence from China. *Journal of Cleaner Production*, *196*, 1329-1340. https://doi.org/https://doi.org/10.1016/j.jclepro.2018.06.132
Lima, M., Mendes, L., Mothé, G., Linhares, F., de Castro, M., Da Silva, M., & Sthel, M. (2020). Renewable energy in reducing greenhouse gas emissions: Reaching the goals of the Paris agreement in Brazil. *Environmental Development*, *33*, 100504.
Lin, C., Liu, S., & Manso, G. (2021). Shareholder litigation and corporate innovation. *Management Science*, *67*(6), 3346-3367. https://doi.org/10.1287/mnsc.2020.3626
Liu, Y., Wei, Z., & Xie, F. (2014). Do women directors improve firm performance in China? *Journal of Corporate Finance*, *28*, 169-184. https://doi.org/https://doi.org/10.1016/j.jcorpfin.2013.11.016
Lucas, K., Brooks, M., Darnton, A., & Jones, J. E. (2008). Promoting pro-environmental behaviour: Existing evidence and policy implications. *Environmental Science & Policy*, *11*(5), 456-466.
Majone, G. (1997). From the positive to the regulatory state: Causes and consequences of changes in the mode of governance. *Journal of Public Policy*, *17*(2), 139-167. https://doi.org/10.1017/S0143814X00003524
Mani, V., & Muthulingam, S. (2019). Does learning from inspections affect environmental performance? Evidence from unconventional well development in Pennsylvania. *Manufacturing & Service Operations Management*, *21*(1), 177-197. https://doi.org/10.1287/msom.2017.0695
Manski, C. F., & Pepper, J. V. (2018). How do right-to-carry laws affect crime rates? Coping with ambiguity using bounded-variation assumptions. *The Review of Economics and Statistics*, *100*(2), 232-244. https://doi.org/10.1162/REST_a_00689

Melnyk, S., Sroufe, R., & Calantone, R. (2003). Assessing the impact of environmental management systems on corporate and environmental performance. *Journal of Operations Management*, *21(3)*, 329-351. https://doi.org/10.1016/S0272-6963(02)00109-2
Meng, X., & Yu, Y. (2023). Can renewable energy portfolio standards and carbon tax policies promote carbon emission reduction in China's power industry? *Energy Policy*, *174*, 113461.
Morgan, K. (2007). The learning region: Institutions, innovation and regional renewal. *Regional Studies*, *41*(sup1), S147-S159. https://doi.org/10.1080/00343400701232322
Moser, A. K. (2015). Thinking green, buying green? Drivers of pro-environmental purchasing behavior. *Journal of Consumer Marketing*, *32*(3), 167-175.
Ngan, H. W. (2010). Electricity regulation and electricity market reforms in China. *Energy Policy*, *38*(5), 2142-2148. https://doi.org/https://doi.org/10.1016/j.enpol.2009.06.044
Park, H., Blanco, C., & Bendoly, E. (2022). Vessel sharing and its impact on maritime operations and carbon emissions. *Production and Operations Management*, 33(7), 2925-2942. https://doi.org/10.1111/poms.13730
Patel, J., Modi, A., & Paul, J. (2017). Pro-environmental behavior and socio-demographic factors in an emerging market. *Asian Journal of Business Ethics*, *6*, 189-214.
Porteous, A. H., Rammohan, S. V., & Lee, H. L. (2015). Carrots or sticks? Improving social and environmental compliance at suppliers through incentives and penalties. *Production and Operations Management*, *24*(9), 1402-1413. https://doi.org/https://doi.org/10.1111/poms.12376
Porter, M. E., & Kramer, M. R. (2006). The link between competitive advantage and corporate social responsibility. *Harvard Business Review*, *84*(12), 78-92.
Quairel-Lanoizelée, F. (2011). Are competition and corporate social responsibility compatible? The myth of sustainable competitive advantage. *Society and Business Review*, *6*(1), 77-98.
Rader, N. A., & Norgaard, R. B. (1996). Efficiency and sustainability in restructured electricity markets: The renewables portfolio standard. *The Electricity Journal*, *9*(6), 37-49.
Reid, E. M., & Toffel, M. W. (2009). Responding to public and private politics: Corporate disclosure of climate change strategies. *Strategic Management Journal*, *30*(11), 1157-1178. https://doi.org/https://doi.org/10.1002/smj.796
Sarkis, J., Gonzalez-Torre, P., & Adenso-Diaz, B. (2010). Stakeholder pressure and the adoption of environmental practices: The mediating effect of training. *Journal of Operations Management*, *28*(2), 163-176. https://doi.org/https://doi.org/10.1016/j.jom.2009.10.001
Schmalensee, R. (2012). Evaluating policies to increase electricity generation from renewable energy. *Review of Environmental Economics and Policy*.
Schrettle, S., Hinz, A., Scherrer -Rathje, M., & Friedli, T. (2014). Turning sustainability into action: Explaining firms' sustainability efforts and their impact on firm performance. *International Journal of Production Economics*, *147*, 73-84. https://doi.org/https://doi.org/10.1016/j.ijpe.2013.02.030
Scott, A., Li, M., Cantor, D., & Corsi, T. (2022). Do voluntary environmental programs matter? Evidence from the EPA SmartWay program. *Journal of Operations Management*, *69*(2), 84-304. https://doi.org/10.1002/joom.1209
Scott, D., Hall, C. M., & Gössling, S. (2016). A review of the IPCC fifth assessment and implications for tourism sector climate resilience and decarbonization. *Journal of Sustainable Tourism*, *24*(1), 8-30.
Shafiq, A., Klassen, R. D., Johnson, P. F., & Awaysheh, A. (2014). Socially responsible practices: An exploratory study on scale development using stakeholder theory. *Decision Sciences*, *45*(4), 683-716. https://doi.org/https://doi.org/10.1111/deci.12085
Shrimali, G., & Kniefel, J. (2011). Are government policies effective in promoting deployment of renewable electricity resources? *Energy Policy*, *39*(9), 4726-4741. https://doi.org/https://doi.org/10.1016/j.enpol.2011.06.055
Solomon, B. D., & Zhou, S. (2021). Renewable portfolio standards: Do voluntary goals vs. mandatory standards make a difference? *Review of Policy Research*, *38*(2), 146-163.

Stafford, S. L. (2002). The effect of punishment on firm compliance with hazardous waste regulations. *Journal of Environmental Economics and Management*, *44*(2), 290-308. https://doi.org/https://doi.org/10.1006/jeem.2001.1204

Sunar, N., & Plambeck, E. (2016). Allocating emissions among co-products: Implications for procurement and climate policy. *Manufacturing & Service Operations Management*, *18*(3), 414-428. https://EconPapers.repec.org/RePEc:inm:ormsom:v:18:y:2016:i:3:p:414-428

Tuladhar, S. D., Mankowski, S., & Bernstein, P. (2014). Interaction effects of market-based and command-and-control policies. *The Energy Journal*, *35*(1_suppl), 61-88.

Walker, K., Ni, N., & Huo, W. (2014). Is the red dragon green? An examination of the antecedents and consequences of environmental proactivity in China. *Journal of Business Ethics*, *125*(1), 27-43. https://doi.org/10.1007/s10551-013-1903-z

Weigelt, C., & Shittu, E. (2016). Competition, regulatory policy, and firms' resource investments: The case of renewable energy technologies. *Academy of Management Journal*, *59*(2), 678-704.

Wiser, R., Barbose, G., Bird, L., Churchill, S., Deyette, J., & Holt, E. (2008). Renewable portfolio standards in the United States: A status report with data through 2007. *Lawrence Berkeley National Laboratory.*

Wiser, R., Barbose, G., & Holt, E. (2011). Supporting solar power in renewables portfolio standards: Experience from the United States. *Energy Policy*, *39*(7), 3894-3905. https://doi.org/https://doi.org/10.1016/j.enpol.2010.11.025

Wolverton, A., Shadbegian, R., & Gray, W. B. (2022). The US manufacturing sector's response to higher electricity prices: evidence from state-level renewable portfolio standards. *Environmental Protection Agency.* https://www.epa.gov/environmental-economics/us-manufacturing-sectors-response-higher-electricity-prices-evidence-state

Yi, H. (2015). Clean-energy policies and electricity sector carbon emissions in the US states. *Utilities Policy*, *34*, 19-29. https://doi.org/https://doi.org/10.1016/j.jup.2015.04.001

Yin, H., & Powers, N. (2010). Do state renewable portfolio standards promote in-state renewable generation?. *Energy Policy*, *38*(2), 1140-1149. https://doi.org/https://doi.org/10.1016/j.enpol.2009.10.067

Yu, S., Wei, Y.-M., & Wang, K. (2014). Provincial allocation of carbon emission reduction targets in China: An approach based on improved fuzzy cluster and Shapley value decomposition. *Energy Policy*, *66*, 630-644.

Yuan, B., & Zhang, Y. (2020). Flexible environmental policy, technological innovation and sustainable development of China's industry: The moderating effect of environment regulatory enforcement. *Journal of Cleaner Production*, *243*, 118543. https://doi.org/https://doi.org/10.1016/j.jclepro.2019.118543

Zhang, S., Wang, Z., & Zhao, X. (2019). Effects of proactive environmental strategy on environmental performance: Mediation and moderation analyses. *Journal of Cleaner Production*, *235*, 1438-1449. https://doi.org/https://doi.org/10.1016/j.jclepro.2019.06.220

Zhao, J., Liu, H., & Sun, W. (2020). How proactive environmental strategy facilitates environmental reputation: Roles of green human resource management and discretionary slack. *Sustainability*, *12*(3), 763. https://www.mdpi.com/2071-1050/12/3/763

Zhou, S., & Solomon, B. D. (2020). Do renewable portfolio standards in the United States stunt renewable electricity development beyond mandatory targets? *Energy Policy*, *140*, 111377.

Zhu, Q., & Sarkis, J. (2007). The moderating effects of institutional pressures on emergent green supply chain practices and performance. *International Journal of Production Research*, *45*(18-19), 4333-4355. https://doi.org/10.1080/00207540701440345

Appendix 1: Timeline of RPS

State	Initiate years	Aggressive or Conservative target	Progressive milestone based (PMB) or Long-term absolute (LTA) targets
AZ	2001	Conservative	LTA
CA	2003	Aggressive	PMB
CO	2007	Conservative	PMB
CT	2001	Aggressive	LTA
DC	2007	Conservative	LTA
DE	2014	Aggressive	LTA
HI	2010	Aggressive	PMB
IA	2000	Conservative	LTA
IL	2009	Conservative	LTA
MA	2003	Aggressive	PMB
MD	2006	Conservative	LTA
ME	2000	Aggressive	LTA
MI	2012	Conservative	PMB
MN	2005	Aggressive	PMB
MO	2011	Conservative	PMB
MT	2008	Aggressive	PMB
NC	2012	Conservative	PMB
NH	2008	Conservative	PMB
NJ	2002	Conservative	LTA
NM	2006	Conservative	PMB
NV	2003	Aggressive	PMB
NY	2017	Aggressive	LTA
OH	2009	Conservative	LTA
OR	2011	Conservative	PMB
PA	2007	Conservative	LTA
RI	2007	Conservative	LTA
TX	2002	Conservative	LTA
VA	2021	Aggressive	LTA
VT	2017	Aggressive	LTA
WA	2012	Conservative	PMB
WI	2006	Conservative	PMB

Appendix 2: Visualization of RPS classification

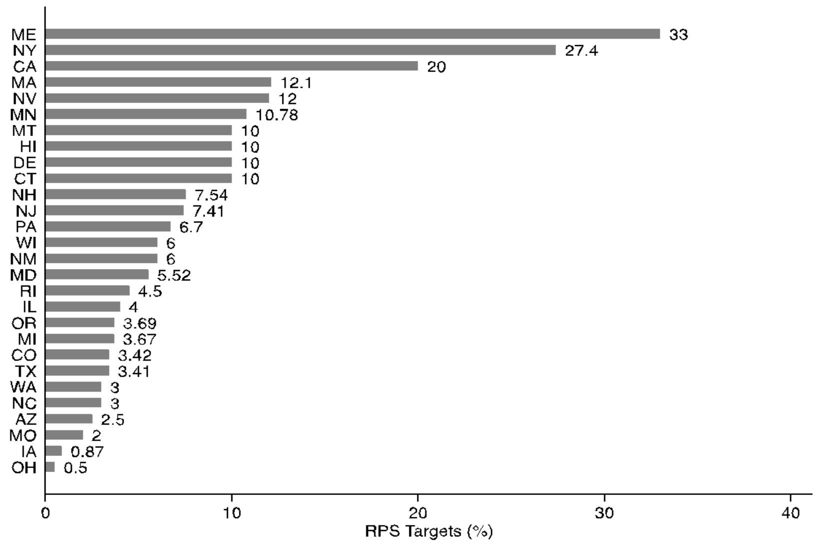
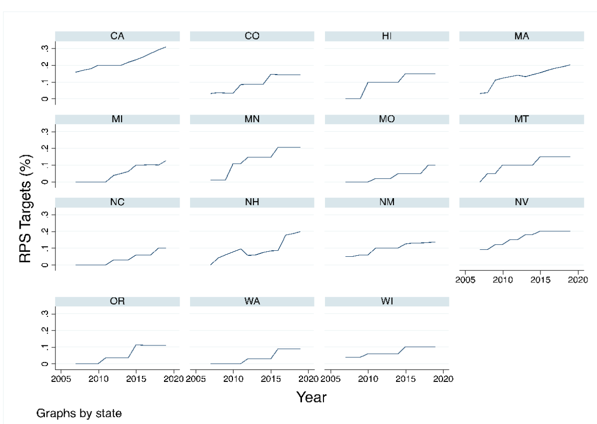


Figure A2-1: Visualization of the specific RPS targets set for each state in the first year

Panel A: Progressive milestone-based targets



Panel B: Long term absolute-targets

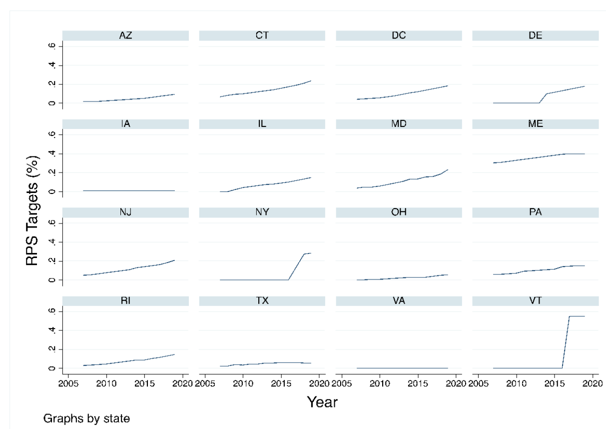


Figure A2-2: Progressive milestone-based vs. Long-term absolute RPS Targets By State