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# The Effect of Regulatory Uncertainty on Investment: Evidence from Renewable Energy Generation

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How are firms' investment decisions influenced by potential instability in the regulatory environment? Firms that anticipate regulatory change may alter their responses to current policies, potentially rendering those policies less effective. This article explores the pattern of investments in renewable generation assets in the US electricity industry following the implementation of Renewable Portfolio Standard (RPS) policies. Viewing these investments through the lens of transaction cost economics, the article investigates whether the likelihood of future regulatory change in a state dampened (or spurred) firm responses to RPS policies in that state. I find that firms invested less in new assets in states that had previously passed and repealed legislation to restructure the electricity industry, indicating that perceived regulatory instability reduces new investment and undermines policy goals. (*JEL* D02, D81, D23, D21, K2)

## 1. Introduction

How does uncertainty about future regulatory change influence firms' willingness to invest in new assets? I view the potential for regulatory changes as akin to opportunistic behavior by a contracting partner and use transaction cost economics (TCE) theory to predict the impact of uncertain regulatory environments on new sunk investments. Several studies examine regulation and public policy through the lens of TCE (e.g., see Levy and Spiller 1994; Crocker and Masten 1996), but there is little direct evidence for the impact of regulatory uncertainty on firm behavior.[1] This article argues that under conditions of asset specificity, the perception of regulatory instability restrains firm investments, undermining the effectiveness of regulatory initiatives.

The investments required by a particular regulatory policy may be specific to that policy, just as the investments required to fulfill a contract between firms may be specific to that contract. Should the policy (or contract) change, assets specific to that policy (or contract) will be worth substantially less.

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1. Prior studies that examine the impact of political risk on firm investment are described below.

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When firms perceive that new regulatory initiatives are unstable, specific investments appear more risky. Firms will be less willing to invest in specific assets when they perceive that future regulatory changes could reduce the value of those assets. Therefore, my central prediction is that policy initiatives launched in less-stable regulatory environments will create less new investment in specific assets.

My empirical setting is the enactment of state-level Renewable Portfolio Standard (RPS) policies in the US electric utility industry. State policymakers designed RPS regulations to encourage investment in renewable electricity generation, a specific asset that has much less value in the absence of an RPS. I use unit-level data on the installation year, location, and fuel type of all US electric generating plants to determine annual investments in new renewable generation assets in each state. Because 29 states adopted RPS policies between 1995 and 2006, I am able to estimate the effect of RPS enactment on investment in new renewable generation assets. I use a state's history of policy stability in electricity industry restructuring as a proxy for regulatory uncertainty. Prior policy reversals may indicate that state institutions are unable to constrain the state's political actors from altering established policies. Among the 24 states that passed restructuring policies between 1996 and 2001, eight states subsequently repealed those policies.[2] Such a prior exhibition of regulatory instability may cause firms to anticipate that subsequent policies will also be modified or repealed. I test whether the positive effect of RPS enactment on investments in renewable generation assets in a given state was *smaller* in states where such risks were perceived to be greater.

RPS enactment in a state did generate an increase in investment in new renewable generating assets, on average. However, my results show that investment increased *significantly less* in states with a history of regulatory reversal. In states that had not previously repealed restructuring legislation (including those states that never passed restructuring as well as those that passed and retained restructuring), the average increase in new renewable generation assets after RPS enactment was approximately 7.5 megawatts (MWs) per year more than in states that did not enact an RPS. In states with a history of regulatory repeal, the increase in investment after RPS enactment was not statistically significant relative to states that did not enact RPS. I confirmed my results with an instrumental variables analysis, predicting prior regulatory repeal with measures of state-level institutions that influence policy stability. Although these results are specific to this policy and industry setting, the theoretical implication extends to other settings where specific investments depend on (uncertain) policies, such as current carbon tax/abatement policies.

The remainder of the article is organized as follows. Section 2 briefly reviews TCE theory and, in particular, its application to political risk. Section 3 provides contextual details about electricity industry restructuring and its

2. I use the term "repeal" throughout to refer to a suspension or repeal of either wholesale or retail competition and rely on the identification of repeal and suspension from the US Energy Information Administration.

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subsequent repeal, RPS policies, and why investments in renewable generation assets are policy-specific. Section 4 describes my empirical approach. Section 5 presents the data and describes the variables I used in my analysis. Section 6 provides my empirical results and Section 7 discusses my interpretation of those results. Section 8 reports additional robustness tests. I conclude in Section 9 by discussing the implications of my results for theory and public policy.

## 2. TCE and Regulatory Uncertainty

Investment in new electricity generation assets is a function of the anticipated future demand for electricity, the installed and anticipated new supply of electricity available to meet that demand, the current and anticipated prices at which the electricity could be sold in the market, and the regulatory framework that will govern the operating environment of the generating unit. This article draws on TCE to explore how regulatory instability affects firm investment in long-lived generation assets specific to a regulatory environment. TCE posits that asset specificity and uncertainty about future conditions increase the hazards of procurement through markets and contracts. This article extends that theory in two ways: first, by applying it to the implicit contract between regulators and firms (Williamson 1976) and second, by considering uncertainty originating in the institutional environment. Neither of these extensions is entirely novel; there is a small body of related cross-national research examining the impact of political risk on investment, which I discuss below.

The TCE literature has traditionally considered the hazards of procurement transactions between firms and the role of transaction characteristics in determining the risk of hold up and expropriation of one firm by a partner firm. When future conditions are uncertain, investing in relationship-specific assets exposes a firm to expropriation hazards (Williamson 1975, 1985). Because contracts are necessarily incomplete and individuals are boundedly rational, it is impossible to include conditions addressing all future contingencies. As the state of the world is revealed and cooperative adaptation is required, firms that make specific investments may be "held up" by opportunistic transaction partners who know that specific investments command less value in their next-best use. Firms that anticipate a potential loss in value under certain future conditions will be less willing to invest in relationship-specific assets.

Several studies have extended TCE to explore the effect of "political risk" on firm investment patterns (Henisz and Williamson 1999; Henisz 2000a). Political risk increases with the likelihood that a host country's political actions will diminish a firm's return on investment (either by seizing assets directly or by altering policies, taxes, or regulations). Different institutional environments—across countries or within countries over time—provide different levels of constraint on the parties in power (Williamson 1991). When institutions effectively restrain the opportunistic actions of parties in power, they reduce the risk of hold-up and *ex post* expropriation by state actors, creating conditions under which firms are more willing to make sunk investments. Based on case studies of the telecommunications industry in five countries, Levy and Spiller (1994)

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describe the importance of restraints on regulators that "reduce the potential for administrative expropriation or a manipulation" to foster private investment. In a cross-national empirical analysis based on 147 countries, Henisz and Zelner (2001) study investment in telecommunications infrastructure and find that institutional determinants of political risk are important predictors of new investment.[3] Although this line of research has focused on cross-national differences in political risk, I believe the same logic applies to investment environments *within a country* when differences between states and regions alter the likelihood of expropriation by political actors.

The relationship between firms and political/regulatory actors can be viewed as an implied contract. Like any complex contract, it is necessarily incomplete and does not provide recourse for every possible future contingency. Terms can be altered over time through legislative initiatives and regulatory rulings. The legislature or the regulatory body often has unilateral power to change the regulatory contract. These changes may modify what regulators require of firms or it may change the terms by which firms are compensated. The regulatory contract therefore leaves firms vulnerable to opportunistic behavior by policy makers or regulators.

Firm investments can be specific to a particular regulatory policy, just as they can be specific to particular firm-to-firm relationships. Assets are policy specific when their value in their next-best use is substantially lower than their value under the governing policy. The risk that specific assets will lose value increases with the likelihood of future policy modifications. Thus, by applying TCE logic to the regulatory contract, I can predict that firms will be less willing to make sunk investments that are specific to a regulation when the regulatory environment is uncertain.

Two related literatures in economics examine uncertainty and investment: real options theory (Cikierman 1980; Bernanke 1983; McDonald and Siegel 1986; Pindyck 1988, 1991; Dixit and Pindyck 1994) and existing models of regulatory uncertainty (Brennan and Schwartz 1982; Kolbe and Tye 1991; Lyon 1991; Teisberg 1993; Gilbert and Newbery 1994; Lyon and Mayo 2005).[4] The primary prediction of the real options literature is that firms will delay investments in long-lived irreversible assets when there is sufficient uncertainty that resolves over time.[5] Because uncertainty created by the potential actions of regulators and legislators may *not* resolve over time, this theory

3. Related empirical evidence is supplied by Oxley (1991), who examines the impact of a country's intellectual property protection on firm governance choices in alliances, and Henisz (2000a) who demonstrates that firms are more likely to partner with local (host-country) firms in multinational investments when the level of political risk is high, presumably to protect their investments from government expropriation.

4. In addition, there is a literature on the multidimensional uncertainty regarding environmental impacts, costs and benefits that complicates environmental policymaking. See Pindyck (2007), for a review.

5. This proposition has empirical support in recent studies that investigate firm investment as a function of demand and price uncertainty (Cortazar et al. 1998; Guiso and Parigi 1999; Bloom et al. 2007; Kellogg 2010).

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offers no prediction in my setting. Existing studies of regulatory uncertainty focus on the potential for regulators to retroactively "disallow" regulated utilities from recovering the costs of building new assets and how the risk of disallowance changes the incentives (allowed rate of return) needed to spur new efficient investments. As Teisberg (1993) and Lyon (1991) emphasize, regulatory uncertainty presents asymmetric risk to regulated firms because cost disallowances are uniformly negative shocks and there is no potential for positive regulatory action. My study takes a broader view by allowing the possibility that future regulatory and legislative actions might reduce the rents of regulated *and* unregulated firms making policy-specific investments. Nevertheless, the risks are similarly asymmetric.

By using TCE theory to consider the impact of regulatory uncertainty on investment, this article adds to the literature in several ways. First, it allows us to explicitly consider the conditions under which regulatory uncertainty impacts firm investments, even when uncertainty is not resolved over time, by focusing on the degree to which investment is specific to the regulation. Second, building on the assertion in TCE and New Institutional Economics that underlying institutional characteristics impact economic behavior, this article shows that sources of regulatory instability may vary even within a country due to state-level differences in formal and informal institutional characteristics. Finally, my article demonstrates the advantage of leveraging existing work in TCE to generate potential solutions to regulatory risk.

## 3. Policy Initiatives and Investments in Renewable Generation

### 2.1 Restructuring and Repeal

During the 1980s and 1990s, a wave of "deregulation" swept a variety of US industries: Trucking, airlines, natural gas, telecommunications, and electricity each experienced some form of restructuring intended to remove regulatory barriers to competition. In the electric utility industry, the generation segment had been traditionally regulated at the state level, whereas the transmission segment and interstate wholesale trade were regulated by the Federal Energy Regulatory Commission (FERC). Through the Public Utilities Regulatory Policy Act (PURPA) in 1978 and the Energy Policy Act in 1992, federal legislators began to open the wholesale power market to competition from independent power producers (IPPs). In 1996, FERC issued rules securing nondiscriminatory access to interstate transmission assets for any electricity generator, effectively opening wholesale electricity markets to competition. This was just part of a substantial shift to promote competition in the generation segment of the electricity industry. In response to federal initiatives and internal pressures, legislators and regulators in states such as California, Massachusetts, and New York began to consider removing entry barriers in the generation segment and creating competitive wholesale and retail markets to encourage competition, improve efficiency, and reduce electricity prices for end users. Ultimately, these three states and 21 others passed restructuring policies between 1996 and 2001 (Energy Information Administration 2000).

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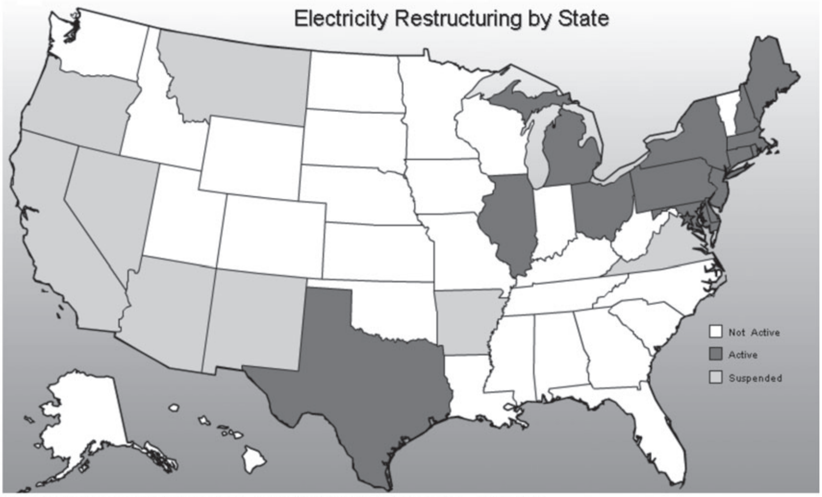


Source: Energy information Administration Website, 11/9/09,

Figure 1. Status of Electric Utility Restructuring by State.

When the California energy crisis unfolded in the summer of 2000, followed by the spectacular collapse of Enron in 2001, restructuring policies took much of the blame (Duane 2002). States that were considering restructuring either suspended activity or declared that they would not pass such a policy (Smith 2002). Many states that had already passed restructuring legislation came under pressure to suspend or repeal it. For example, the Arizona Corporation Commission (Arizona's regulatory body for public utilities) passed restructuring legislation in 1998. In 2002, it concluded that the wholesale market for electricity was not sufficiently competitive and that reliance on the market would not result in reasonable rates (Energy Information Administration 2000, EIA Status of State Restructuring). The commission subsequently suspended the state's restructuring activities. Eventually, almost one-third of the states that had passed a restructuring policy repealed it, formally suspending restructuring activity. The map in Figure 1 indicates which states (1) never passed, (2) passed and suspended, or (3) passed and sustained restructuring of the generation segment of the electric utility industry.

## 2.2 Renewable Portfolio Standards

In response to growing pressure to provide "clean" energy and lacking a federal policy to require investments in renewable generation assets, several states pursued their own renewable energy initiatives. Twenty-nine states and the District of Columbia enacted RPS policies between 1995 and 2006, to take effect between 2000 and 2025. Figure 2 provides a graphical depiction of RPS enactment. An RPS requires electric utilities to procure a certain percentage of their electricity from renewable energy sources such as wind, solar, and

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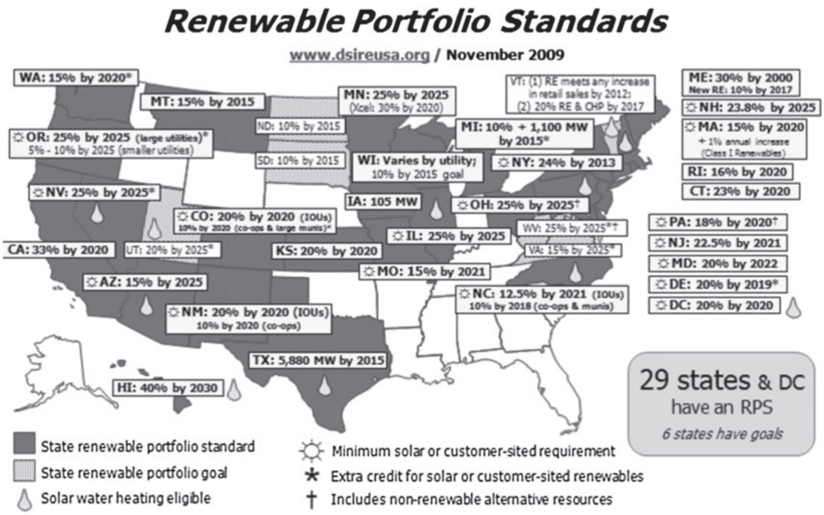

Source: DOE DSIRE Website http://www.dsireusa.org/summarymaps

Figure 2. Status of State RPS Policies.

biomass. State policies differed in terms of the ultimate percentage of renewable energy required (from 10% to 40%), the starting year, and the target year for reaching the required percentage. All states established annual or biannual requirements for renewable energy sourcing (typically by approximating a linear increase toward the ultimate target) and authorized regulatory bodies to issue fines for noncompliance. In most states, regulators assess noncompliant utilities a fee equal to or exceeding the cost of compliance, equal to either the market rate for enough renewable energy credits (RECs) to fulfill the requirements or the cost of installing renewable generation assets. Several states allowed additional penalties for utilities that failed to meet their annual requirements.

RPS policies did not stipulate whether utilities should own renewable generation assets or purchase power from IPPs. Many utilities sought to meet their requirements by issuing requests for proposals to establish purchase agreements. RPS policies also allowed utilities to meet their requirements by purchasing RECs.[6] RPS policies required that qualified renewable electricity (or RECs) be purchased from renewable generation sources located in the same state or region of the country, limiting the geographic market for RECs and the electricity produced from renewable generation. Many, but not all, states mandated that only electricity from new generation assets was eligible to meet requirements and established installation dates before which assets

6. RECs are certificates generated along with renewable energy that provide a mechanism by which the "credit" for renewable electricity sources (embodied in the REC) may be sold separately from the electricity itself. Therefore, utilities can purchase RECs to fulfill their required portfolio without purchasing electricity produced from renewable resources.

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would not be considered "new." Existing empirical evidence suggests that RPS policies had a significant and positive effect on renewable energy development (Yin and Powers 2010).

## 2.3 Investments in Renewable Generation

The decision to invest in generation assets generally depends on the anticipated future demand for electricity, the installed and anticipated supply of electricity available to meet that demand, and the current and anticipated price at which the electricity could be sold in the market. Any regulated utility seeking to build a new generating plant must apply to the state regulatory commission for approval, which is based on the anticipated need for additional generating capacity. IPPs need to demonstrate need for additional capacity in order to attract investors and may also need to demonstrate the need for additional capacity to state regulators if the plant will require ratepayers to pay for new transmission lines or interconnects. In addition, long-term contracts with utility buyers, often needed to secure funding for IPP-developed generation plants, require approval from state regulators. Even in the absence of these requirements, profit-maximizing firms would make investment decisions based on the expected demand for electricity, the expected supply available to meet that demand, and the expected market price at which the electricity generated could be sold.

Investments in renewable source generation assets specifically depend on these same criteria, as well as on stakeholder (regulator and customer) preferences and the gap between the cost of generation with renewable technology and the cost of generating with traditional technologies. With current technology, the costs of generating electricity from wind, solar, and biomass technologies exceed the cost of traditional fossil-fuel generation (Energy Information Administration 2010b). On the wholesale market (or in arms-length contracts), utilities would not be willing to pay more than the marginal (market setting) price for electricity, which is typically set by gas-fired generating units. Therefore, in the absence of policy interventions, electricity generated from renewable technologies and sold into the wholesale market would not recover the total cost of the generation unit. RPS policies (1) created demand for electricity generated from renewable generation resources that would not have existed in the absence of these policies and (2) provided an opportunity for renewable generating assets to command a higher price than the wholesale market-clearing price. As long as the supply of qualified renewable electricity in a market does not exceed the amount that utilities are required to purchase, a renewable generation unit owner operating under an RPS will earn rents.

Nevertheless, these investments are plagued by the types of hazards highlighted in TCE. First, the assets are long-lived. The expected life of renewable generation units installed when RPS policies became effective exceeds even the planned target dates of those policies. Second, the assets are location specific because they are responsive to local (state) regulations, prohibitively expensive to relocate, and sometimes tailored to local demand and transmission conditions. Although the electricity they generate can, in theory, be sold

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anyplace within the locally connected transmission grid, contracting over greater distances increases contract complexity and incurs transmission losses. In addition, because RPS policies typically specify that renewable electricity must be generated within the same region and because many provide incentives for purchasing renewable energy produced instate, the number and geographic range of potential buyers is limited. Finally, these investments must be made under considerable uncertainty about future demand and the regulatory policies that influence demand.

Therefore, firms investing in renewable generation assets are investing in long-lived assets that will have significantly less value if the demand for renewable energy decreases in proximity to the generation asset. Electricity that renewable generating units create is indistinguishable from electricity generated from cheaper fossil fuels. If legislators remove or reduce the regulatory requirement to utilize renewable generation, forcing these generating units to compete with traditional electricity sources in the wholesale market, the units could obtain a substantially lower price for their electricity. The potential for regulatory changes or reversal puts potential investors and developers at significant risk. My central prediction is that the increase in investment in renewable generation assets following an RPS policy will be smaller in states where the level of regulatory risk is higher.

The level of investment in new renewable generation assets in response to an RPS policy is a result of both the decision of utility companies to comply with the policy, resulting in demand for renewable energy, and the decision of investing firms (utilities and IPPs) to invest in new assets. An observed lack of investment may result from *either* a lack of demand from utilities or an unwillingness to invest. Most RPS policies specify alternative compliance payments for utilities that do not meet the RPS requirements, and these payments are typically set at a level intended to meet or exceed the cost of compliance. As a result, utilities that anticipate the statute's full enforcement have an incentive to comply in the short term. Still, because my data do not include a record of utility company initiatives (such as requests for proposals) and because there is no consistent record of RPS enforcement, my empirical approach cannot distinguish whether the observed relationship between uncertainty and investment response to the RPS policy is attributable to the effect of uncertainty on utility company demand or the effect of uncertainty on firm investment in asset development.

## 3. Empirical Approach

To investigate whether RPS policies induced a smaller increase in investment in states with greater regulatory risk, I examined new investments in renewable generation assets in each state in 1990–2010. The empirical model controls for the underlying demand, supply, and stakeholder drivers of investment in renewable generation, as described below. I exploited variation in the presence and timing of RPS policies to estimate the impact of these policies on new investments in renewable generation in a state. I tested whether the (positive)

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impact of an RPS policy on new investments was systematically smaller in states with more regulatory risk. States without an RPS policy (to date) provided a natural control group, allowing me to identify the effect of RPS policies on investments separately from changes in investments over time. Among the states that passed RPS policies, variation in regulatory risk across states allowed me to identify the effect of regulatory instability on the increase in investments following RPS enactment.

To accommodate the nonnegative distribution of the dependent variable (MW capacity of new renewable generation assets online in the state-year), I used Poisson quasi-maximum-likelihood estimation with conditional (state) fixed effects (Wooldridge 1999; Simcoe 2007). This method does not rely on the often-violated assumption of mean variance equivalence and provides robust standard errors that accommodate arbitrary patterns of correlation among the observations for each state.[7] The basic empirical model is as follows:

$$E\left(\mathrm{Invest}_{st}\middle|X_{st}\alpha_{\mathrm{s}}\right) = e^{\beta_1 \mathrm{RPS}_{st}+\beta_2 \mathrm{RPS}_{st}\times \mathrm{Risk}_s+\beta_3 \mathrm{X}_{st}+\delta_t+\alpha_s},$$

where $\mathrm{Invest}_{st}$ is the amount of investment in new renewable generation assets in state $s$ in year $t$. $\mathrm{RPS}_{st}$ is an indicator equal to one in each year following the effective date of an RPS policy in state $s$ and zero otherwise.[8] $\mathrm{Risk}_s$ is the level of regulatory risk in state $s$, proxied by whether the state passed and repealed restructuring legislation, as described below. $X_{\mathrm{st}}$ is a vector of state-year level control variables, also described below. The $\delta_t$ are year indicator variables that control for common patterns of investments in renewable generation assets over time, including the impact of federal incentives and policies that apply to all states. This empirical model provides the standard difference-in-differences estimation, estimating the increase in investment from before to after an RPS policy in a given state, relative to the control group of states without an RPS policy. However, by including the interaction of the RPS policy indicator with the state-level *Risk* measure, it also allows the level of regulatory instability in a state to moderate the effect of the RPS "treatment."

Two key identifying assumptions of my empirical approach are that the enactment of an RPS policy and the prior repeal of restructuring legislation are not correlated with unobserved factors that also affect the level of investment in renewable generation assets.[9] I included controls for the underlying drivers of investments in renewable generation assets that vary across states and over time. I also included (conditional) state-level fixed effects ($\alpha_s$) to

7. This method provides consistent parameter estimates under very general conditions and is appropriate for both count and nonnegative continuously distributed outcome variables (Wooldridge 1999).

8. I tested whether there was any effect of an RPS policy in the year prior to the effective date and found no evidence of a significant effect on investment.

9. For the models using the *StateGap* in place of the 0/1 RPS indicator, the assumption is that the level of unmet RPS policy-induced demand is not correlated with unobserved factors that also affect the level of investment.

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control for time-invariant unobserved heterogeneity across states, including geographic and weather conditions. The next section provides a comparison of relevant subsamples to test for significant differences. The most significant remaining concern is that there is some unobserved, time varying factor(s) that is correlated with repeal and also with the increase in investment following RPS enforcement. Although this is difficult to rule out, section 7 describes the results of an instrumental variables analysis (reported in detail in the Appendix). Section 8 discusses the robustness of the results to a variety of additional control variables.

The other challenge to identification comes from the small number of units (states) that I observe over time and their dispersion across categories of interest. My empirical model proposes to separately identify the effects of restructuring, risk, RPS policies, and the interactions of the restructuring and risk with RPS policies. I describe the distribution of states and state-year observations across policy categories below. Empirically, the data are able to separately identify the effects of restructuring, regulatory instability (as indicated by a prior repeal of restructuring), and RPS policies by virtue of the cross-sectional differences (across states) and also by the variation in the timing (across states) of restructuring and the effective start dates of RPS policies.

## 4. Data and Measurement

### 4.1 Data and Sample

I combined publicly available secondary data to create a new panel data set at the state-year level, covering the period 1990–2010. These data detail the investments in renewable generation assets, policy histories, institutional structures of the governing and regulatory bodies, and conditions in the electricity market. The sample period captures the enactment of RPS policies—the first of which became effective in 2000—with a substantial pre-policy period.

### 5.2 Investments in Renewable Generation Assets

Annual investments in renewable energy (in MWs of capacity) were collected from the Platts (formerly UDI) Database of World Electric Power Producers.[10] I used the North American generating units data set, limited to units in the United States. This database provides a record of every retired, operational, and planned generating unit, including the size, location, fuel type, and the operator/owner company. Selecting the renewable generating units (i.e., wind, biomass, hydroelectric, landfill gas, photovoltaic, fuel cell, geothermal) in 1990–2010 yields 2018 units, 86% of which were operational, 12% of which were planned or under construction, and 2% of which were retired as of July 2009. Using the on-line year provided, I aggregated the data to create

10. These data are periodically updated. I used the database version as of July 2009.

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a state-year panel data set reflecting the megawatts of new renewable generation brought online each year in each state in 1990–2010 ($\text{Invest}_{st}$).[11]

## 5.2 RPS Policies

The US Department of Energy's division of Energy Efficiency and Renewable Energy maintains a record of state-level RPS policies, the Database of State Incentives for Renewables and Efficiency (DSIRE). I used their September 30, 2009 update. Figure 2 gives a pictorial representation of the policy distribution. This database provides the enactment date of the policy and the year the portfolio standard took effect. The effective date of the policy is up to 10 years subsequent to enactment. I used the effective date as a measure of when the RPS policy was in place and created a variable, RPS, equal to 1 in each year following the effective date of the policy in a state that passed an RPS policy and zero otherwise. Although companies could be expected to start planning new investments in renewable resources between the enactment date and the effective date, such planning can take a number of years and the goal may be to have the unit come on line when the policy takes effect.

I also made use of a continuous measure of the unmet demand for renewable energy created by each state's RPS policy. First, I calculated the implied required renewable energy (in MWhs) to meet the mandated target by forecasting the total MWh sales in the state in the target year (based on 2010 sales and recent growth rates) and multiplying this by the percentage of energy required from renewable resources. Second, I calculated the amount of eligible energy available each year based on the record of previously installed units and a state policy's eligibility criteria. For example, if a state RPS policy specified that energy from generation units installed prior to 1999 was not eligible to meet requirements, I included only units installed in 1999 or later. I used the average capacity factors specified in Tidball et al. (2010) for each type of generation (wind, solar, etc.) to calculate the potential energy output from each eligible unit[12] and summed the potential eligible energy from installed units in each state-year. The difference between the implied required energy and the eligible energy from installed units is the unmet demand created by the RPS policy. I created a variable, *StateGap,* equal to this unmet demand in each year following the effective date of the RPS policy in a state and zero otherwise.[13] In all post-RPS policy years in the analysis, the amount of eligible

11. I use the online date of the generation facility because the decision to make an investment anticipates the demand for the capacity. Developers have an expectation about when a new plant can be operational and seek to match the online date with the need for the production. In the case of assets developed to meet anticipated demand due to RPS policies, the decision to invest maybe made even before the effective date of the RPS policy, in anticipation of the increase in demand subsequent to the effective date, so that the facility can be operational to meet this demand.

12. Potential MWh output is equal to the capacity factor times MW capacity of the unit time 8760 hours per year.

13. This variable is not available for Texas because the Texas RPS program includes a capacity requirement rather than a percentage-of-electricity-sales requirement.

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energy from installed units fell short of the total RPS-required renewable energy. In analyses below, I also used an analogous regional measure equal to the unmet demand within the state's region but outside of the focal state. I calculate *RegionGap* as the aggregate unmet regional demand, based on the RPS requirements, eligibility requirements, and installed generating units outside the state but within the state's region.

### 5.3 Regulatory Risk

As reviewed above, the existing empirical literature that examines political risk and the resulting hazards of expropriation uses underlying institutional structures to measure constraints on political actors, typically in cross-national studies (e.g., Levy and Spiller 1994; Bergara et al. 1998). This literature, based in new institutional economics, emphasizes the value of checks and balances in the institutional environment to protect investments. Henisz (2000b) pioneered the use of an index measure of political constraint based on underlying institutions and the opportunity for checks and balances in different countries. Such indexes provide valuable measures of the political institutions that constrain political actors' power to alter the policy environment or otherwise opportunistically expropriate firms' rents.

I took a complementary approach here by relying not on an index measuring characteristics of the underlying institutions but on a prior outcome that reflects precisely what indexes seek to measure: the ability of political actors to alter the policy environment and cause the modification of recently enacted policy. I identified states in which political actors had previously suspended or repealed electricity industry restructuring policies, indicating that state-level institutions were not robust enough to prevent a regulatory reversal of a recently enacted policy. Specifically, I collected a history of restructuring proceedings in each state from the Energy Information Administration. I identified the date a restructuring law passed (if passed), and the date a restructuring law was repealed or suspended (if repealed or suspended). States debated and passed restructuring laws in the mid- and late-1990s. Repeals occurred between 2001 and 2008.[14] My proxy for regulatory risk is whether a state's legislators passed and later repealed restructuring legislation. The time-invariant indicator *Repeal* is equal to one for states that passed and repealed (or suspended) restructuring legislation and zero otherwise.[15]

Because legislation must be passed before it can be repealed, I controlled for whether a state passed restructuring legislation initially. While persistent (unobserved) attributes of a state associated with passing restructuring are

14. In all states, the effective date of an RPS policy followed the repeal of restructuring legislation.

15. I view the Repeal indicator as reflecting the underlying, consistent instability of policy in these states. In unreported analyses, I experimented with including a time-varying measure equal to 1 following repeal. The estimated coefficient on that measure was not significant and its inclusion did not impact the results.

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controlled for with the state fixed effect, I also controlled for the passage of restructuring legislation with a time-varying measure, *Restruc*, equal to one in all years after a state passed a restructuring policy, zero in all years after repeal, and zero in all years for states that never passed restructuring legislation. This accounts for any difference in the incentive or ability to develop new renewable generating assets following restructuring. I also controlled for the interaction of restructuring and an RPS policy to allow for the possibility that there are differences in the impact of RPS policies in the set of states that did pass restructuring policies.[16]

### 5.4. Control Variables

In addition to the state fixed effects, I included controls for several time-varying state-level characteristics expected to influence the demand for, and the supply of, investments in new renewable generation assets. As described above, investments in generation depend on the balance between demand for electricity, the supply of electricity, and the market price. To account for the impact of anticipated demand and the demand/supply balance, I controlled for the reserve margin (*Reserve Margin*) in the region, which is a measure of unused capacity relative to peak demand, drawn from the NERC Electricity Supply and Demand database,[17] the annual state population (*Population*) (US Census Bureau), annual state level electricity sales (*Elec Sales*), and the growth rate of electricity sales (*Sales Growth*) in the state (Energy Information Administration 2010a). I also controlled for the average electricity price (*Elec Price*) in each year in the state (Energy Information Administration 2010a), which influences the expected market price and the relative costs of traditional and renewable energy. Because demand for renewable energy also depends on the preference of the customers, I controlled for the environmental disposition of a state's constituents using the percentage of Democrats in the state legislature in each year, from the US Census Bureau Statistical Abstract *(Percent Dem*), and per capita Sierra Club membership. With or without RPS policies, investments in renewable generation may be higher in states where customers place a higher value on environmental stewardship. Utilities could make investments to satisfy regulator requests and offer green-power programs that allow customers to voluntarily pay more for renewable energy. Finally, I controlled for the ability of customers in a state to pay a premium for renewable power with the gross state product (GSP) (Bureau of Economic Analysis 2010), which reflects the wealth of a state's customers.

16. Of the 22 states for which I observe post-RPS years, five states did not pass restructuring legislation.

17. NERC data does not cover Alaska and Hawaii. For these states, I used data drawn from the EIA Electric Power Annual Report (EIA 2010a) to calculate a proxy for the reserve margin equal to MWhs of electricity generated divided by MWs of installed capacity times 8760 hours per year. This proxy is not directly comparable to the reserve margins provided by NERC, but is comparable over time within the state, as required for the empirical analysis presented here.

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While the reserve margin controls for the overall supply/demand balance in the state, it does not capture the balance for renewable energy specifically. To control for the existing supply of renewable generation, I included the amount of eligible existing renewable generation capacity in a state (*State Cum MW*) and region (*Region Cum MW*), as of the prior year. I used region definitions consistent with the Department of Energy (Bird et al. 2009: 5) to "reflect the ability of renewable energy generators to meet state RPS demand within the presumed constraints of power markets or electricity-deliverability requirements." For each state-year after eligibility, I aggregated the new capacity (as of the prior year) for renewable generation (in-state and in-region). When the state policy did not require new assets to generate the electricity, I considered all previously installed (but not yet retired) units eligible. In robustness tests, I also explored controls for the potential wind, biomass, and solar energy in a state (Elliott, Wendell, and Gower 1991; NREL 1991; Walsh et al. 2000; U.S. Department of Agriculture 2003).[18]

Finally, I controlled for the presence of two institutions expected to influence investments in independent (nonutility owned) generation assets, regardless of fuel type. There are well-established transaction hazards associated with market transactions for the procurement of electricity (Joskow 1996). Two institutions established to alleviate these problems and encourage the development of a competitive market for electricity generation are state-level interconnection policies and regional independent system operators (ISOs). The DSIRE database provides a record of the interconnection policies enacted by each state. I created a variable, *Post_Interconnect*, equal to one in each year beginning with the effective date in each state that passed an interconnection standard and zero otherwise. Based on reports from the EIA, I also created a variable, *ISO*, equal to one for all state-years in which there was an established ISO and zero otherwise.

### 5.5 Summary Statistics

Table 1 reports summary statistics for the balanced panel of 49 states for the 21-year period, 1990–2010. Delaware is not included in the empirical analysis because there were no new investments in renewable generation assets during the sample period. Alaska and Hawaii lack data on wind and biomass potential but are included in the primary analysis. The measures of potential wind, biomass, and solar energy are state-level, time-invariant measures intended to reflect the potential for various renewable fuels in a state. Given the empirical specification, the state fixed effects absorb these time-invariant measures, although I return to discuss them in robustness checks. As the table reports, 45% of the observations were in states that passed restructuring legislation at some point, and 16% were in states that passed and repealed

18. These time-invariant measures are not included in the models with state-level fixed effects. Any effect of variation in natural resource endowments across states is absorbed in the state-fixed effects.

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Table 1. Summary Statistics: Panel Data set Including 49 States Over 21 years ($N = 1029$, except for policy dates, which summarize observations with that policy)

| Variable | Mean | Standard deviation | Min | Max |
|---|---|---|---|---|
| Investment (MWs) | 44.93 | 176.01 | 0 | 2844.70 |
| RPS start year (if enacted) | 2007 | 2.90 | 2000 | 2012 |
| State RPS (0/1) | 0.55 | 0.50 | 0 | 1 |
| RPS (0/1) | 0.10 | 0.30 | 0 | 1 |
| StateGap[a] ($10^6$ MWhs) | 1.51 | 8.04 | 0 | 88.21 |
| Repeal date (if repealed) | 2003 | 1.84 | 2001 | 2008 |
| State repeal (0/1) | 0.16 | 0.37 | 0 | 1 |
| Restruct law date (if law passed) | 1998 | 1.44 | 1996 | 2001 |
| State restruc (0/1) | 0.45 | 0.50 | 0 | 1 |
| Restruc (0/1) | 0.28 | 0.45 | 0 | 1 |
| ISO (0/1) | 0.24 | 0.43 | 0 | 1 |
| Interconnect (0/1) | 0.24 | 0.43 | 0 | 1 |
| Electricity Price (cents per Kwh) | 7.62 | 2.79 | 3.37 | 29.20 |
| Population (‘000) | 5676.15 | 6154.63 | 453.40 | 37295.12 |
| GSP (billions of current $) | 200.66 | 252.23 | 11.51 | 1921.56 |
| Electricity Sales (‘000 MWhs in state-yr) | 66813.36 | 61551.95 | 4253.84 | 348132.50 |
| Electricity sales growth (%) | 1.57 | 3.20 | −21.49 | 18.69 |
| % Dem in legislature | 0.53 | 0.15 | 0.11 | 0.91 |
| Per Capita Sierra Club Membership (per ‘000) | 2.13 | 2.04 | 0.31 | 52.84 |
| Solar potential ($10^6$ MW/day) | 944.63 | 914.69 | 18.01 | 5233.73 |
| Wind potential (1000 sq km windy land area)** | 22.12 | 36.21 | 0 | 123.69 |
| Biomass potential ($10^6$ dry tons/year)** | 10.86 | 8.40 | 0.12 | 33.36 |

[a]$N = 1008$, excludes Texas because comparable state gap cannot be calculated due to policy structure.

[b]$N = 987$ because there are no data on wind and biomass potential for Alaska and Hawaii.

restructuring legislation. More than half (55%) of states passed RPS policies and 10% of the state-year observations in the analysis occurred when these policies were in effect. Although the average *StateGap* appears small, this is because this variable is equal to zero in all pre-RPS years and in all years for states that did not pass RPS policies. For the post-RPS years in states with a policy, *StateGap* ranges between 0.79 and 88.21, with a mean of 15.85. In my sample, I observed post-RPS years for 22 states, of which 17 passed restructuring legislation and 5 did not. Of those 17 states, 5 subsequently repealed restructuring.[19] The correlation matrix (see Table 2) suggests that passage of RPS policies and restructuring legislation were positively correlated and

19. It should be noted that, among states that did not pass RPS policies, three states passed restructuring legislation and two of the three later repealed restructuring. This allows us to separately identify the effects of restructuring and repeal from those of the RPS policies.

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Table 2. Correlation Matrix ($N = 1029$, $N = 987$ for correlations with wind and biomass potential)

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Investment | | | | | | | | | | | | | |
| 2 | RPS | 0.25 | | | | | | | | | | | | |
| 3 | Repeal | −0.00 | 0.08 | | | | | | | | | | | |
| 4 | Restruc | 0.13 | 0.44 | 0.32 | | | | | | | | | | |
| 5 | ISO | 0.21 | 0.38 | −0.12 | 0.54 | | | | | | | | | |
| 6 | Interconnect | 0.25 | 0.42 | 0.13 | 0.33 | 0.31 | | | | | | | | |
| 7 | Electricity Price | 0.09 | 0.49 | −0.07 | 0.38 | 0.44 | 0.35 | | | | | | | |
| 8 | Population | 0.26 | 0.19 | 0.10 | 0.26 | 0.25 | 0.18 | 0.20 | | | | | | |
| 9 | GSP | 0.34 | 0.33 | 0.11 | 0.36 | 0.37 | 0.31 | 0.30 | 0.95 | | | | | |
| 10 | Electricity Sales | 0.30 | 0.12 | 0.00 | 0.19 | 0.19 | 0.19 | 0.03 | 0.91 | 0.85 | | | | |
| 11 | Electricity sales growth | −0.11 | −0.21 | 0.06 | −0.14 | −0.16 | −0.23 | −0.26 | −0.07 | −0.11 | −0.04 | | | |
| 12 | Solar potential | 0.20 | 0.01 | 0.27 | 0.00 | −0.12 | −0.00 | −0.04 | 0.20 | 0.19 | 0.21 | 0.09 | | |
| 13 | Wind potential | 0.20 | −0.05 | −0.02 | −0.08 | −0.00 | −0.02 | −0.24 | −0.11 | −0.09 | −0.06 | 0.09 | 0.54 | |
| 14 | Biomass potential | 0.16 | −0.18 | −0.23 | −0.23 | −0.06 | −0.07 | −0.33 | 0.19 | 0.14 | 0.31 | 0.04 | 0.12 | 0.36 |



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that RPS policies were enacted in states with higher-than-average electricity prices and higher GSPs. There appears to be little correlation between the passage of RPS and a state's natural resource endowments.

The importance of regulatory risk is evident in the summary statistics of the average level of investment in new renewable generation before and after RPS policies took effect. Table 3 reports the average annual MWs of new renewable generation before and after RPS policies for states with greater regulatory risk (i.e., with a prior repeal of restructuring) and lower regulatory risk (i.e., no prior repeal). These statistics are based on investments in states that did pass RPS policies. In the pre-RPS years, states that repealed restructuring had higher average annual investments, although the difference across the two groups of states was not statistically significant. In the post-RPS years, investments increased in both groups of states but increased significantly more in states that did not experience a prior regulatory repeal. This basic pattern in the data is consistent with the primary prediction: that RPS policies were followed by a significantly smaller increase in renewable generation investments in states with a greater regulatory risk of policy reduction or reversal.

The empirical analysis examined whether this aggregate pattern is robust. As noted above, the empirical strategy depends on the adequacy of untreated states (those without RPS policies and those that did not repeal prior restructuring legislation) as suitable controls. If there are unobserved differences across the sets of states, this could bias the coefficient on the indicators for RPS policy, repeal, and their interaction. I examined two pairs of state subsets to evaluate this concern. Table 4 presents the comparison of means for states that passed and maintained a restructuring policy and states that passed and repealed a restructuring policy. The difference of means tests are based on data from the year 1999, before the first RPS policy became effective. The mean level of annual investment in renewable generation was larger in states that repealed restructuring but the two subsets are statistically indistinguishable. The recent growth in investments in renewable generation assets, measured by the average increase in investment during the previous 5 years, was also larger in states that repealed restructuring, but again the subsets are statistically indistinguishable. The two sets of states were also indistinguishable

Table 3. Average Annual Renewable Generation Investments Pre- and Post-RPS Policies (includes observations only for states that passed RPS policies)

| | States without repeal | States with repeal |
|---|---|---|
| Pre-RPS annual MW investment | 28.31 | 44.95 |
| | (5.41) | (10.84) |
| Post-RPS Annual MW Investment | 203.93 | 108.40 |
| | (57.93) | (27.75) |
| Pre to Post Increase in MW Investment | 175.62 | 63.45 |
| | (28.71)** | (25.49)* |

Standard errors in parentheses; *significant at the 5% level; **significant at the 1% level.

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Table 4. Summary Statistics: Comparison of States with Restructuring Policies that Did and Did Not Repeal Restructuring, 1999 data ($N = 14$ no repeal, $N = 8$ repeal)

| | Restructuring, No Repeal | | Restructuring, Repeal | | Difference |
|---|---|---|---|---|---|
| | Mean (1) | Standard deviation (2) | Mean (3) | Standard deviation (4) | (1)–(3) |
| Investment (MWs) | 9.88 | 36.79 | 45.32 | 92.31 | −35.44 |
| Increase in investment (MWs) | 6.33 | 39.71 | 35.68 | 73.39 | −29.36 |
| Electricity price (cents per Kwh) | 8.18 | 1.89 | 6.20 | 1.31 | 1.98* |
| Population | 8075.63 | 6152.29 | 6886.97 | 10782.34 | 1188.66 |
| GSP | 286.42 | 224.32 | 239.47 | 398.34 | 46.94 |
| Electricity sales (MWhs in state-year) | 89696.91 | 80482.24 | 66304.24 | 72693.22 | 23392.67 |
| Electricity sales growth (%) | 2.14% | 0.02 | 0.73% | 0.03 | 1.41% |
| Solar potential ($10^6$ MW/day) | 643.96 | 958.51 | 1502.44 | 228.96 | −858.48* |
| Wind potential (1000 sq km windy land area) | 16.62 | 36.10 | 20.16 | 34.76 | −3.54 |
| Biomass potential ($10^6$ dry tons/year) | 8.82 | 9.87 | 6.59 | 5.15 | 2.22 |
| % Dem in legislature | 56.5% | 0.15 | 52.3% | 0.16 | 4.2% |
| Sierra Club membership (per '000) | 2.11 | 0.82 | 2.64 | 1.48 | −0.53 |

*Significant at the 5% level.

in terms of population, GSP, the composition of the state legislature, and the natural resource potential for wind and biomass energy generation. The only significant differences across these states were higher average electricity prices in states that did not repeal restructuring and a greater potential for solar power generation in states that repealed restructuring. To the extent that these differences across repeal and nonrepeal states moderate the impact of the RPS policy, this would undermine the interpretation of my results. I return to these differences in section 8 when I discuss the robustness tests.

Table 5 provides the difference of means tests for states that did and did not enact an RPS policy, again comparing 1999 data. The average annual investment in renewable generation assets, and the recent growth in these investments, is statistically indistinguishable across the two groups. The natural resource potential was not significantly different, either. There were differences in the average electricity price and GSP (those that enacted an RPS were higher in both regards). Previous studies have found that natural resource potential, state-level restructuring, economic conditions, population growth, and political preferences drove state RPS adoption (Huang et al. 2007; Chandler 2009; Lyon and Yin 2010). I controlled for these characteristics and others in the analysis and will discuss them in detail in the robustness tests.

## 5. Results

The empirical approach is to estimate the effect of RPS policies on the annual level of investment in new renewable generation assets and test whether this effect differs systematically with regulatory instability in a state. Table 6

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Table 5. Summary Statistics: Comparison of States that Did and Did Not Enact RPS Policies, 1999 data ($N = 22$ no RPS, $N = 27$ RPS)

| | Did not enact RPS | | Enacted RPS | | Difference |
|---|---|---|---|---|---|
| | Mean (1) | Standard deviation (2) | Mean (3) | Standard deviation (4) | (1)–(3) |
| Investment (MWs) | 21.17 | 55.59 | 21.02 | 59.18 | 0.14 |
| Increase in investment (MWs) | 19.63 | 56.20 | 11.51 | 54.57 | 8.12 |
| Electricity price (cents per Kwh) | 5.86 | 1.52 | 7.38 | 2.10 | −1.52** |
| Population | 3602.22 | 3330.16 | 7017.40 | 7238.83 | −3515.16* |
| GSP | 108.31 | 105.65 | 252.22 | 264.89 | −143.91* |
| Electricity sales (MWhs in state-year) | 54394.31 | 45422.86 | 77571.93 | 71286.20 | −23177.61 |
| Electricity sales growth (%) | 2.40% | 0.03 | 1.72% | 0.02 | 0.67% |
| Solar potential ($10^6$ MW/day) | 932.35 | 1008.66 | 954.64 | 867.92 | −22.29 |
| Wind potential (1000 sq km windy land area) | 23.41 | 37.52 | 21.08 | 36.52 | 2.33 |
| Biomass potential ($10^6$ dry tons/year) | 12.75 | 7.84 | 9.33 | 8.82 | 3.43 |
| % Dem in legislature | 48.98% | 0.16 | 54.33% | 0.15 | −5.35% |
| Sierra Club membership (per '000) | 1.31 | 0.91 | 2.53 | 1.00 | −1.22** |

*Significant at the 5% level; **Significant at the 1% level.

reports the results of estimates of the annual investment in new renewable generation assets as a function of RPS policies, regulatory risk, and controls. All specifications included conditional state fixed effects and year indicator variables. The reported standard errors are robust and clustered by state.[20]

Model 1 includes control variables reflecting a state's economic and policy characteristics and the RPS policy indicator. The coefficient on the RPS policy indicator is positive and significant, indicating an increase in investments in renewable generation assets in years following an RPS policy's effective date. Model 2 adds to this model the controls for the existing installed renewable generation in the state and region, neither of which are significant predictors of current investment. Because this is a nonlinear model, the estimated coefficients do not indicate the marginal effects, making interpretation of the results difficult without further calculation. (The impact of a change in one variable depends on the level of the other variables.) In order to provide a meaningful interpretation of the results, I used the simulation-based approach to statistical inference developed by King et al. (2000). The simulation approach, like traditional hypothesis testing, is based on the central limit theorem. The premise is that if enough samples are drawn from the sampling population and used for estimation, the resulting coefficient estimates will be distributed joint normally. The difference is that the researcher simulates the distribution of coefficient estimates directly by repeatedly drawing estimates from the multivariate normal distribution. The mean simulated coefficient vector converges

20. A Wooldridge test for serial correlation in panel data failed to reject the null of no first-order serial correlation ($p$ value = 0.44).

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Table 6. Investment in New Renewable Generation as a Function of RPS Policy and Regulatory Risk

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| RPS | 0.499 | 0.765 | 0.694 | 0.965 |
| | (0.254)* | (0.324)* | (0.279)* | (0.456)* |
| Repeal X RPS | | | **−0.960** | **−1.255** |
| | | | **(0.446)*** | **(0.440)**** |
| ISO | 0.648 | 0.717 | 0.591 | 0.650 |
| | (0.323)* | (0.371) | (0.345) | (0.413) |
| Post interconnect | −0.529 | −0.630 | −0.506 | −0.648 |
| | (0.222)* | (0.260)* | (0.232)* | (0.267)* |
| Restructure | 1.152 | 1.218 | 0.896 | 0.908 |
| | (0.446)** | (0.473)* | (0.539) | (0.548) |
| Restructure X RPS | | | −0.037 | 0.091 |
| | | | (0.434) | (0.488) |
| Electricity Price | 0.324 | 0.292 | 0.252 | 0.180 |
| | (0.159)* | (0.145)* | (0.154) | (0.141) |
| Population | −0.000 | 0.000 | −0.001 | −0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| GSP | −0.002 | −0.004 | −0.001 | −0.003 |
| | (0.001)* | (0.001)** | (0.001) | (0.001) |
| Electricity sales | 0.000 | 0.000 | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Electricity sales growth | 1.801 | 1.938 | 1.448 | 1.615 |
| | (3.922) | (3.899) | (3.901) | (3.955) |
| Reserve margin | −1.345 | −1.608 | −1.233 | −1.502 |
| | (0.861) | (0.957) | (0.930) | (0.989) |
| % Democrat | 6.299 | 7.459 | 6.073 | 7.342 |
| | (2.104)** | (2.246)** | (2.156)** | (2.259)** |
| Sierra Club membership | −0.013 | −0.011 | −0.015 | −0.013 |
| | (0.028) | (0.030) | (0.027) | (0.029) |
| State cum MW | | −0.182 | | −0.235 |
| | | (0.108) | | (0.114)* |
| Region cum MW | | −0.000 | | −0.000 |
| | | (0.000) | | (0.000) |
| Observations | 1029 | 1029 | 1029 | 1029 |
| Log Likelihood | −26581 | −26257 | −26358 | −25910 |

Estimation is Quasi-maximum-likelihood Poisson with state-level conditional fixed effects. Year indicator variables included in every model. Robust standard errors in parentheses. *Significant at the 5% level; **Significant at the 1% level. Bold font indicates estimates of primary interest for hypothesis testing.

to the original estimated coefficient vector, and the distribution of the draws of coefficient vectors reflects the precision of the coefficient estimates (King et al. 2000). This allows the calculation of predicted values and associated confidence intervals. Using the Clarify software (Tomz et al. 2001), I calculated the average effect of an RPS policy on renewable generation asset investments for a state that passed restructuring legislation, with all other variables at their mean. As depicted in the first bar of Figure 3, RPS policies were associated with an average increase in investments of nearly 7 MWs annually during the sample period, a substantial increase considering that the mean level of annual investment was 45 MWs.

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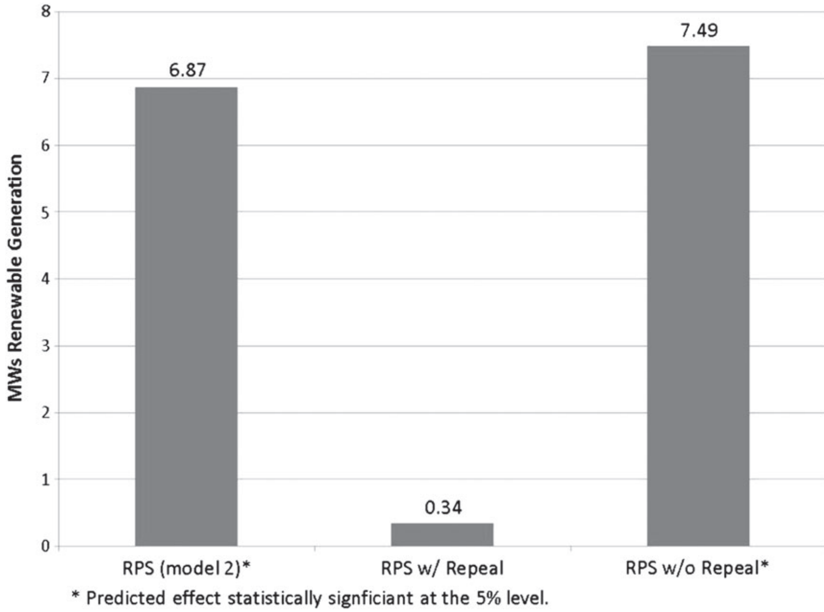


Figure 3. Estimated Impact of RPS Policy and Regulatory Risk on Investments in Renewable Generation.

Model 3 added the variable of interest, *Repeal*, which proxies for regulatory risk in the state, interacted with the RPS policy indicator. Model 4 adds to this model the controls for the existing installed renewable generation in the state and region. The coefficient estimates indicate that the increase in investment in renewable generation following an RPS policy was smaller in states that passed and repealed restructuring legislation. Figure 3 depicts the predicted increase in investments in bars (2) and (3). In states that repealed restructuring legislation, annual investments did not increase following an RPS policy (i.e., the small predicted increase is not statistically different from zero). In states without a history of restructuring repeal, annual investments in renewable energy assets increased by 7.5 MWs. This supports the prediction that the exogenous increase in demand associated with an RPS policy would inspire less investment in states with higher levels of regulatory risk.

Models using the alternative measure of RPS policies, equal to the gap between the policy mandated required renewable energy and the amount available in the state (*StateGap*), are reported in Table 7.[21] Model 1 includes the same controls as model 2 in Table 6 but uses the *StateGap* measure in place of the 0/1 RPS policy indicator. Results indicate that investments in renewable generation assets increased with the larger unmet demand driven by RPS

21. The number of observations is smaller in these estimates because the *StateGap* is not a relevant measure for the RPS policy in Texas, as noted above.

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Table 7. Investment in New Renewable Generation as a Function of RPS Policy and Regulatory Risk

| | (1) | (2) | (3) |
|---|---|---|---|
| StateGap | **0.174** | **0.178** | **0.190** |
| | **(0.036)**** | **(0.036)**** | **(0.038)**** |
| Repeal X StateGap | | **−0.033** | **−0.041** |
| | | **(0.015)*** | **(0.015)**** |
| RegionGap | | | **0.024** |
| | | | **(0.011)*** |
| Repeal X RegionGap | | | **0.004** |
| | | | **(0.018)** |
| ISO | 0.999 | 0.992 | 1.123 |
| | (0.456)* | (0.466)* | (0.471)* |
| Post interconnect | −0.420 | −0.529 | −0.623 |
| | (0.286) | (0.297) | (0.290)* |
| Restructure | −0.192 | −0.422 | −0.386 |
| | (0.484) | (0.519) | (0.540) |
| Restructure X State Gap | −0.172 | −0.146 | −0.151 |
| | (0.036)** | (0.036)** | (0.039)** |
| Electricity price | −0.032 | −0.073 | −0.020 |
| | (0.108) | (0.112) | (0.099) |
| Population | −0.001 | −0.001 | −0.001 |
| | (0.000)* | (0.000) | (0.000)* |
| GSP | 0.003 | 0.003 | 0.004 |
| | (0.002) | (0.002) | (0.002)* |
| Electricity sales | −0.000 | −0.000 | −0.000 |
| | (0.000) | (0.000) | (0.000) |
| Electricity sales growth | 1.476 | 1.658 | 1.524 |
| | (2.925) | (2.976) | (2.905) |
| Reserve margin | −2.653 | −2.186 | −2.398 |
| | (1.391) | (1.371) | (1.361) |
| % Democrat | 6.144 | 6.183 | 4.417 |
| | (2.453)* | (2.400)* | (2.502) |
| Sierra Club membership | −0.032 | −0.034 | −0.033 |
| | (0.026) | (0.025) | (0.025) |
| State Cum MW | −1.113 | −1.101 | −0.955 |
| | (0.317)** | (0.312)** | (0.322)** |
| Region Cum MW | 0.000 | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) |
| Observations | 1008 | 1008 | 1008 |
| Log likelihood | −22732 | −22593 | −22282 |

Estimation is Quasi-maximum-likelihood Poisson with state-level conditional fixed effects. Year indicator variables included in every model. Robust standard errors in parentheses. *Significant at the 5% level; **Significant at the 1% level. Bold font indicates estimates of primary interest for hypothesis testing.

policies, as expected. Model 2 includes the interaction of interest, of the *StateGap* with the *Repeal* indicator, analogous to model 4 in Table 6. These results confirm those derived using the categorical RPS policy measure: the increase in renewable generation assets associated with demand created by RPS policies was roughly 17% smaller in states with a history of policy repeal than in other states.

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Using this alternative measure of RPS-induced demand also allows an additional test of the theory. To the extent that investments were made partly to serve demand for renewable energy within the same region, one would expect investments to increase with the analogous "gap" between available energy and mandated targets in the region but outside of the focal state. Furthermore, investments to serve regional demand (outside of the focal state) should not be influenced by policy instability in the focal state. To test this, I estimated the model again including the *RegionalGap* variable and *RegionalGap* interacted with *Repeal*. Results, reported in model (3) of Table 7, are consistent with this prediction. Investments in a focal state increased with the regional demand gap created by RPS policies in surrounding states, and this increase was unaffected by the repeal status in the focal state.

Given the heterogeneity in state RPS policies, one potential alternative explanation is that states that repealed restructuring legislation also enacted RPS policies that were systematically less stringent. This does not appear to be the case. As reported in Table 8, a difference in means test for the effective year of an RPS policy demonstrates that states that repealed restructuring subsequently enacted RPS policies with slightly earlier effective dates, though the difference is not statistically significant. A difference of means test for the required percentage of renewable energy in the effective year across policies, in states with and without a history of repeal, demonstrates a slightly higher mean target percentage in states that did repeal, but the difference is not statistically significant. The DSIRE database also includes the target percentage for each year following RPS enactment, assuming a linear trajectory between the start year and target years unless the law specified otherwise. A difference of means test of the required percentage of renewable energy in the year 2010 demonstrates that the mean was higher for states with a prior repeal than for other states (indicating a more aggressive policy), although again the difference is not statistically significant. Finally, comparing the percentage of energy that can be met with existing renewable generation assets reveals again that states with a history of repeal also passed slightly more aggressive policies on average (their allowances for existing renewable assets

Table 8. Comparison of RPS Policy Stringency in States That Did and Did Not Repeal ($N = 21$ for no repeal, $N = 6$ for repeal)

| | Restructuring, no repeal | | Restructuring, repeal | | Difference |
|---|---|---|---|---|---|
| | Mean (1) | Standard deviation (2) | Mean (3) | Standard deviation (4) | (1)-(3) |
| Target renewable % | 20.38 | 9.58 | 22.17 | 6.94 | −1.78 |
| Required % renewable in 2010 | 7.35 | 8.36 | 8.42 | 7.23 | −1.07 |
| Policy effective year | 2007.52 | 3.09 | 2006.67 | 2.50 | 0.86 |
| Allowed % existing renewables | 53.48 | 50.24 | 33.33 | 51.64 | 20.14 |

None of the reported differences are statistically significant.

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were lower), though again the difference is not statistically significant. Based on this comparison, it does not appear that states with a history of regulatory repeal enacted less-stringent RPS policies.

## 6. Interpretation

The empirical results demonstrate that RPS policies had a significantly smaller effect in states that previously passed and repealed electric utility industry restructuring legislation. I interpret these results to mean that a prior repeal indicates underlying policy instability in a state and that RPS policies incited less investment in states where policy instability increased the risk of RPS policy reduction or repeal. It is natural to ask whether this is the correct interpretation. There could be something unobserved in the states that repealed prior restructuring legislation, unrelated to policy stability or regulatory risk, that created the pattern I observe.

Although it is not possible to rule this out entirely, I do not believe this is the case. The difference of means tests reported in Table 3 and Table 4, and the robustness tests described below, suggest that observed differences across states are not driving the results. To further test this interpretation, I explored several factors underlying the likelihood of policy repeal in a state and examined the extent to which these underlying factors drive investments. In an analysis reported in the appendix, I drew on existing literature to explore measures of state political and institutional structures as predictors of policy instability. I found that several aspects of state institutional and political structures are, indeed, significant predictors of repeal. In particular, I found the likelihood of repeal increased with (1) the presence of a Democratic governor, (2) the presence of a consumer advocate representing ratepayers, and (3) the election (rather than appointment) of regulatory commissioners. Because these state attributes are unlikely to be correlated with the error term (they do not independently drive investment decisions except through their influence on policy stability), they provide potentially useful instruments for repeal. Results from the two-stage instrumental variables Poisson estimation using these attributes as instruments (see Appendix) are consistent with those reported previously: The effect of an RPS policy on investment in renewable generation assets was significantly lower in states with a prior repeal. This provides stronger support for my primary results and for the interpretation that a history of policy instability deters firms from investing in regulation-specific assets.

## 7. Robustness Tests

The empirical strategy assumes that there are no unobserved time varying differences across states that are correlated with RPS policy enactment or restructuring repeal and also correlated with the error term. Although it is not possible to examine unobserved variables, I pursued several robustness tests based on the observed differences across states in order to examine whether these differences across states could have moderated the effect of the RPS policy on investment and generated the observed pattern. First, the summary statistics suggest that the average price of electricity was higher in states that *did not* repeal restructuring and that *did* enact an RPS policy. A higher average price of

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electricity might encourage investments in renewable generation assets in response to an RPS policy, all else equal. The difference in means argues against this as an explanation for the demonstrated negative effect of prior repeal on investments because states without a prior repeal also had higher average prices than other states. I experimented with including a control for the electricity price interacted with the RPS policy indicator. Results in column (1) of Table 9 suggest that this is not a significant predictor of increased investment following an RPS policy, and the coefficient estimates on the variables of interest are unchanged.

Second, I added controls for the state-level potential for solar energy. Firms operating in states with more natural renewable energy resources could be expected to respond more to RPS policies, all else equal. The only difference in natural resource potential evident in the summary statistics is that states that repealed restructuring also had larger potential for solar energy generation, which could result in these states installing more solar generation in response to RPS policies. Again, this runs counter to the evidence that states that repealed restructuring saw less investment in response to RPS policies. I included the interaction of solar potential with the RPS policy indicator. Results are reported in column (2) of Table 9. The coefficient on the interaction term is not significant, and the coefficients of interest did not change.

Third, the estimated coefficient on the GSP variable was highly significant in models 1 and 2 of Table 6 but became insignificant when I introduced the repeal variables in models 3 and 4.[22] This may cause concern that the repeal variables reflect differences in GSP, although the summary statistics do not suggest any significant difference in GSP across states with and without a regulatory repeal. To explore this further, I estimated a model including GSP interacted with the RPS policy indicator. The results, in model 3 of Table 9, suggest that this control is not significant; the estimated coefficients on the variables of interest did not change.

Finally, because the ISO indicator variable is a significant predictor of investment, it is possible that the negative correlation of prior repeal and ISO presence could cause the negative coefficient estimate on the interaction of *Repeal* and *RPS*. The final model in Table 9 reports results including a control for the ISO indicator interacted with the RPS policy indicator. This interaction was not significant, and the coefficients on the variables of interest did not change.

## 8. Conclusions

This article examined how the perceived risk of future regulatory change affects firm responses to a policy initiative designed to increase investment in location-specific long-lived assets. The results indicate a strong empirical relationship. RPS policies were followed by significant increases in investments in renewable resource generation assets, as the policy intended. However, there was no increase in investments in states with a prior occurrence exhibiting regulatory policy instability. I conclude that firms may be unwilling

22. Due to rounding, the reported results for Model 4 make it appear as if the coefficient on GSP is statistically significant. However, the coefficient on GSP is −0.00269 and the standard error is 0.00141. The *p*-value is 0.056.

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Table 9. Robustness Checks, Additional Controls

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| RPS | 0.980 | 0.676 | 0.903 | 0.879 |
| | (0.883) | (0.485) | (0.473) | (0.558) |
| Repeal X RPS | −**1.255** | −**1.221** | −**1.251** | −**1.196** |
| | (**0.445**)** | (**0.481**)* | (**0.433**)** | (**0.465**)* |
| ISO | 0.649 | 0.719 | 0.680 | 0.653 |
| | (0.397) | (0.422) | (0.384) | (0.410) |
| Post interconnect | −0.648 | −0.560 | −0.640 | −0.648 |
| | (0.264)* | (0.268)* | (0.269)* | (0.268)* |
| Restructure | 0.908 | 0.932 | 0.917 | 0.913 |
| | (0.547) | (0.562) | (0.539) | (0.538) |
| Restructure X RPS | 0.091 | −0.102 | 0.039 | 0.079 |
| | (0.493) | (0.526) | (0.505) | (0.464) |
| Electricity price | 0.180 | 0.160 | 0.183 | 0.181 |
| | (0.138) | (0.141) | (0.141) | (0.141) |
| Population | −0.000 | −0.000 | 0.000 | −0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| GSP | −0.003 | −0.003 | −0.003 | −0.003 |
| | (0.002) | (0.001) | (0.002) | (0.002) |
| % Democrat | 7.340 | 7.271 | 7.384 | 7.383 |
| | (2.257)** | (2.232)** | (2.239)** | (2.235)** |
| Sierra Club member | −0.013 | −0.013 | −0.013 | −0.013 |
| | (0.029) | (0.029) | (0.029) | (0.029) |
| Electricity sales | 0.000 | 0.000 | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Electricity Sales Growth | 1.614 | 1.646 | 1.653 | 1.613 |
| | (3.946) | (3.884) | (3.906) | (3.947) |
| Reserve margin | −1.501 | −1.657 | −1.503 | −1.507 |
| | (0.992) | (1.018) | (0.992) | (0.988) |
| State cum MW | −0.235 | −0.261 | −0.244 | −0.239 |
| | (0.113)* | (0.112)* | (0.107)* | (0.113)* |
| Region cum MW | −0.000 | −0.000 | −0.000 | −0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Elec price X RPS | −0.002 | | | |
| | (0.081) | | | |
| Solar X RPS | | 0.000 | | |
| | | (0.000) | | |
| GSP X RPS | | | 0.000 | |
| | | | (0.001) | |
| ISO X RPS | | | | 0.117 |
| | | | | (0.539) |
| Observations | 1029 | 1029 | 1029 | 1029 |
| Log likelihood | −25910 | −25829 | −25905 | −25908 |

Estimation is Quasi-maximum-likelihood Poisson with state-level conditional fixed effects. Year indicator variables included in every model. Robust standard errors in parentheses. *Significant at the 5% level; **Significant at the 1% level. Bold font indicates estimates of primary interest for hypothesis testing.

to invest in assets that are long-lived and location- and policy-specific in an environment with significant regulatory uncertainty. Consistent with this interpretation, the investment-inducing effect of regional demand for renewable energy was not reduced by instate regulatory uncertainty.

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As noted above, the relationship between uncertainty and investment may be a result of both the demand of utility companies for renewable energy and the willingness of investors (utilities and private firms) to develop new renewable generation assets. If utility companies perceive that an RPS policy is likely to change, they may be unwilling to make long-term commitments to purchase renewable energy. This would obviously deter investors considering the construction of new plants. Even when utility companies respond to an RPS by seeking new renewable energy sources, regulatory policy instability may deter investors from creating those sources. Both of these mechanisms could be responsible for the observed relationship between uncertainty and investment.

By using TCE theory to consider the implied contract between regulators and firms and by explicating how instability in the policy environment affects firms' willingness to invest in specific assets, this study confirms the value of applying TCE theory to analyses of regulatory environments. The evidence that uncertainty about future regulatory policies hampers investment reveals that the same transaction hazards that influence investments in private contracts also impact private–public contracts. In other words, policy makers influence private actors not only through the policies they enact but also through the institutional environment they create, including the level of uncertainty about future policy changes, enforcement, and repeals.

To encourage compliance and private investment, and to achieve public policy goals, regulators need to reduce ex post hazards by credibly committing to policy stability and predictability. One mechanism to enhance credibility and reduce ex post hazards is to create mutual dependence (Williamson 1983). In the case of RPS policies, this could take the form of regulatory bodies supporting investments that would lose a significant portion of their value if legislators reduced renewable energy requirements. By allowing regulated utilities to recover the costs of such investments in their rates, regulators would commit ratepayers to cover the costs and would create pressure to preserve the value of the investments. Investment in transmission assets specific to the location and generating characteristics of renewable energy resources is one example. Regulators could also make choices that make it difficult to reduce renewable energy requirements, such as electing not to approve proposed investments in new natural gas exploration, processing, and transport. An alternative avenue for regulatory commitment would be to adopt requirements and procedures that make repeal or renegotiation of RPS policies more arduous. For example, the Federal Administrative Procedure Act of 1946 and subsequent state-level Administrative Procedure Acts passed by all states in the 20th century created procedures and requirements that increased the difficulty of overturning existing policies (McCubbins et al. 1987; De Figueiredo and Vanden Bergh 2004). In the case of RPS policies, legislative procedures to raise the political access and stature of renewable energy producers would make it more difficult for legislators to abandon these policies. Actions that create a more certain policy environment, including encouraging or disallowing investments and creating procedural hurdles to change as described here, promote both utility demand for renewable generation assets and investors' willingness to invest in such projects.

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The implications of this analysis are critical for policy makers. Policies are enacted to encourage firms to comply with a program's objectives. An uncertain policy environment can critically undermine a policy's effectiveness by making firms less willing to invest in new assets. Firms will be even less willing to make new investments when those investments will have substantially less value under an alternative regulatory scheme. If regulators cannot credibly commit to policy initiatives that require specific investments, the best alternative to achieve policy objectives may be for government to invest in the required assets directly. This would be analogous to firms internalizing transactions in response to unmitigated transaction hazards in private contracting. This is consistent with Williamson's conclusion that government itself will have to bear the investment burden when investments are sunk and there are substantial risks of expropriation associated with policy instability (Williamson 1991).

Although this study tests predictions in a particularly specialized setting—using data on electricity industry investments in response to specific policies—the predictions themselves are not industry specific. The primary insight that uncertainty about future policy stability reduces investment in specific assets is generalizable across industries and settings. For example, firms from multiple industries have expressed frustration with uncertainty about future federal regulation of carbon emissions. Companies claim they are paralyzed because, with ongoing uncertainty about what a carbon policy might entail, they cannot determine which strategies and (policy-specific) investments are optimal. Until policy makers are able to enact legislation and credibly commit to maintaining the policy they adopt, firms will be less willing to invest in developing and adopting new technologies.

## Appendix: Institutional Structure and Policy Repeal

Policy repeal does not occur randomly. As emphasized by new institutional economics, political institutions constrain the ability of one individual or preference group to exert their will and alter existing laws (North 1990). According to North, institutions are the "constraints that human beings impose on themselves" to provide the rules of the game that "shape human interaction" (North 1990: 3–5). These institutions include the formal rules and informal norms that describe which actions are allowed, and disallowed, to different members of society.

In order to examine the role of variation in political institutions in the repeal of electricity industry restructuring legislation, I compared observable characteristics of the relevant political institutions. The 2001 energy crisis in California demonstrated that restructuring the electricity market could result in substantial and unprecedented increases in wholesale electricity rates. Restructuring policies had been viewed as benefitting customers by increasing competition, providing customer choice, and ultimately decreasing rates. The energy crisis provided a new opportunity to debate the impact of restructuring, and some consumer groups lobbied heavily for the halt or repeal of restructuring legislation. For example, the Consumer Federation of America, the country's largest consumer advocacy group, used the California energy crisis to argue that the costs of restructuring outweighed the potential benefits (Rose 2002). This gave utility companies an opening to push back against restructuring legislation.

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I am interested here in whether states that passed and retained restructuring legislation had institutional characteristics that differed systematically from states that passed and repealed restructuring legislation. Where there were institutions in place to support and promote the interests of customers, I would expect to see restructuring legislation preserved. Where these institutions were lacking, utilities could exert more influence on legislative outcomes. I accounted for two state institutions that play a prominent role in the electric utility industry: (1) the presence of a ratepayer advocate in the state and (2) the election, rather than appointment, of public utility commissioners. In the 1970s and 1980s, 31 US states created independent ratepayer advocate offices and empowered them to represent consumer interests in utility proceedings (Holburn and Vanden Bergh 2006). A ratepayer advocate's mission is to represent consumer interests, including low rates, reliability, and environmental issues. Electing public utility commissioners rather than appointing them through governors or state legislatures provides a direct role for customers' interests and makes commissioners more responsive to constituents' interests. Thirteen states have elected commissioners. I created indicators for states with ratepayer advocates based on data reported in Holburn and Vanden Bergh (2006) and for states with elected commissioners based on data from the NARUC Yearbook (NARUC 1996).

Existing research in positive political theory suggests that alignment of interests reduces political constraints (Henisz 2000a, 2000b). In my context, one might expect that states in which political power is more concentrated and aligned with consumer groups would be less likely to experience legislative repeal. Conversely, in states in which power is aligned with interests that favor utilities, policy repeal would be more likely. Based on data reporting the party affiliation of the governor and members of the legislature for each state in each year (U.S. Census Bureau 2010), I created measures indicating alignment between the governor and legislature, distinguishing between alignment under the Democratic Party and alignment under the Republican Party. The excluded condition is a state government in which the majority party in the legislature was different from the party of the governor. I also created indicator variables equal to one in the year and the year following a change in the controlling party of the state legislature, from Democrat to Republican (*Leg Change to Republican*) and from Republican to Democrat (*Leg Change to Democrat*), because a change in party leadership may increase the probability of policy repeal.

In order to evaluate the importance of these institutional characteristics in determining the likelihood of legislative repeal of restructuring, I regressed the *Repeal* indicator on the state-level measures of institutional characteristics and the interaction of each of these measures with an indicator of whether the state passed restructuring legislation (*Restruc*) and included all the controls in the models predicting investment. The results indicate that the strongest predictors of repeal in states that passed restructuring were (1) the presence of a Democrat governor, (2) the presence of a formal ratepayer advocate, and (3) when state regulatory commissioners were elected rather than appointed. Other state characteristics were not statistically significant. I conclude that these state institutional characteristics dispose a state to policy instability in the electric utility industry.

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These exogenous and predetermined factors provide valid instruments for the repeal of restructuring legislation. I estimated a two-stage instrumental variables model, instrumenting for the interaction *Repeal X RPS* with (1) the three institutional indicators (Democratic governor, ratepayer advocate, and elected commissioners); (2) the institutional indicators interacted with the postrestructuring indicator (*Restruc*); and (3) the institutional indicators interacted with the RPS policy indicator.

Appendix Table 1 provides the second-stage estimate based on instrumental variables Poisson estimation using GMM (Mullahy 1997). The estimated coefficient on the interaction of *Repeal* and *RPS* was negative and significant,

Appendix Table 1: Poisson Instrumental Variable Analysis

| | (1) |
|---|---|
| RPS | −0.177 |
| | (0.724) |
| Repeal X RPS | −**5.780** |
| | (**1.011**)** |
| ISO | 0.353 |
| | (0.470) |
| Post interconnect | −1.936 |
| | (0.423)** |
| Restructure | −1.904 |
| | (0.554)** |
| Restructure X RPS | 2.622 |
| | (1.057)* |
| Electricity price | −0.112 |
| | (0.129) |
| Population | 0.000 |
| | (0.001) |
| GSP | −0.003 |
| | (0.003) |
| % Democrat | 6.988 |
| | (2.793)* |
| Sierra Club member | 0.296 |
| | (0.509) |
| Electricity sales | 0.000 |
| | (0.000)** |
| Electricity sales growth | −6.439 |
| | (5.578) |
| Reserve margin | −0.008 |
| | (0.531) |
| State cum MW | −0.802 |
| | (0.176)** |
| Region cum MW | 0.000 |
| | (0.000)** |
| Constant | 0.598 |
| | (2.152) |
| Observations | 1029 |

Bold font indicates estimates of primary interest for hypothesis testing. *Significant at the 5% level; **Significant at the 1% level. Estimation method is GMM for Poisson with instrumental variables.

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confirming the results reported above. In fact, the magnitude and significance levels exceeded those reported above. These results provide stronger evidence that the detrimental effect of legislative repeal on investments following RPS policy enactment was not a spurious result of state selection into the repeal group.

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