Have Renewable Portfolio Standards Raised Electricity Rates? Evidence from U.S. Electric Utilities

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Abstract

Renewable Portfolio Standards (RPS) have been a contentious issue amongst policymakers in recent years. Neoclassical theory would suggest that, in the short-run, RPS mandates will raise electricity rates if the cost of electricity generation via renewable energy technologies exceeds that of convention fossil fuel technologies. This study uses a quasi-experimental approach to investigate the effect of RPS policies on retail residential electricity rates. The study provides one of the first econometric investigations of the economic effect of RPS mandates. The empirical approach uses a panel dataset of 2,602 U.S. electric utilities from 1990 to 2006. The empirical findings provide several policy insights on the effect of RPS mandates. First, a state RPS mandate, on average, positively affects the average residential electricity rate. Second, no spillover effect exists for the RPS effect on electricity rates. In other words, utilities that operate in a RPS state, but are not subject to an RPS requirement, do not experience a significant increase in electric rates. Third, the RPS effect on residential electricity rates is significantly lower in states with a higher wind and solar energy potential. Finally, the magnitude of the RPS effect on residential electricity rates increases for utilities subject to higher requirements. The estimated elasticity of residential electricity rates with respect to an RPS requirement equals roughly 0.3.

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1. Introduction

In recent years, concerns over global climate change have generated increasing public interest in favor of policies that promote the use of clean energy technologies. Renewable Portfolio Standards (hereafter, RPS) are one example of policies that aim to stimulate the supply of renewable energy. In the U.S., many states have adopted RPS mandates as a way to improve the diversity and reliability of their electricity market, as well as improve environmental quality (see, e.g., California Public Utilities Code 399.11-399.20, Oregon Senate Bill 838). Typically, an RPS requires electric utility companies to provide a portion of their electricity sales with electricity generated from renewable energy sources (Wiser et al., 2008). As of December 2008, 26 states and the District of Columbia have implemented RPS mandates.[1] Six other states have adopted renewable portfolio goals, which unlike RPS mandates, do not legally bind. RPS policies also exist in several countries including the United Kingdom, Sweden, Belgium, Italy, Poland, Japan, and Australia (Wiser et al., 2008).

Proponents of RPS policies emphasize the policies' environmental and market benefits (EPA, 2009; Cooper, 2008). RPS policies could lower emissions of air pollutants and greenhouse gases, produce a more diverse and secure energy, as well as generate more stable future energy prices. On the other hand, opponents of RPS policies point to their potential positive effect on electricity generation costs and, ultimately, electricity prices (see, e.g., Michaels, 2008). In August 2007, the U.S. House amended the House bill H.R. 3221 to include a national RPS mandate of 15 percent by 2020. The amendment triggered a controversial debate in the U.S. Senate. The key argument against the RPS mandate was that the policy would increase retail

[1] Source: Database of State Incentives for Renewables and Efficiency (www.dsireusa.org).

electricity prices (Congressional Research Service Report, 2007a). The national RPS mandate disappeared from the final version of the bill (H.R. 6, Public Law 110-140) that the House and the Senate approved and that President George W. Bush signed on December 19, 2007 (Congressional Research Service Report, 2007b).

The Neoclassical model of profit maximization would suggest that, in the short-run, RPS mandates will raise electricity rates if the cost of electricity generation via renewable energy sources, such as wind and solar, exceeds that of convention fossil fuel sources, such as coal.[2] This paper uses a quasi-experimental approach to investigate the effect of RPS mandates on retail residential electricity rates.[3] Using a unique panel dataset of 2,602 electric utilities from 1990 to 2006, I estimate the causal effect of a state's RPS mandate on residential electric utility rates. An important empirical difficulty exists. Electric utilities in RPS states may differ from utilities in non-RPS states and these differences relate to differences in electricity rates. Such unobserved differences cause OLS regressions to produce biased estimates.[4] This study relies on a fixed-effect estimator to identify the effect of a state RPS on electric utility rates. The fixed-effects estimation controls for the potential endogeneity problem from time-invariant omitted characteristics, at the utility or state level, that correlate with the RPS presence.

To date, little econometric evidence exists on the effects of RPS mandates on retail electricity rates. The current empirical evidence regarding the effect of RPS policies on electricity prices relies on energy simulation models. Palmer and Burtraw (2005) find that a 15-percent national RPS mandate raises average electricity rates by 2 percent in 2020 compared to

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[2] In other words, with profit maximizing firms under competition one would expect output prices to rise if firms are constrained to a technology that is not cost-minimizing.
[3] Greenstone and Geyer (2009) discuss the merits of the quasi-experimental approach for evaluating the costs and benefits of environmental policies.
[4] This classic selection bias arises in quasi-experimental studies (see, e.g., Angrist and Krueger, 1999; Greenstone and Geyer, 2009).

the no-mandate baseline scenario. With a 20-percent national RPS, they find that the average electricity price increases by 8 percent in 2020, compared to the baseline scenario.

Other simulation studies by the Energy Information Administration (EIA, 2002) find that a 10-percent national RPS mandate of could raise the electricity price by 1.5 percent, whereas a 20-percent national RPS mandate could raise electric rates by as much as 4 percent. Chen et al. (2008) survey 31 state commissioned studies that investigated the projected effect of RPS policies in several U.S. states. These studies also use energy simulation models. They find that the average RPS effect on retail electricity prices ranges from minus 5 percent for Texas, to plus 9 percent for Arizona. The median effect across the 31 surveyed studies is roughly 0.8 percent or 0.05 cents per kilowatt-hour.

The main advantage of an econometric approach is that one can estimate the effect of RPS mandates on electricity rates, using observed historical data on electricity rates in states with a RPS mandate. Some states adopted RPS mandates as early as 1991 and others as recently as 2008. This study will exploit the variation in electricity rates and the timing of RPS adoption across states and over time to identify the causal effect of RPS mandates on retail electricity prices. The econometric estimates inform policymakers on whether current state RPS policies cause higher rates for electricity consumers. Hence, the paper is of direct relevance to states currently evaluating the future of their RPS programs and to the broad policy debate on climate change.

This study also relates to a larger literature on the effects of regulatory actions in electricity and telecommunication markets. Knittel (2004) finds that increased competition due to deregulation in the telecommunications markets increased residential long-distance rates and lowered business rates, thus reducing the cross-subsidization from business to residential customers. Lyon and Mayo (2005) analyze the effects of regulatory cost disallowances in electricity markets. They find that utilities invest less, when facing regulatory cost disallowances. More recently, Fabrizio et al. (2007) find that investor-owned power plants affected by electricity deregulation reduced their labor and nonfuel expenses by 3 to 5 percent relative to other investor-owned power plants in regulated environments.

The paper is organized as follows. The next section provides some background information on RPS policies in the U.S. and reviews the literature. Section 3 discusses the data sources, the econometric identification issues, and the specification of the econometric model. Section 4 presents the results of the empirical estimation of the causal effect of RPS mandates on electricity rates. The final section concludes the analysis.

2. Background on RPS Policies[5]

2.1. How an RPS works

An RPS policy "requires electric utilities and other retail electric providers to supply a specified minimum amount of customer load with electricity from eligible renewable energy sources (U.S. EPA, 2009)." An RPS policy sets a requirement, for renewable energy supply, which applies to each retail electricity supplier (Wiser et al., 2008). A typical RPS sets a final goal, as a proportion of electricity sales, and target year. For example, the California RPS mandate sets a goal of 20 percent to be reached by the year 2010. In addition, RPS policies set annual requirements that increase over time until reaching the final target. In Nevada, for instance, the RPS began in 2003 as a 1-percent requirement on generating capacity and increased by 2 percent each year until 2013. In addition to setting a requirement, RPS policies also specify penalties for electric utilities that do not comply with the mandate (Wiser et al., 2008).

[5] This section borrows from Wiser et al. (2008) who provide a detailed overview of RPS policies in the U.S.

An electric utility can comply with a state RPS mandate generally in three ways. First, the utility may own a facility that produces electricity from renewable energy sources. Second, the utility may purchase electricity from a renewable energy facility. Lastly, the utility may purchase renewable energy certificates (RECs), also referred to as renewable energy credits. The U.S. EPA (2009) defines an REC as "a tradable right to claim the environmental and other attributes associated with 1 megawatt-hour of renewable electricity from a specific generation facility." A retail electric utility can purchase the REC to meet its RPS requirement. Except for New York, Iowa, and Hawaii, all other state RPS policies allow the use of RECs to comply with RPS requirements.

RPS policies also typically provide a list of eligible renewable energy sources. The standard eligible renewable technologies among all RPS states include wind, solar, hydroelectric, hydrogen, land-fill gas, and geothermal.[6] A few states, however, also identify ethanol, nuclear, and clean-coal technologies as eligible sources.

2.2. State RPS Policies in the U.S.

Table 1 summarizes the adoption of RPS by states for the period 1990 to 2006. All RPS mandates became effective after 1990.[7] By the end of 2006, 20 U.S. states and the District of Columbia had adopted RPS mandates. Iowa adopted the first state RPS mandate. The legislation, referred to as the Alternative Energy Law, required the state's two investor-owned utilities to purchase a combined total of 105 megawatt-hours of their production capacity from qualified renewable energy production facilities. The Iowa legislation, originally enacted in 1983, became

[6] As of 2008, renewable energy sources accounts for 3 percent of all U.S. electricity generation. Wind energy accounted for 32 percent of total renewable electricity generation. Solar and geothermal energy accounted for 0.6 percent and 14 percent, respectively. The remainder of U.S. renewable electricity generation is produced from wood waste (37 percent) and biomass (15.7 percent).

[7] The Iowa Alternative Energy Law was enacted as a voluntary program in 1983. The renewable energy standard became mandatory in 1991.

effective in 1991.[8] The 1990s period saw many states restructuring their electricity markets, and adopting RPS mandates. The last column of Table 1 identifies the states without restructured electricity markets as of 2006. Of the 21 states and DC, that had adopted an RPS mandate by 2006, 5 states had not restructured their electricity market. These states included Arizona, Connecticut, Maine, Massachusetts, Nevada, New Jersey, New Mexico, Texas, and Pennsylvania. Many states' RPS mandates were implemented as part of electricity restructuring legislation.

State RPS policies vary widely in terms of the goal, target year, yearly requirement, eligible renewable technologies, and the type of electric utilities that are required to comply with the mandate. Most RPS goals reflect a percentage of the annual retail sales in megawatt-hours. In a few states, however, the RPS goal reflects the production capacity (either in nominal or percentage terms). All state RPS requirements apply to investor-owned electric utilities.[9] The treatment of municipal utilities and electric cooperatives, however, varies across states. Some states exempt municipal and cooperative utilities from their RPS mandate, whereas in other states these utilities must comply with a lesser RPS mandate than investor-owned utilities.

3. Why Might an RPS Raise Electricity Rates?

The anticipated effect of RPS mandates on electric utility rates stems from the regulated structure of electricity markets. Retail customers purchase their electricity from regulated utilities that distribute electricity in their area. These regulated monopolies charge a regulated price for electricity, which the state regulatory commission approves and reflects the utility's operating and capital costs (see, e.g., Joskow, 1997; Lyon and Mayo, 2005). Hence, one would expect that, at least in the short run, RPS mandates may cause higher electricity rates if the cost of electricity

[8] Source: Database of State Incentives for Renewables and Efficiency (www.dsireusa.org).
[9] Investor-owned utilities account for roughly 75 percent of U.S. retail electricity sales (Joskow, 1997).

generation via renewable energy technologies, such as wind and solar, exceeds that of convention fossil fuel technologies, such as coal.[10] The estimated cost of electricity generation from coal is roughly 6 cents per killowhatt-hour (kwh). Electricity generation cost estimates range from 7 to 12 cents per kwh for wind energy, and 15 to 28 cents per kwh for solar energy.[11]

Fischer (2006) presents a theoretical model of the effect of RPS mandates on electricity prices, using a simple partial equilibrium framework. The analysis suggests that the effect of an RPS on electricity rates depends on the relative elasticities of the supply curves for renewable and fossil-fuel energy sources. An RPS mandate basically subsidizes the production of electricity from renewable sources while taxing the production of electricity from fossil-fuel sources. Suppliers of electricity from renewable sources get a subsidy equal to the value of their RECs, whereas suppliers of electricity from fossil-fuel sources pay a tax proportional to the number of RECs needed to meet the RPS mandate. Hence, an RPS lowers electricity prices if the supply curve for fossil-fuel electricity generation is sufficiently steeper than that of renewable electricity generation. On the other hand, an RPS mandate raises electricity prices if the supply curve for renewable electricity generation is steeper compared to that of fossil-fuels. A corollary of this result is that an RPS mandate is less likely to raise electricity prices in those states with abundant sources of renewable energy, whereas states that do not have abundant sources of renewable energy are more likely to experience an increase in electricity prices if an RPS mandate affects electric utilities.

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[10] Roughly 3 percent of U.S. electricity is produced from renewable energy sources. Coal accounts for roughly 50 percent of U.S. electricity generation.

[11] Levelized costs of electricity generation without carbon capture. Source: National Renewable Energy Laboratory (www.nrel.gov).

4. Empirical methodology

4.1. Data

The empirical analysis uses publicly available data from various sources. A complete list of the data sources is given in Table 2. The electricity price series was constructed using the Form EIA-861 database of the Energy Information Administration (EIA). These data provide information on retail revenue, sales and customer count, by retail sectors (i.e., residential, commercial, and industrial), for all electric distribution utilities in the U.S. The data also provide the ownership type of the utility, as well as the state served by the utility. The variables characterizing the presence of an RPS, as well as other regulations related to renewable energy, were constructed using the Database of State Incentives for Renewables and Efficiency (DSIRE).[12] The analysis accounts for whether the state in which a utility operates has a deregulated electricity market. The variable representing electricity deregulation was constructed from EIA's online report on the status of electricity restructuring in the U.S. (EIA, 2009). I use the EIA's State Electricity Profiles (EAI, 2006) to construct annual state-level variables for the percentage of electricity generation from coal and the average price of coal delivered to electric utilities.

The data comprises over 3,500 electric utilities and roughly 55,000 observations from 1990 to 2006, an unbalanced panel, since not all the utilities appear in each year. The EIA classifies electric utilities are classified into nine ownership types.[13] Of these nine types of utilities, only the three major utility types operate in all states. The remaining utility types only operate in a few states. I focus on the three major electric utility types: (1) investor-owned utilities, (2) municipal utilities, and (3) electric cooperatives.[14] Together these three types of

[12] The data are publicly available at www.dsireusa.org.
[13] These are: cooperative, facility, federal, investor-owned, municipal, political subdivision, power marketer, state, and other.
[14] This causes the loss of roughly 3,500 observations.

utilities account for roughly 84 percent of all electricity sales and about 90 percent of residential electricity sales in the U.S. from 1990 to 2006. The final sample, which I use in the estimation, has 2,602 utilities and a total of 44,149 observations.[15]

Table 2 also provides a summary of means for the variables used. The dependent variable is the average residential electricity price of an electric utility provider operating in one state. For each utility, I calculate the annual average residential electricity rate by dividing the utility's annual residential state revenues[16] by its residential electricity sales in kilowatt-hours. In addition to electricity prices, state characteristics control for variation in electricity demand and supply shifters across states. The estimation controls for differences in fuel costs, using the average state coal price and natural gas price paid by electric utilities. All other things equal, one expects electricity prices to correlate positively with fuel costs. The estimation also controls for the state population and the state population density. All things equal, a higher state population likely causes a more congested electricity grid, which will result in higher electricity rates. A higher population density will reduce capital costs and thus electricity rates.

4.2. Descriptive Evidence

This subsection provides some descriptive evidence from the data regarding the effect of RPS mandates on electricity rates. Average electricity rates in the United States have risen sharply since 1999. The average nominal residential price of electricity rose from roughly 8.3 cents per kwh in 1999 to 10.3 cent per kwh in 2006, as shown by the top line in Figure 1. During that same period, a substantial number of states implemented RPS mandates. The proportion of states with

[15] Some utilities report duplicate observations within a state. Other utilities did not serve residential customers. Still other utilities operated in multiple states. Finally, we included only utilities that appeared in each year of the sample. In total, these various reasons eliminated 7,000 observations.

[16] These are revenues received for the direct sale of energy to retail customers. These do not include revenues for the sale of wholesale power, revenues for providing willing services, utiltity property rentals, electric service reconnection fees, fuel adjustments, state and local taxes, federal taxes, and other taxes paid by the utility.

RPS mandates rose from 10 percent in 1999 to 40 percent in 2008, as shown by the bottom line in Figure 1.

Figure 2 shows the evolution of the average residential electricity rate in RPS states and non-RPS states. On average, electricity rates in RPS states remained above those of non-RPS states. The gap in electricity rates also grew wider between RPS states and non-RPS states since 1990. This gap widens further when we restrict the RPS states to the states that did not restructure their electricity markets.

Table 3 summarizes electricity retail rates among RPS and non-RPS states, showing similar retail electricity between RPS and non-RPS states in 1990 before the adoption of RPS mandates. The national average nominal residential electricity price was 7.66 cents per kilowatt-hours (kwh) in 1990. Among the RPS states, the 1990 average residential electricity price was 8.28 cents per kwh. This rate compares to the mean residential electricity rate of 7.22 cents per kwh among non-RPS states in the same year. Although these two rates differ significantly (column 5), they do not differ significantly when we restrict the RPS states to the states that did not restructure their electricity markets (column 6).

The national average nominal residential electricity price was 10.31 cents per kwh in 2006. The mean residential electricity rate in 2006 was roughly 12.30 cents per kwh in RPS states compared to only 8.91 cents per kwh in non-RPS states. Hence, the difference in average electricity rates between RPS states and non-RPS states is larger in 2006, after most states implemented their RPS mandates.

Though the evidence from the raw data seems to support the hypothesis that RPS mandates contributed to higher electricity rates in RPS states compared to non-RPS states, this descriptive evidence does not control for other factors that can affect the differential. The econometric model addresses this problem, using a fixed-effect regression approach.

4.3. Econometric Specification

The empirical analysis uses a panel dataset of 2,602 U.S. electric utilities from 1990 to 2006. I identify the causal effect of an RPS mandates on electric utility rates from the variation in the timing of RPS policies across states and over time. The main obstacle to the identification of the causal effect arises if unobserved characteristics of a state's utilities, which relate to electricity prices, also influence the adoption of the RPS regulation. A regression specification that does not account for these factors will lead to an inconsistent estimate of the effect of RPS adoption on electricity rates. I address this potential endogeneity problem by way of a utility-specific fixed effect. This assumes that the unobserved utility characteristics that could potentially influence RPS adoption are time-invariant. The basic regression equation is given by the following model:

$$\begin{aligned}\log pr_{ist} &= \alpha \cdot RPS_{st} + \beta \cdot Deregulated_{st} + \gamma \cdot Otherregulation_{st} \\ &+ \delta \cdot Controls_{st} + \phi \cdot Year_t + \theta \cdot Utility_i + \varepsilon_{ist},\end{aligned} \tag{1}$$

where $log\ pr_{ist}$ is the natural log of the average residential nominal price of electricity for the electric utility i in state s during year t. For each state s, RPS_{st} is an indicator variable that equals 1 if an RPS mandate is in effect during year t.[17] All other things equal, we would expect a positive coefficient on the RPS policy, reflecting the high general cost of renewable energy technologies, such as wind and solar, relative to conventional fossil-fuel technologies.

[17] Note that I use the effective date of the RPS policy instead of the adoption date, since most RPS mandates only become binding after their effective date.

Following the Energy Policy Act of 1992, several states restructured their electricity markets to allow for retail price competition. Twenty-three states had adopted electricity restructuring legislation by the end of 2000 (Rose, 2004). In addition, many states implemented other rules and regulations on electric utilities to promote renewable energy and energy efficiency. The presence of these policies could confound the effect of an RPS on electric utility rates. My estimation isolates the effect of RPS mandates from the effect of both electricity deregulation and other renewable energy policies that affect electric utilities.

The estimation captures the presence of electricity restructuring regulation by the indicator variable *Deregulated*, which equals 1, if electricity restructuring is active in state s during year t. We would expect a negative sign for the coefficient on *Deregulated,* implying that electricity deregulation successfully increases competition among retail electricity providers thereby reducing electricity generation costs and retail rates.[18] The indicator variable $Otherregulation_{st}$ indicates the presence of other statewide renewable energy regulatory rules that affect electric utilities. These regulatory rules include production incentives for renewable energy, public benefit funds, generation disclosure rules, net metering, interconnection standards, and mandatory green power options.

The vector $Controls_{st}$ captures observable state characteristics that affect the retail price of electricity. These characteristics include the state population, population density, and the average price of coal and natural gas delivered to electric utilities. The term $Year_t$ is a time period fixed effect that controls for any national trends in electricity rates. The term $Utility_i$ is a

[18] Fabrizio et al. (2007) find that investor-owned electricity generation plants affected by deregulation experienced reductions in generation costs by 3 to 5 percent relative to other investor-owned plants.

utility-specific fixed effect which captures time-invariant unobserved differences among electric utilities.[19] The mean causal effect of an RPS on the electric utility retail rates equals α.

The identification of the effect of an RPS on electric utility rates is further complicated if time-varying unobserved characteristics exist that affect electric utility rates and correlate with the adoption of an RPS mandate. In this case, the endogenous RPS regulatory variable causes inconsistent estimates of the RPS effect. In the next section, I explicitly test for the endogeneity of the RPS regulatory variable following Hausman (1978). The results of the Hausman test suggest that the endogeneity of the RPS regulatory variable does not seem to matter when investigating the effects of RPS mandates on residential electricity rates.

5. Empirical Results

5.1. The Effect of RPS Mandates on Residential Electricity Rates

Table 4 presents the empirical evidence on the effect of a state RPS mandate on the residential electricity rate of the utilities operating within the state. Column (1) presents the results of a simple OLS regression which does not include utility-specific fixed-effects, while Column (2) presents the results of the fixed-effects regression specification in equation (1). The estimated RPS coefficient in Column (2) suggests that state RPS mandates positively and significantly affects residential electricity rates by roughly 4 percent. This finding is similar to the simulation evidence of Palmer and Burtraw (2005), who find that a 15-percent national RPS raises electricity rates by 2 percent by the year 2020. The estimated RPS coefficient in the simple OLS regression is smaller in magnitude. In addition, the fit of the OLS regression model is significantly lower than that of the fixed-effect specification.

[19] The regression equation (1) can be estimated via either a fixed effects or a random effect method. The Hausman specification test, however, rejects the null hypothesis that the unobserved utility term $Utility_i$ is a random effect.

Column (3) reports the estimates of an alternative version of equation (1), where the RPS policy variable interacts with the *Affected* dummy variable, which equals 1 for an electric utility that must comply with an RPS mandate. This specification tests whether the presence of a RPS mandate spills over onto the non-affected electric utilities. The estimated coefficients on the RPS variable suggest that the RPS effect mainly affects the utilities that must comply with the mandate. Hence, no evidence of a spillover effect exists. This result corresponds to the finding of Lyon and Mayo (2005) that electric utilities affected by state regulatory cost disallowances reacted by reducing their investments, while other utilities in the same state did not exhibit significant reductions in investment.

The estimated effect of electricity deregulation on residential electricity rates is positive across all regression specifications. The prevailing thought among proponents of electricity deregulation is that competitive pressures resulting from deregulation would force electric utilities to operate more efficiently and ultimately yield lower electricity costs and retail prices. Fabrizo et al. (2007) find empirical evidence that electricity deregulation has resulted in reduced generation costs for investor-owned power plants. However, some studies have also shown that imperfect competition due to either market power (e.g., Green and Newbery, 1992) or limited transmission capacity (e.g., Borestein et al., 2000) can give electric utilities the incentive to restrict output. Under such conditions, a utility's retail electricity rate could be higher after deregulation. This is consistent with this paper's estimate of the effect of deregulation on residential electricity rates.[20]

[20] It is also possible that states adopt deregulation in response to high electricity rate levels (see e.g. Knittel, 2004; White, 1996). As a result the deregulation variable is endogenous and the resulting bias is positive. This positive bias could turn the otherwise negative effect of deregulation of electricity deregulation into a positive effect.

5.2. Heterogeneity in the RPS effect

The regression specifications in columns (4) through (8) address additional questions related to the heterogeneity of the RPS effect across states. The regression specification in column (4) addresses the heterogeneity of the RPS effect between states with different endowment of renewable energy resources. Fisher's (2006) theoretical analysis shows that the differential effect from an RPS mandate will generate lower, and possibly negative, effects in states with abundant renewable energy sources. To evaluate this hypothesis, the specification interacts the RPS variable with two variables that indicate the state's potential for wind and solar energy.[21] As expected, the effect of an RPS mandate on residential electricity prices is lower in states with a higher potential for wind and/or solar energy compared to other RPS states.[22]

The basic specification assumes that RPS mandates are homogeneous across states. State RPS mandates, however, differ in the requirements that they impose on each type of utility. State RPS requirements in a given year will also differ depending on the age of the state RPS policy. The specification in Column (5) includes two additional policy variables that capture the state RPS requirement in percentage points and the age of the RPS policy in years. The magnitude of the RPS effect on residential electricity rates increases for utilities subject to higher requirements. A 1-percentage increase in the RPS requirement leads to about a 0.3 percent increase in residential electricity rates, so that the elasticity of residential electricity rates with respect to a RPS requirement equals roughly 0.3. The RPS effect also increases by roughly 0.2 percent for each additional year after implementation of the RPS. That is consistent with the fact

[21] These variables come from the National Renewable Energy Laboratory's (NREL) wind and solar energy resource's maps. The NREL provides an estimate of the annual wind resource for the conterminous U.S. with a resolution of 1/3 degree latitude and 1/4 degree latitude.
[22] Note that the mean RPS effect in column (4) is 0.068. This is because the mean solar energy potential is 4.3 and the mean wind energy potential is 2.9.

that most RPS requirements gradually increase every year until the final RPS target is reached (see, e.g., Wiser et al., 2008).

The specifications in columns (6) through (8) compare the RPS effect, on residential electric rates, across electric utilities of different size. We define three size categories: less than 10,000 megawatt-hours (MWH) of residential sales per year, between 10,000 and 100,000 MWH of residential sales per year, and more than 100,000 MWH of residential sales per year. The estimated RPS positively affects residential electricity rates across all three specifications. The magnitude of the RPS effect, however, for small electric utilities exceeds that for medium-sized and large utilities.

5.3. Comparing the effect of RPS mandates across retail electricity sectors

Electricity rates vary significantly between residential and commercial customers (see Figure 1). Furthermore, some empirical evidence exists that regulatory actions may differentially affect residential and business customers (see, e.g., Knittel, 2004). Hence, it also makes sense to assess the effect of RPS mandates on commercial electricity rates. The results in Table 5 compare the RPS effect on residential rates, commercial rates, and all retail electric rates. The estimated RPS effect is similar across the three regressions.

5.4. Endogeneity of RPS Policies

The fixed effect identification strategy collapses if time-varying unobserved characteristics exist that affect electric utility rates and correlate with the adoption of an RPS mandate. In this case, the endogenous RPS regulatory variable causes inconsistent estimates of the RPS effect. To address this issue, I explicitly test for the endogeneity of the RPS variable. Following Hausman (1978), I estimate the following augmented version of the regression equation (1):

$$\log pr_{ist} = \alpha \cdot RPS_{st} + \beta \cdot Deregulated_{st} + \gamma \cdot Otherregulation_{st} + \delta \cdot Controls_{st} + \phi \cdot Year_t + \theta \cdot Utility_i + \lambda \cdot RPS_{st}^{hat} + \varepsilon_{ist}, \quad (2)$$

where RPS^{hat} is the predicted value of the RPS variable from the reduced-form regression of RPS on a set of instruments Z. Hausman (1978) showed that an endogeneity test involves testing the hypothesis that λ = 0 in equation (2). The set of instruments Z, in the reduced-form regression of the RPS variable include all the remaining regressors in equation (1) plus one instrument.[23] We use the average environmental score for the state's members of the U.S. House as the instrument. The League of Concerned Voters annually compiles this since 1970, which strongly correlate with the presence of an RPS mandate.[24] Table 6 reports the results of the estimation for the residential, commercial, and all-retail rate specifications. I cannot reject the null hypothesis of exogeneity in the residential and all-retail rates regression. I do reject, however, the exogeneity of the RPS variable in the commercial rates specification. These results suggest that the endogeneity of the RPS regulatory variable does not seem to matter when investigating the effects of RPS mandates on residential electricity rates.

6. Conclusions

RPS policies have been a contentious issue amongst policymakers in recent years. On February 26, 2009, the U.S. House subcommittee on Energy and the Environment held a hearing to address the potential role of renewable electricity in achieving greenhouse gas reductions and the viability of a federal renewable electricity standard for increasing renewable electricity production and encouraging technological improvement (U.S. House of Representatives: Subcommittee on Energy and the Environment, 2009). This study provides one of the first

[23] The reduced-form regression clusters within state-year cells, since both the dependent variable and the regressors are state-level variables.
[24] The data are publicly accessible at http://lcv.org/scorecard/past-scorecards.

econometric investigations of the economic effect of RPS mandates. The analysis uses a panel data of 2,602 U.S. electric utilities from 1990 to 2006. I estimate the effect of an RPS mandate on the average residential rate of electric utilities. The empirical analysis provides policymakers with key insights on the anticipated effects of RPS mandates.

The empirical results suggest that a state RPS mandate exerts, on average, a positive effect on the average residential electricity rates. I find no evidence of a spillover effect for the RPS effect on electricity rates. Utilities that operate in a RPS state, but are not subject to an RPS requirement, do not experience a significant increase in residential electric rates. The RPS effect on residential electricity rates is significantly lower in states with a higher wind and solar energy potential. In addition, the magnitude of the RPS effect on residential electricity rates is higher for utilities subject to a higher RPS requirement. The estimates suggest that the elasticity of residential electricity rates with respect to a RPS requirement is roughly 0.3.

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Table 1: States with RPS Mandates by 2006

State	Adoption Year	Effective Year	Affected Utilties	Target	Electricity Market Restructured Between 1990 and 2006
Arizona	2006	2007	All utilities	15% by 2025	YES
California	2002	2003	All utilities	33% by 2021	YES
Colorado	2004	2004	All utilities	20% by 2020	NO
Connecticut	1998	1998	All utilities	27% by 2020	YES
District of Columbia	2005	2005	All utilities	20% by 2020	YES
Delaware	2005	2005	All utilities	20% by 2019	YES
Hawaii	2004	2004	All utilities	20% by 2021	NO
Iowa	1983	1991	MidAmerican Energy , Interstate Power and Light	105 Megawatt-hours each year	NO
Maine	1999	2000	All utilities	10% by 2017	YES
Maryland	2004	2004	All utilities	20% by 2022	YES
Massachusetts	1997	2002	All utilities	15% by 2021	YES
Montana	2005	2006	Investor-owned utilities (IOUs)	15% by 2015	YES
Nevada	1997	1997	IOUs	20% by 2015	YES
New Jersey	1999	2001	All utilities	22.5% by 2021	YES
New Mexico	2002	2004	Cooperatives, IOUs	20% by 2020	YES
New York	2004	2004	IOUs	24% by 2013	YES
Pennsylvania	2004	2005	IOUs	18% by 2021	YES
Rhode Island	2004	2004	All utilities	16% by 2020	YES
Texas	1999	1999	IOUs	5880 Megawatt-hours by 2015	YES
Washington	2006	2006	All utilities	15% by 2020	NO
Wisconsin	1999	2001	Cooperatives, municipal utilities, IOUs	10% by 2016	NO

Source: http://www.dsireusa.org/library/includes/seeallincentivetype.cfm?type=RPS&currentpageid=7&back=regtab&EE=1&RE=1. Accessed, December 2008. IOU = Investor-owned utility.

Table 2: Data Sources and Summary Statistics

Variables	Description	Mean	Standard Deviation	Minimum	Maximum	Source
Residential price	Average retail residential electricity rate (cents/kwh)	7.855	1.714	0.575	96.324	I
Commercial price	Average retail commercial electricity rate (cents/kwh)	7.179	1.726	0.577	294.737	I
All-retail price	Average retail electricity rate for all customers (cents/kwh)	6.967	1.612	0.575	79.292	I
RPS	One if a state RPS is effective in year t	0.173	0.378	0	1	II
Affected	One if utility is required to comply with an RPS mandate	0.357	0.479	0	1	II
RPS requirement	RPS requirement as a percentage of utility's sales	0.115	1.158	0	16	II
RPS years	Number of years since RPS was effective	1.198	3.226	0	16	II
Wind potential	State average wind energy potential	2.893	0.546	1	4.571	VII
Solar potential	State average solar energy potential	4.314	0.670	2.467	6.945	VIII
Deregulated	One if state electricity market is deregulated	0.070	0.255	0	1	III
Incentives for Renewable Energy	State has production incentive for renewable energy	0.531	0.499	0	1	II
Coal price	State average price of coal delivered to electric utilities (cents per million Btu)	120.870	31.712	55	327	IV
Primary fuel is coal	One if coal is the state's primary fuel for electricity generation	0.804	0.397	0	1	IV
Natural gas price	State average price of coal delivered to electric utilities (cents per million Btu)	384.210	209.215	113	4,519	IV
Primary fuel is gas	One if natural gas is the state's primary fuel for electricity generation	0.146	0.353	0	1	IV
Population	State population estimates (millions)	6.27	5.19	0.45	36.25	V
Population density	State population density (persons per square mile)	101.72	99.05	0.97	1,168.41	V
Observations		44,149	44,149	44,149	44,149	

Note: Standard deviations are in parentheses. Source I: U.S. Energy Information Administration (EIA) Form 861 Database. Source II: Database of State Incentives for Renewables and Efficiency (www.dsireusa.org). Source III: Status of Electricity Restructuring by State (EIA, 2009). Source IV: State Electric Profiles (EIA, 2006). Source V: U.S. Census State Population Estimates. Source VI: U.S. Census County Business Patterns. Source VII: National Renewable Energy Laboratory (NREL) National Wind Resource, low resolution data (www.nrel.gov/gis/cfm/input.cfm). Source VIII: NREL national solar photovoltaics, low resolution data (www.nrel.gov/gis/cfm/input.cfm). Source IX: NREL U.S. Biomass Assessment Data (www.nrel.gov/gis/cfm/input.cfm).

Table 3: Average Electricity Rates (cents per kilowatt-hour), 1990-2006

	All states (1)	RPS states[1] (2)	Regulated RPS states[2] (3)	Non-RPS states (4)	Mean Difference (2) vs. (4) (5)	Mean Difference (3) vs. (4) (6)
1990						
Mean residential rate	7.66	8.28	7.22	7.23	1.06**	0.00
	(1.69)	(1.91)	(2.12)	(1.38)		
Mean commercial rate	6.96	7.48	6.41	6.60	0.88**	0.19
	(1.50)	(1.76)	(2.25)	(1.18)		
Mean all-retail rate	6.47	7.05	5.92	6.07	0.98**	0.15
	(1.59)	(1.80)	(2.02)	(1.32)		
2006						
Mean residential rate	10.31	12.30	11.87	8.91	3.38***	2.95**
	(3.39)	(3.88)	(6.56)	(2.12)		
Mean commercial rate	9.09	10.99	10.25	7.76	3.23***	2.49**
	(3.19)	(3.63)	(6.28)	(2.00)		
Mean all-retail rate	8.87	10.86	9.92	7.47	3.38***	2.45**
	(3.28)	(3.65)	(6.08)	(2.11)		

Standard deviations are in parentheses. *** Significant at the 1% level. ** Significant at the 5% level. Mean difference are based on a two-group mean comparison test.

[1] RPS states are those states that have implemented renewable portfolio standards by 2006. States with renewable portfolio goals are not included.

[2] Regulated RPS states are those RPS states that did not restructure their electricity market between 1990 and 2006.

Table 4: The Effect of RPS Adoption on Residential Electricity Rates

Variables	(1) OLS Full Sample	(2) FE Full Sample	(3) FE Full Sample	(4) FE Full Sample	(5) FE Full Sample	(6) FE Small Utilities	(7) FE Mid-Size Utilities	(8) FE Large Utilities
RPS	0.0143***	0.0388***	0.000901	0.399***	0.0317***	0.0671***	0.0297***	0.0229***
	(2.75)	(14.19)	(0.18)	(14.64)	(10.38)	(9.89)	(8.17)	(5.26)
RPS *Affected			0.0540***					
			(9.29)					
RPS* Solar potential				-0.0180***				
				(-6.17)				
RPS* Wind potential				-0.0875***				
				(-11.66)				
RPS requirement (%)					0.00288***			
					(3.65)			
RPS years					0.00171***			
					(4.18)			
Deregulated	0.0298***	0.0121***	0.0164***	0.0112***	0.0129***	0.0175**	0.00253	0.0256***
	(4.55)	(4.77)	(6.34)	(4.43)	(5.02)	(2.47)	(0.75)	(7.30)
Other renewable energy policies	-0.0926***	-0.00582***	-0.00629***	-0.00471**	-0.00448**	-0.00348	-0.00491*	-0.0102***
	(-24.80)	(-2.98)	(-3.22)	(-2.42)	(-2.26)	(-0.65)	(-1.85)	(-3.82)
Population	-0.00579***	0.0144***	0.0212***	0.0151***	0.0132***	0.0364***	0.0182***	0.0101***
	(-17.57)	(11.65)	(14.83)	(9.72)	(10.51)	(7.27)	(11.38)	(6.06)
Population density	0.000113***	-0.00104***	-0.00135***	-0.00111***	-0.00100***	-0.00139***	-0.000954***	-0.000856***
	(9.02)	(-11.49)	(-13.35)	(-11.47)	(-10.89)	(-4.29)	(-7.91)	(-7.20)
Coal price*Primary fuel is coal	0.000183***	0.000196***	0.000223***	0.000223***	0.000212***	0.000141	0.000173***	0.000264***
	(5.71)	(5.49)	(6.21)	(6.20)	(5.93)	(1.20)	(3.71)	(5.74)
Natural gas price*Primary fuel is gas	0.000408***	0.0000316***	0.0000402***	0.0000398***	0.0000317***	0.0000262	0.0000313***	0.0000417***
	(32.34)	(5.29)	(6.66)	(6.55)	(5.31)	(1.52)	(3.91)	(5.19)
Year Fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Utility (Firm) Fixed-effects	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-value for Utility Fixed-effects	-	141.7***	141.6***	139.8***	140.9***	112.2***	121.5***	113.9***
R^2	0.0898	0.329	0.330	0.332	0.330	0.255	0.360	0.460
Observations	44,149	44,149	44,149	44,149	44,149	12,971	20,077	11,101

Notes: T-statistics are in parentheses. * P-value<0.10. ** P-value<0.05. *** P-value<0.01. Dependent variable is the log of average residential electricity price in cents/kwh.
Small: utilities with average annual residential sales less than 10,000 Megattwatt-hours. Medium-size: utilities with average annual residential sales between 10,000 and 100,000 Megattwatt-hours.
Large: utilities with average annual residential sales greater than 100,000 Megattwatt-hours.
Column (4): The mean RPS effect in is 0.068. This is because the mean solar potential is 4.3 and the mean wind potential is 2.9.

Table 5: The Effect of RPS Adoption across Retail Electricity Sectors

Variables	Residential (1)	Commercial (2)	All-Retail (3)
RPS	0.0388***	0.0268***	0.0353***
	(14.19)	(6.32)	(13.40)
Deregulated	0.0121***	0.0209***	0.0172***
	(4.77)	(5.32)	(7.03)
Other renewable energy policies	-0.00582***	-0.00225	-0.00576***
	(-2.98)	(-0.74)	(-3.06)
Population	0.0144***	0.0130***	0.0144***
	(11.65)	(6.79)	(12.03)
Population density	-0.00104***	-0.00133***	-0.00125***
	(-11.49)	(-9.40)	(-14.25)
Coal price*Primary fuel is coal	0.000196***	0.000290***	0.000199***
	(5.49)	(5.26)	(5.80)
Natural gas price*Primary fuel is gas	0.0000316***	0.0000630***	0.0000460***
	(5.29)	(6.80)	(7.99)
F-value for Utility Fixed-effects	141.7***	58.0***	161.5***
R^2	0.329	0.119	0.230
Observations	44,149	43,393[†]	44,149

(1) Dependent variable is the log of average residential electricity price in cents/kwh. (2) Dependent variable is the log of average commercial electricity price in cents/kwh. (3) Dependent variable is the log of average all-retail electricity price in cents/kwh. T-statistics are in parentheses.
* Significant at 10 percent level. ** Significant at 5 percent level. *** Significant at 1 percent level.
[†] The number of observations is lower because some of the utilities do not provide commercial service.

Table 6: Hausman Test for the Endogeneity of RPS

Variables	Residential (1)	Commercial (2)	All-Retail (3)
RPS	0.0384***	0.0285***	0.0354***
	(13.93)	(6.65)	(13.34)
RPS_hat[†]	0.0267	-0.105***	-0.00722
	(1.20)	(-3.05)	(-0.34)
Deregulated	0.00991***	0.0295***	0.0177***
	(3.19)	(6.11)	(5.93)
Other renewable energy policies	-0.00549***	-0.00356	-0.00585***
	(-2.78)	(-1.16)	(-3.08)
Population	0.0112***	0.0257***	0.0152***
	(3.82)	(5.62)	(5.37)
Population density	-0.000981***	-0.00157***	-0.00126***
	(-9.38)	(-9.67)	(-12.54)
Coal price*Primary fuel is coal	0.000179***	0.000357***	0.000204***
	(4.67)	(6.01)	(5.52)
Natural gas price*Primary fuel is gas	0.0000242***	0.0000922***	0.0000480***
	(2.82)	(6.92)	(5.81)
F-value for Utility Fixed-effects	127.7***	51.7***	146.4 ***
R^2	0.332	0.119	0.303
Observations	44,149	43,393[‡]	44,149

(1) Dependent variable is the log of average residential electricity price in cents/kwh. (2) Dependent variable is the log of average commercial electricity price in cents/kwh. (3) Dependent variable is the log of average all-retail electricity price in cents/kwh. T-statistics are in parentheses.
* Significant at 10 percent level. ** Significant at 5 percent level. *** Significant at 1 percent level.
[†] Predicted value of the RPS variable from the reduced form regression of RPS on a set of instruments Z.
[‡] The number of observations is lower because some of the utilities do not provide commercial service.

Figure 1: Average Electricity Rates in the U.S., 1990-2006

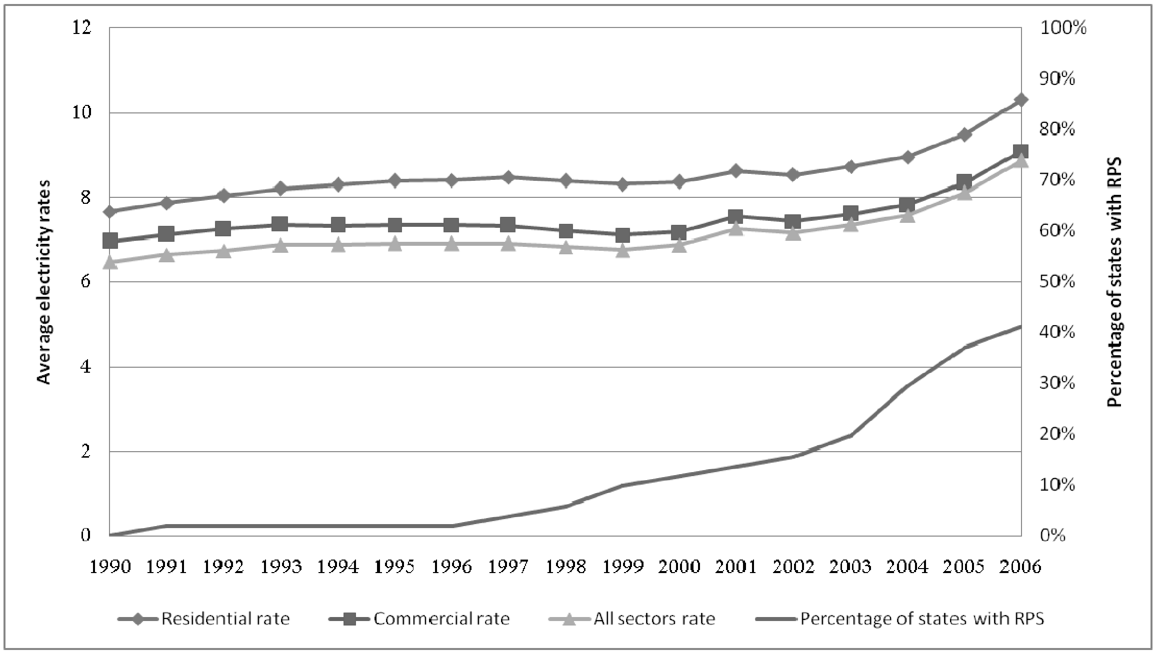
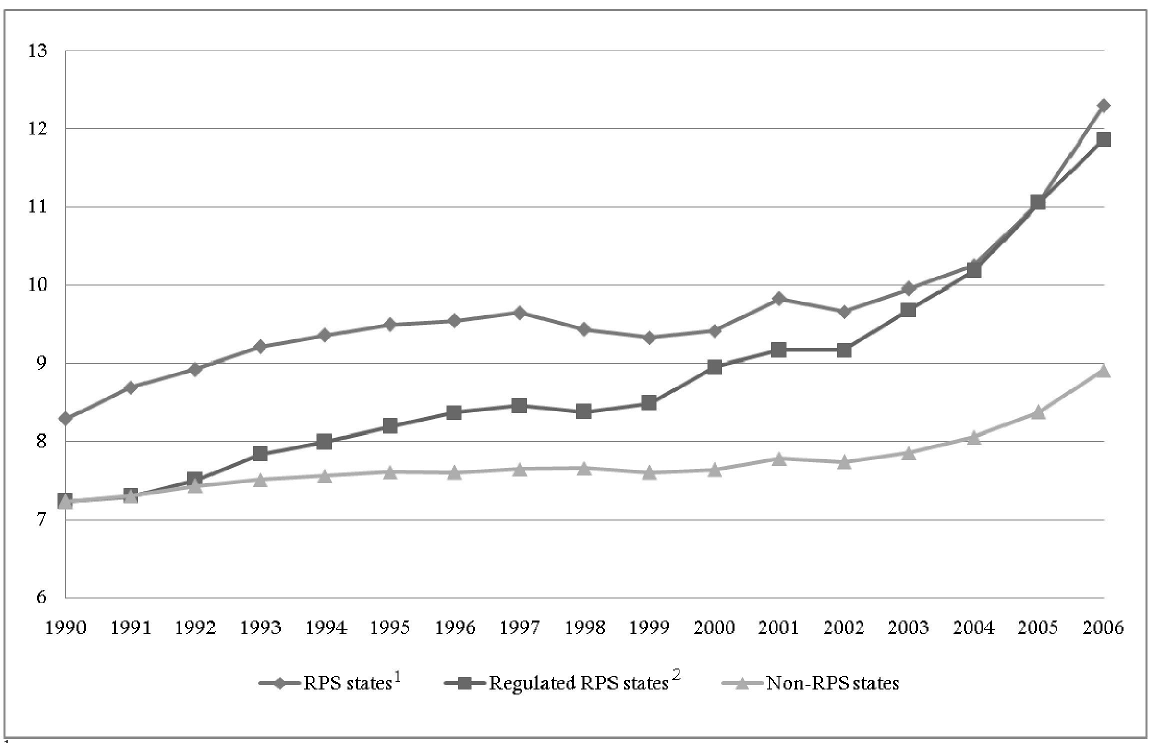


Figure 2: Average Residential Electricity Rates by RPS Status, 1990-2006



[1] RPS states are those states that have implemented a Renewable Portfolio Standard by 2006.
[2] Regulated RPS states are those RPS states that did not restructure their electricity market between 1990 and 2006.