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Abstract

Renewable Portfolio Standards (RPS) are U.S. state mandates that utilities produce some of their electricity using renewable energy sources in an effort to reduce greenhouse gas emissions. While advocates highlight the potential long-term benefits of RPS, critics argue that RPS will increase electricity prices due to the higher costs of renewable energy generation. However, to date, there are no published empirical studies of the effect of RPS on electricity prices. Using state-level panel data from 1990 to 2011 and the difference-in-differences (DID) method, I find that implementation increases electricity prices when the RPS policy first becomes binding.

JEL: Q48, Q42

Keywords: Renewable Portfolio Standards; State electricity prices

1. INTRODUCTION

In recent years, global climate change and concerns over scarcity of conventional energy resources increased interest in renewable energy sources. In the United States, states have enacted a variety of policy instruments to promote the use of renewable energy. One of the most common state-level policies is known as Renewable Portfolio Standards (RPS). The goals of a RPS policy are reducing emissions of air pollution and greenhouse gases and generating more stable energy prices in the long-run. A majority of states have enacted RPS with more states likely to in the future because of the recent proposal by the Obama Administration to reduce state carbon emissions by 30 percent (Metheny, 2014). According to the Database of State Incentive for Renewables and Efficiency (DSIRE),[1] as of November 2012, 29 states and the District of Columbia have adopted mandatory RPS, while 8 states have adopted voluntary renewable portfolio goals. Moreover, the states adopting RPS policies all set up a schedule of intermediate goals for the utilities to make sure they meet the final RPS mandates by the required year.[2]

Renewable portfolio standards require electricity retailers to provide a minimum percentage or quantity of their electricity supplies from renewable resources, such as wind, solar, biomass and geothermal. A number of studies have found RPS policies to increase the amount of renewable energy generation in a state (Langniss and Wiser, 2003; Carley, 2009; Shrimali and Kniefel, 2011). While advocates highlight these long-term benefits of RPS, critics contend that RPS, at least in the short-run, increase retail electricity prices because of the required extra investments or costs to using renewable energy (Lesser, 2013). Rising electricity prices would adversely affect the state economy through increasing household cost of living and business production costs.

[1] Database of State Incentive for Renewables and Efficiency (www.dsireusa.org).
[2] All these final RPS mandates will occur after 2011.

To be sure, Ohio governor, John Kasich signed a bill into law, which would freeze Ohio's renewable energy efficiency standards for two years, citing concerns that the standards would adversely affect the Ohio economy. Ohio became the first state in the U.S to renege on its renewable standards (Knox, 2014). Other states, including Kansas, Minnesota, North Carolina, Texas, Virginia, West Virginia, likewise have considered or are considering repealing RPS or weakening targets (Gallucci, 2013). Despite the concerns that RPS increases the retail price of the electricity, to date, there is little published research that provides empirical evidence for the argument, especially at the state level. The existing research primarily uses numerical simulations to evaluate the role of a hypothetical national RPS such as Palmer and Burtraw (2005) and Kydes (2007).

This paper uses a state-year difference-in-differences (DID) analysis over the period 1990 to 2011 across 47 states, excluding Iowa, Hawaii and Alaska to examine the impact of state RPS on state electricity prices.[3] To address the special features that RPS vary in different timing and magnitude of intermediate mandates and final mandates, this paper employs multiple measures of RPS, including the first year of RPS mandate enactment, the first year of RPS implementation and the year that the first intermediate RPS goal becomes binding, instead of assuming only one binary RPS variable across states.

The remainder of the paper is organized as follows. Section 2 presents background information on electricity generation and renewable energy sources, while section 3 discusses the existing literature on Renewable Portfolio Standards. Section 4 describes the empirical methodology and data used in the analysis. Section 5 presents and discusses the main findings. The primary findings are that RPS increase electricity prices when the mandates become binding.

[3] Iowa was excluded from the sample was because it first adopted RPS in 1983. Hawaii and Alaska were excluded from sample due to their special locations.

Section 6 summarizes and concludes the paper. The overall recommendation is that policy makers need to consider the electricity price increases in deciding whether to enact RPS because of their potential economic impacts.

2. BACKGROUND

2.1 Background of the Electricity Market

Most electricity in the United States is generated by three fuels: coal, natural gas and nuclear power. Renewable energy, including hydroelectric power, is still a small percentage of all power generated. According to the US Energy Information Administration (EIA),[4] renewable energy sources only made up 13% of total electricity generation in the United States as of 2011. Maine had non-hydroelectric renewable electricity generation at 27% of total in-state generation. South Dakota and Iowa had 21% and 17% of electricity generation from renewable energy sources. When a state implements RPS, it induces shifts from electricity generation using traditional resources to renewable resources. Because of potential effects on utility cost structures from the shifts, RPS may affect electricity prices as regulatory commissions allow utilities to set prices to recoup the costs (Lazar, 2011).

Customers in the electricity market can be classified into four groups: residential, commercial, industrial and transportation. According to EIA, there were 3,726 billion kWh of electricity sold to customers in 2011. The residential customers group purchased 38% of the electricity that was generated. The commercial group purchased approximately 35%, while around 26% was purchased by industrial customers. The electricity prices vary by each customer group (Figure 1). Thus, it is necessary to test the impact of electricity prices in each group separately. The residential group is the primary focus in this paper.

2.2 Background of Renewable Portfolio Standards

[4] The US Energy Information Administration (http://www.eia.gov/).

Renewable Portfolio Standards (RPS) according to EIA (2014 a), require or encourage electricity producers to supply a certain minimum share of their electricity from designated renewable resources within a given jurisdiction. RPS are enacted at the state level in the United States. After Iowa adopted the first RPS in 1983, the majority of states passed or strengthened their standards after 2000. Altogether, 29 states and the District of Columbia had enacted RPS or other mandated renewable capacity policies by 2011. In addition, eight states have voluntary goals for renewable generation. Figure 2 shows the locations of mandatary renewable capacity policies.

Often, the selected eligible resources are tailored to best fit the state's particular resource base or local preferences. Some states also set targets for specific types of renewable energy sources or technologies to encourage their development and use. As mentioned by Yin and Power (2010), there are three ways for a utility to meet the requirement from the state mandate: produce electricity from renewable energy sources through its own facility; purchase electricity from other renewable energy facilities; and purchase renewable energy certificates (RECs). In general, the utilities are allowed to recover the costs combined with the standards in the form of electricity rates.

Even though the RPS law may provide compliance cost caps and provisions for delaying compliance, many state RPS programs have "escape clauses" if the extra cost of renewable generation exceeds a specific threshold. For example, in Maryland, it has been stated that "if the actual or projected dollar cost for purchasing solar RECs in any one year is greater than or equal to 1% of the electric supplier's total annual electricity sales revenues in Maryland, the electricity supplier may request that the PSC delay by 1 year each of the scheduled percentages for solar and allow the solar percentage required for that year to continue to apply to the electricity supplier for the following year. The delay will continue each year until the actual or anticipated cost is less than 1% of the supplier's annual sales revenue in Maryland, at which time the supplier will be subject to the next scheduled percentage increase" (see www.dsireusa.org). Based on the above information, imposing state-level RPS would influence utilities' cost structures due to the incremental investments and costs in providing obligated renewable electricity proportion. And, allowing utilities to recover the cost may cause electricity prices to rise.

3. PREVIOUS RPS STUDIES

Previous studies of RPS policy effects on electricity prices have ranged from using numerical simulation models of national electricity generation to empirical estimation using state-level data. There is a near absence of studies on RPS at the regional level. The variation across states in enacting RPS policies, and timing of policy enactment and implementation, can be used to assess whether the policies increase electricity costs.

Palmer and Burtraw (2005) in their discussion paper used the Haiku electricity market model and performed numerical simulations to predict the effects of the two leading government policies, RPS and Renewable Energy Production Credit (REPC), in increasing the amount of renewable energies of the United States electricity supply. The simulation results of four national RPS of 5%, 10%, 15% and 20% indicated that the cost of the RPS in terms of changes in electricity price or social cost were relatively low at levels up to 15%; the price effects rose dramatically for targets of 20%.

Kydes (2007) analyzed the impacts of imposing a 20% federal RPS in energy markets of the US, excluding non-hydropower by 2020. He conducted this empirical study using the December 2001 version of the National Energy Modeling System (NEMS) of EIA and the assumption and results of the Annual Energy Outlook 2002 reference case. The study showed that electricity costs increased about 3% with a 20% RPS. Even though, on the national level, the results did not appear to be significant, the regional distributional price effects were quite significant. The RPS was predicted to increase the costs from 35 to 60 billion dollars for the power generation industry by the end of 2020. Although this research focused on the impact of federal-level RPS, it provided the reference of the fundamental hypothesis of this study that imposing an RPS would change utilities' cost structures.

Bowen et al. (2013) examined whether RPS increased the number of green businesses and jobs at the state level. They report little evidence of such an effect. Instead, they suggest that green jobs are created by the factors that affect overall job creation; e.g., investments in education and infrastructure.

In an unpublished paper, Tra (2009) evaluated the effect of RPS policies on retail residential electricity rates using utility-level panel data from 1990 to 2006. This study provided one of the first empirical investigations of the economic effect of RPS mandates on retail rates. After taking the restructuring of the electricity market into consideration, the author used a fixed effects model to address the time-invariant unobserved differences among utilities and year specific effects while controlling for state population, population density, and the average price of coal and natural gas delivered to electric utilities. Tra found that, on average, a state RPS had a positive effect on the average nominal residential electricity rates and higher RPS requirements had larger magnitude effect on the rates.

4. EMPIRICAL IMPLEMENTATION

4.1 Empirical Model

Currently, there is no national RPS policy and not all states have adopted RPS policies. So, it is possible to construct a treatment group and a control group by using the states that have RPS and states that do not have RPS. Also, it is possible to compare the RPS impacts by comparing the electricity prices before and after the states adopted mandatory RPS. Therefore, the difference-in-differences (DID) method is employed to examine the state mandatory RPS impacts on electricity prices.

One of the potential problems with using the states without RPS as a control group is that electricity prices might systematically vary across states because of other influences than policy changes. States with significant renewable resources, such as wind, may be more willing and able to adopt RPS, with potentially different price effects. Thus, state fixed effects are included to control for time invariant variables.

Other factors such as temperature in each state also may have impacts on electricity prices. Temperatures influence peak load demand, influencing costs of generating electricity (U.S. Energy Information Administration, 2014 b). So, January and July temperatures of each state are incorporated into the model. With state fixed effects included, however, the temperature variables only reflect within-state variation across time.

Moreover, national level economic shocks might influence electricity prices. Because the time span of the data is from 1990 to 2011, three recessions during the period, July 1990 to March 1991, March 2001 to November 2001, and December 2007 to June 2009, may have impacts on the electricity prices. Although I use the real price of electricity, there still might be shocks related to a specific year, such as changes in national taxes, subsidies, and the political environment. If the omitted characteristics correlate with electricity prices and RPS, biased and inconsistent estimates of the impacts of the RPS on the electricity prices result. Hence, to capture national shocks, year fixed effects are included. In addition, electricity market deregulation might have impacts on the price setting of different states and producers.[5] A deregulation indicator variable is included then to control for the impact of electricity market restructuring.

[5] Taber et al., (2006) did not find that deregulation leads to lower electricity rates. However, Fabrizon et al (2007) estimated that electricity deregulation had resulted in reduced generation costs for investor-owned power plants.

Finally, it is possible that there may be long-term trends in electricity prices not related to RPS. Consequently, linear and quadratic time trend dummies are added into the model. Considering that time trends may vary across geographic areas, I interact the time trend variables with Census division dummy variables.

The basic regression equation is as follows:

$$\log P_{st} = \alpha RPS_{st} + \theta Deregulation_{st} + \tau_1 Time_t + \tau_2 Time_t^2 + \tau_3 Time_t * Division_i + \tau_4 Time_t^2 * Division_i + \delta_1 Jan\ temperature_{st} + \delta_2 Jul\ temperature_{st} + \varphi Year_t + \eta State_s + \mu_{st}$$

where $\log P_{st}$ is the natural log of the average residential real price of electricity for state s during year t. For each state s, RPS_{st} is an indicator variable that equals 1 if RPS is implemented in year t and 0 otherwise. $Deregulation_{st}$ is the electricity market restructuring indicator and equals 1 if electricity restructuring is active in state s during year t and 0 otherwise.[6] $Time_t$ is the time trend dummy indicator for year t. $Division_i$ represents a vector of indicator variables for the Census divisions (from 1 to 9) that state s belongs in, where the first division, the New England division, is omitted to avoid perfect collinearity. $Jul\ temperature_{st}$ is the average July temperature for the state s during year t whereas $Jan\ temperature_{st}$ represents the average January temperature. $Year_t$ is the year fixed effect in year t. $State_s$ is the state fixed effect for the state s. μ_{st} is the error term, which is clustered by state across time to correct the standard errors for serial correlation. A check for potential endogeneity of RPS policies follows in Section 5.2.

[6] According to EIA, some states had restructuring activities or allowed utilities to recover transition costs that were incurred during the restructuring process after electricity market restructuring was suspended, such as CA, AZ, VA, MT and NM. Considering these activities would have impacts on electricity prices and related to the electricity market restructuring behavior, I include them into the deregulation indicators. For the sensitivity analysis, firstly, I use a separate indicator to indicate these market behaviors. In the results not shown, the coefficient of the separate indicator is negative and significant. Secondly, I use only the active electricity restructuring year to identify the deregulation indicator. In the results not shown, the coefficients of deregulation indicators are all negative and significant; the impacts of RPS becoming binding on the electricity prices are all positive and significant.

Using a single binary variable for RPS_{st} as an indicator of an RPS mandate implicitly assumes that RPS policies are equivalent across states. In reality, however, the policies are disparate in the sectors which are required to meet the RPS mandates. By 2020, for example, Colorado requires RPS with 30% for investor-owned utilities, 10% for electric cooperatives serving fewer than 100,000 meters, 20% for electric cooperative serving 100,000 or more meters and 10% for municipal utilities serving more than 4,000 customers. Also, the RPS may vary on magnitude and timing of the final and intermediate mandates. Therefore, each RPS policy has a date of when it was enacted, became effective and became binding. For instance, the first RPS authority of Massachusetts is documented in section 11F from chapter 25 A of General Law (M.G.L. ch. 25A, § 11F). The date of enacted is Nov. 25, 1997 and the date of effective is April, 2002, while the first compliance year of the RPS is 2003. Colorado, as another example, shows that the enacted year and effective year are both 2004, while the first binding date is 2007. Other aspects of state RPS policies are examined in sensitivity analysis.

Table 1 summarizes the enactment, effective, and binding year for the first RPS in each state.[7] The timing difference might result in different schedules of utilities in shifting to the use of renewable resources. As a consequence, a model employing only a single binary variable identified by using the effective date could not reflect the special features of the RPS programs. Although electricity producers can be forward looking, they might not immediately take any action to meet the RPS requirements when the policies are just enacted. Some states set intermediate binding mandates schedule that must be met before implementation of the final goals of state' RPS; if not met, states will impose financial penalties on the utilities. I expect that

[7] The first RPS binding year of Connecticut is defined as 2001 which is different to the initial compliance year, 2004, of Bowen et al. (2013). The identification follows Public Act No. 98-28 (http://www.cga.ct.gov/ps98/Act/pa/1998PA-00028-R00HB-05005-PA.htm). In results not shown, while using year 2004 as the RPS first binding year of Connecticut, the positive impact of the first RPS binding mandate on electricity prices is statistically significant.

the timing difference between RPS implementation and the first binding renewable requirements may influence the schedule with which utilities implement renewable generation. Consequently, this study uses multiple measures of RPS, both implementation and the year that the first intermediate RPS became binding. Meanwhile, in order to avoid neglecting that forward looking utilities reacted quickly after RPS policies enacted, I also use the first enactment year of RPS policies.

4.2 Data

This study uses publicly available data from various sources. Table 2 summarizes the sources of the main variables. The EIA website provides state-level aggregated electricity prices from 1990 to 2011. Altogether, 47 states are included in the sample. Hawaii and Alaska are excluded from the dataset because of their location. Iowa is excluded because its RPS policy was implemented prior to the sample period. The real electricity price is obtained using the U.S. GDP deflator with 2005 as the base year. RPS information was collected from the November, 2012 DSIRE database.[8] The state average temperature can be obtained from the National Oceanic and Atmospheric Administration (NOAA, 2014) of the National Climatic Data Center (NCDC). The status of electricity regulation can be found on the EIA (2014c).

5. FINDINGS AND DISCUSSION

5.1 Main Findings

Tables 3 and 4 show the regression results for alternative model specifications using state-level panel data from 1990 to 2011. Table 3 shows the results using alternative single indicators of RPS policies. Table 4 shows the corresponding results using multiple RPS indicators in each regression.

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[8] The link of the Energy Division website for each state can be found on the DSIRE website.

Column (1) of each table shows the impact of RPS policies on the natural logarithm of real residential electricity prices controlling only for state fixed effects; whereas, column (2) adds linear and quadratic time trends and linear and quadratic time trends that interact with Census division indicator variables. Columns (3) and (4) add average July temperature and January temperature of each state and electricity market restructuring, respectively. Column (5) shows the results when controlling for all the right-hand-side variables included in the column (1) to (4) models: state fixed effects, time trend, January and July temperatures and the deregulation of the electricity market. Column (6), the full model, shows the results from adding year fixed effects to the column (5) model.

The empirical results shown in Table 3 reveal that RPS policies had positive impacts on residential electricity prices. All three single indicator RPS variables were significant in the full model regressions. The first binding year was significant across half of the model specifications (Columns (4) to (6)), in which the price of electricity increased by nearly seven percent in the full model. The electricity price increased over five percent based on the effective year of the RPS policy. Even the first year of policy enactment was significant with about a nearly five percent effect. Extreme temperatures appeared to increase electricity prices, while moving to a deregulated market lowered the prices.

It might be expected that electric utilities would not immediately shift current or traditional resources to renewable electricity generators or purchase REC to meet the RPS mandate after enactment because initially violation of RPS is not costly. Yet, if utilities are forward looking they may begin compliance immediately prior to the required date of implementation, as suggested by the significant variable for policy enactment. The larger value for the date of the policy becoming binding in Panel A of Table 3, however, suggests that some utilities wait on implementation until they are required to meet the RPS standards.

To further investigate the importance of date of enactment versus effective and binding dates of the policies, it is necessary to take a look at the results while using multiple RPS measurements in the regressions. Thus, Table 4 examines the inclusion of each policy variable in combination with the other policy variables, including a model with all three policy variables added concurrently.

I find that the impact of enactment year was not statistically significant when the other measures of RPS policies were included. Moreover, it was collinear with the first effective year of RPS policies, which was consistent with the RPS identification in Table 1 that most of the RPS enactment years were the same as the effective year, the exceptions being AZ, CA, DE, MA, NC, and PA. The collinearity explains why the first enactment year was significant when using single RPS policy variables in the regressions.

The binding date of RPS policies was significant across all model regressions in Table 4, regardless of which other policy variable was included. When all three variables were included (Panel D), policy enactment of the RPS policy and effectiveness of the RPS policy did not affect electricity prices, whereas, the date the policy first becomes binding increases electricity prices by over five percent in the full model regression.[9] Therefore, any response by utilities to RPS policies did not show up in electricity prices until the date the RPS policies became binding.

From Panel D of Table 4, electricity market deregulation reduced prices by approximately nine percent.[10] While some studies showed that imperfect competition due to market power or limited transmission capacity could result in higher electricity rate if these conditions gave electric utilities the incentive to restrict output (Green and Newbery, 1992 and

[9] In results not shown, the variable obtained from interacting the RPS first binding year variable with the RPS percentage requirement of the first binding goal was statistically insignificant when added to the full model in Panel D.

[10] In results not shown, when the electricity market restructuring indicator is defined by the starting year of the restructuring rather than the completed year, the coefficient of market deregulation indicator was negative and statistically significant. The positive impact of the first RPS binding mandate on electricity prices was still statistically significant.

Borestein et al., 2000), a prevailing perspective about electricity market restructuring was that deregulation would induce more efficient operation. Fabrizon et al (2007) estimated that electricity deregulation had resulted in reduced generation costs for investor-owned power plants. My finding is consistent with this viewpoint.[11]

July temperature had about a 0.4% impact on the change of real residential electricity prices per degree, while the January temperature's impact was less than 0.1% per degree and insignificant. Recall that these were within-state changes in temperatures over time; across state differences were captured by the fixed effects. These results were consistent with the hypothesis that summer or winter temperatures would affect peak time usage of electricity, which affects utilities' cost structures and electricity prices.

5.2 Endogeneity Check

Despite the number of control variables, including state and time fixed effects, I cannot rule out the potential of reverse causality between state-level electricity prices and RPS adoption. To address this issue, I compare whether enactment of RPS policies had differential changes in electricity prices than other states prior to the time of RPS enactment. Firstly, I calculate the 5-year change in electricity prices prior to the first enactment year of the states that have RPS. Secondly, I calculate the mean of the price change in the states that have no RPS in the same time period. I use the price change difference between these two groups to address whether endogeneity potentially existed. Figure 3 demonstrates that the price change differences between states with RPS and states without RPS were scattered along 0, indicating a lack of clear pattern of price changes prior to the RPS enactment. Therefore, I conclude that there was no reverse causality between state-level electricity prices and RPS adoption.

[11] In results not shown, variables obtained from interacting the RPS policy variables with the deregulation variable were all statistically insignificant when added to the full model.

6. SUMMARY AND CONCLUSION

Using state-level panel data from 1990 to 2011 and a difference-in-differences approach, I examined whether adoption of Renewable Portfolio Standards (RPS) by U.S. states caused electricity prices to increase. A notable contribution of the study is the use of multiple policy measures of RPS policies to distinguish between whether policies have their effects at time of enactment, time of effectiveness or when the policies become binding. In addition, the empirical approach accounted for state and time fixed effects, differential time trends, while also controlling for changes in temperature and regulation of the electricity markets.

The study found that state adoption of RPS increased electricity prices. Electricity prices increased for those states that have implemented binding targets during the sample period. The first RPS binding mandate increased prices by over 5 percent. Thus, this study found that RPS increased the residential electricity prices in the short run and this variation was captured by the first intermediate binding mandate of the policy. The findings suggest that policy makers should consider the increase in electricity prices when deciding whether to adopt RPS. For example, the economic development benefits of constructing and putting in place wind turbines may be offset by the reduction in state economic competitiveness from increased electricity prices. Yet, the recently announced plan by the Obama administration to cut carbon emissions from U.S. power plants by 30 percent may reduce cost-competitiveness pressures as all states face the possibility of more costly power generation. For example, the emissions reductions are based on 2005 levels, which means that state RPS policies enacted since then will be credited towards the 30 percent (Metheny, 2014). Ultimately, however, the decision regarding whether to enact RPS and how to design them may be based on whether state residents wish to pay for improved air quality and reduced impact on global emissions of greenhouse gases.

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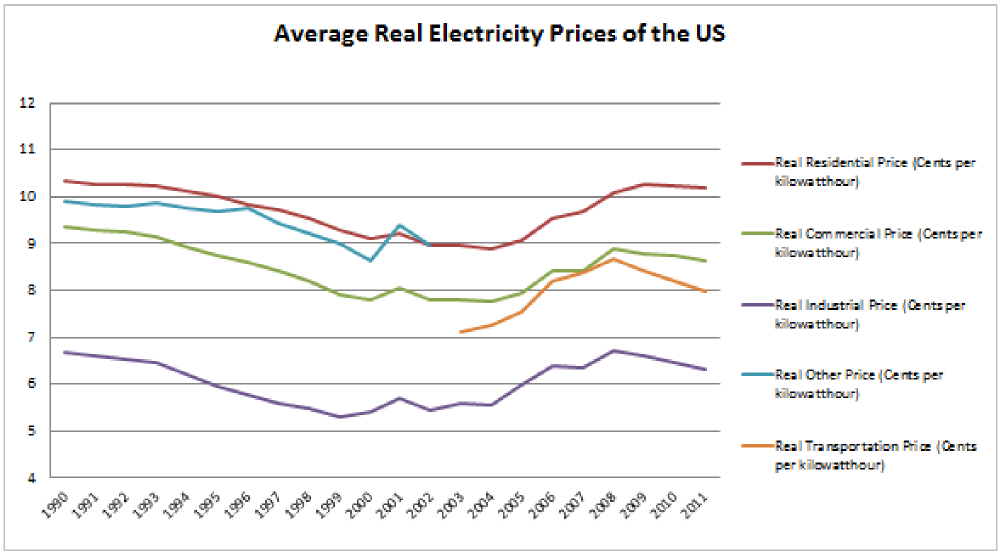

Figure 1: Average Real Electricity Prices of the US

RPS Location			
• Northeast	• Midwest	• South	• West
CT	IL	DE	AZ WA
ME	MI	DC	CO
MA	OH	MD	MT
NH	WI	NC	NV
RI	IA	TX	NM
NJ	KS		CA
NY	MN		HI
PA	MO		OR

Source: Database of State Incentive for Renewables and Efficiency (www.dsireusa.org)

Figure 2: States with RPS

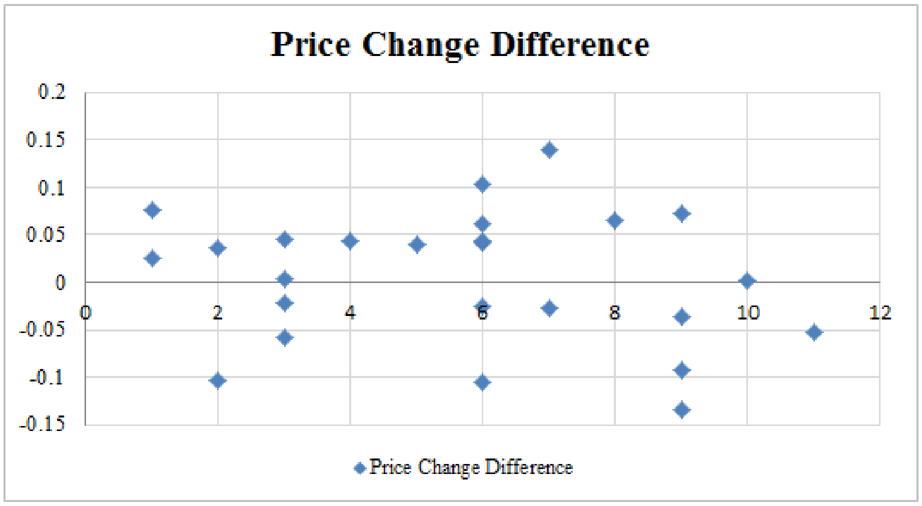

Figure 3: Price Change Differences between States with RPS and States without RPS

Table 1: RPS' 1st binding year, 1st enact year and 1st effective year

State	1st Binding Year	1st Enactment Year	1st Effective Year
Arizona	2001	1998	1999
California	2004	2002	2003
Colorado	2007	2004	2004
Connecticut	2001	1998	1998
Delaware	2007	2005	2006
Illinois	2008	2007	2007
Kansas	2011	2009	2009
Maine	2000	1999	1999
Maryland	2006	2004	2004
Massachusetts	2003	1997	2002
Michigan	2012	2008	2008
Minnesota	2005	2000	2000
Missouri	2011	2008	2008
Montana	2008	2005	2005
Nevada	2003	1997	1997
New Hampshire	2008	2007	2007
New Jersey	2001	1999	1999
New Mexico	2006	2004	2004
New York	2006	2004	2004
North Carolina	2010	2007	2008
Ohio	2009	2008	2008
Oregon	2011	2007	2007
Pennsylvania	2007	2004	2005
Rhode Island	2007	2004	2004
Texas	2002	1999	1999
Washington	2012	2006	2006
Wisconsin	2000	1998	1998

Source: Database of State Incentive for Renewables and Efficiency (www.dsireusa.org) and states websites.

Table 2: Main Variables and Data Sources

Main Variables	Mean	Std. Dev.	Source
Residential Price (Cents per kwh)	8.98	2.65	EIA website http://www.eia.gov/
Deregulation Indicator	0.20	0.40	
July Temperature	74.27	5.53	NOAA website http://www.ncdc.noaa.gov/
Jan Temperature	31.30	11.56	
GDP Deflator	92.42	12.46	BEA website http://www.bea.gov/
Binding Indicator	0.15	0.36	DSIRE and each state website http://www.dsireusa.org/
Enact Indicator	0.23	0.42	
Effective Indicator	0.22	0.41	

Table 3: RPS Impacts on Residential Electricity Prices using Single RPS Indicators

Pane A: Using first binding year as RPS indicator

	Ln Real Residential Electricity Price					
Dependent Variable	(1)	(2)	(3)	(4)	(5)	(6)
RPS_Binding year	0.0337	0.0461	0.0461	0.0756**	0.0755**	0.0679**
	(1.409)	(1.552)	(1.547)	(2.683)	(2.678)	(2.399)
July Temperature			0.00209**		0.00144	0.00375***
			(2.558)		(1.592)	(2.989)
Jan Temperature			-0.000486		-9.62e-05	0.000694
			(-1.148)		(-0.237)	(1.465)
Deregulation Indicator				-0.102***	-0.102***	-0.0859***
				(-3.853)	(-3.833)	(-3.009)
Constant	2.238***	2.380***	2.242***	2.368***	2.265***	2.033***
	(612.7)	(160.8)	(39.60)	(176.7)	(36.38)	(21.95)
Time trend	N	Y	Y	Y	Y	Y
Time trend^2	N	Y	Y	Y	Y	Y
Time *Division	N	Y	Y	Y	Y	Y
Time^2 *Division	N	Y	Y	Y	Y	Y
State FE	Y	Y	Y	Y	Y	Y
Year FE	N	N	N	N	N	Y
Serial correlation adjusted	Y	Y	Y	Y	Y	Y
N	1,034	1,034	1,034	1,034	1,034	1,034
R2	0.014	0.396	0.398	0.463	0.464	0.513
No. of State id	47	47	47	47	47	47

Panel B: Using first enact year as RPS indicator

	Ln Real Residential Electricity Price					
Dependent Variable	(1)	(2)	(3)	(4)	(5)	(6)
RPS_Enact year	0.00687	0.0188	0.0193	0.0495**	0.0496**	0.0465**
	(0.363)	(0.894)	(0.919)	(2.436)	(2.448)	(2.239)
July Temperature			0.00213**		0.00159*	0.00387***
			(2.510)		(1.749)	(3.038)
Jan Temperature			-0.000561		-0.000256	0.000675
			(-1.295)		(-0.654)	(1.386)
Deregulation Indicator				-0.0983***	-0.0975***	-0.0826**
				(-3.391)	(-3.372)	(-2.650)
Constant	2.242***	2.382***	2.243***	2.372***	2.264***	2.027***
	(519.0)	(168.2)	(38.60)	(186.4)	(36.43)	(21.69)
Time trend	N	Y	Y	Y	Y	Y
Time trend^2	N	Y	Y	Y	Y	Y
Time *Division	N	Y	Y	Y	Y	Y
Time^2 *Division	N	Y	Y	Y	Y	Y
State FE	Y	Y	Y	Y	Y	Y
Year FE	N	N	N	N	N	Y
Serial correlation adjusted	Y	Y	Y	Y	Y	Y
N	1,034	1,034	1,034	1,034	1,034	1,034
R2	0.001	0.384	0.386	0.444	0.445	0.499
No. of State id	47	47	47	47	47	47

Panel C: Using first effective year as RPS indicator

	Ln Real Residential Electricity Price					

Dependent Variable	(1)	(2)	(3)	(4)	(5)	(6)
RPS_Effective year	0.0130	0.0275	0.0280	0.0551**	0.0551***	0.0507**
	(0.679)	(1.293)	(1.314)	(2.686)	(2.691)	(2.467)
July Temperature			0.00214**		0.00157*	0.00381***
			(2.499)		(1.716)	(2.986)
Jan Temperature			-0.000577		-0.000274	0.000633
			(-1.345)		(-0.695)	(1.277)
Deregulation Indicator				-0.0981***	-0.0973***	-0.0822***
				(-3.498)	(-3.476)	(-2.716)
Constant	2.240***	2.382***	2.243***	2.372***	2.265***	2.033***
	(530.2)	(168.5)	(38.51)	(187.2)	(36.26)	(21.71)
Time trend	N	Y	Y	Y	Y	Y
Time trend^2	N	Y	Y	Y	Y	Y
Time *Division	N	Y	Y	Y	Y	Y
Time^2 *Division	N	Y	Y	Y	Y	Y
State FE	Y	Y	Y	Y	Y	Y
Year FE	N	N	N	N	N	Y
Serial correlation adjusted	Y	Y	Y	Y	Y	Y
N	1,034	1,034	1,034	1,034	1,034	1,034
R2	0.003	0.387	0.389	0.448	0.450	0.502
No. of State id	47	47	47	47	47	47

*** p<0.01, ** p<0.05, * p<0.1

Table 4: RPS Impacts on Residential Electricity Prices using Multiple RPS Indicators

Panel A: Using first binding year and enact year as RPS indicators to check the joint effect

	Ln Real Residential Electricity Price					
Dependent Variable	(1)	(2)	(3)	(4)	(5)	(6)
RPS_Binding year	0.0572**	0.0483*	0.0479*	0.0654**	0.0652**	0.0577**
	(2.265)	(1.757)	(1.736)	(2.495)	(2.482)	(2.183)
RPS_Enact year	-0.0296	-0.00400	-0.00338	0.0213	0.0215	0.0212
	(-1.460)	(-0.275)	(-0.233)	(1.487)	(1.502)	(1.393)
July Temperature			0.00209**		0.00147	0.00371***
			(2.542)		(1.607)	(2.925)
Jan Temperature			-0.000480		-0.000118	0.000714
			(-1.105)		(-0.294)	(1.531)
Deregulation Indicator				-0.107***	-0.106***	-0.0907***
				(-3.955)	(-3.937)	(-3.091)
Constant	2.241***	2.380***	2.242***	2.368***	2.264***	2.036***
	(483.1)	(161.3)	(39.58)	(180.0)	(36.24)	(21.85)
Time trend	N	Y	Y	Y	Y	Y
Time trend^2	N	Y	Y	Y	Y	Y
Time *Division	N	Y	Y	Y	Y	Y
Time^2 *Division	N	Y	Y	Y	Y	Y
State FE	Y	Y	Y	Y	Y	Y
Year FE	N	N	N	N	N	Y
Serial correlation adjusted	Y	Y	Y	Y	Y	Y
N	1,034	1,034	1,034	1,034	1,034	1,034
R2	0.021	0.396	0.398	0.466	0.467	0.515
No. of State id	47	47	47	47	47	47

Panel B: Using first binding year and effective year as RPS indicators to check the joint effect

	Ln Real Residential Electricity Price					
Dependent Variable	(1)	(2)	(3)	(4)	(5)	(6)
RPS_Binding year	0.0504*	0.0429	0.0425	0.0618**	0.0616**	0.0548**
	(1.938)	(1.556)	(1.535)	(2.347)	(2.334)	(2.064)
RPS_Effective year	-0.0204	0.00544	0.00603	0.0256*	0.0257*	0.0243
	(-0.984)	(0.377)	(0.418)	(1.764)	(1.769)	(1.657)
July Temperature			0.00211**		0.00147	0.00369***
			(2.554)		(1.600)	(2.915)
Jan Temperature			-0.000499		-0.000134	0.000692
			(-1.164)		(-0.332)	(1.455)
Deregulation Indicator				-0.107***	-0.106***	-0.0900***
				(-4.017)	(-3.997)	(-3.132)
Constant	2.240***	2.380***	2.241***	2.368***	2.265***	2.038***
	(497.7)	(161.6)	(39.52)	(180.3)	(36.26)	(21.91)
Time trend	N	Y	Y	Y	Y	Y
Time trend^2	N	Y	Y	Y	Y	Y
Time *Division	N	Y	Y	Y	Y	Y
Time^2 *Division	N	Y	Y	Y	Y	Y
State FE	Y	Y	Y	Y	Y	Y
Year FE	N	N	N	N	N	Y
Serial correlation adjusted	Y	Y	Y	Y	Y	Y
N	1,034	1,034	1,034	1,034	1,034	1,034
R2	0.017	0.396	0.398	0.467	0.468	0.516

No of State id	47	47	47	47	47	47

Panel C: Using first enact year and effective year as RPS indicators to check the joint effect

	Ln Real Residential Electricity Price					
Dependent Variable	(1)	(2)	(3)	(4)	(5)	(6)
RPS_Effective year	0.0773***	0.0650**	0.0648**	0.0602**	0.0601**	0.0509**
	(3.021)	(2.559)	(2.546)	(2.536)	(2.527)	(2.228)
RPS_Enact year	-0.0669***	-0.0405**	-0.0399**	-0.00568	-0.00548	-0.000197
	(-3.917)	(-2.352)	(-2.324)	(-0.318)	(-0.311)	(-0.00994)
July Temperature			0.00211**		0.00157*	0.00381***
			(2.446)		(1.714)	(2.985)
Jan Temperature			-0.000580		-0.000276	0.000633
			(-1.332)		(-0.698)	(1.296)
Deregulation Indicator				-0.0977***	-0.0969***	-0.0821**
				(-3.403)	(-3.384)	(-2.648)
Constant	2.242***	2.381***	2.245***	2.372***	2.266***	2.033***
	(523.3)	(168.5)	(38.45)	(187.0)	(36.29)	(21.74)
Time trend	N	Y	Y	Y	Y	Y
Time trend^2	N	Y	Y	Y	Y	Y
Time *Division	N	Y	Y	Y	Y	Y
Time^2 *Division	N	Y	Y	Y	Y	Y
State FE	Y	Y	Y	Y	Y	Y
Year FE	N	N	N	N	N	Y
Serial correlation adjusted	Y	Y	Y	Y	Y	Y
N	1,034	1,034	1,034	1,034	1,034	1,034
R2	0.009	0.389	0.392	0.448	0.450	0.502
No of State id	47	47	47	47	47	47

Panel D: Using first binding year, enact year and effective year as RPS indicators to check the joint effect

	Ln Real Residential Electricity Price					
Dependent Variable	(1)	(2)	(3)	(4)	(5)	(6)
RPS_Binding year	0.0514*	0.0431	0.0427	0.0618**	0.0616**	0.0548**
	(1.996)	(1.572)	(1.550)	(2.344)	(2.331)	(2.062)
RPS_Effective year	0.0464*	0.0434**	0.0434**	0.0289	0.0288	0.0234
	(1.977)	(2.047)	(2.026)	(1.438)	(1.428)	(1.263)
RPS_Enact year	-0.0701***	-0.0412**	-0.0406**	-0.00362	-0.00336	0.00100
	(-4.116)	(-2.154)	(-2.121)	(-0.191)	(-0.179)	(0.0498)
July Temperature			0.00207**		0.00147	0.00369***
			(2.498)		(1.601)	(2.916)
Jan Temperature			-0.000502		-0.000135	0.000693
			(-1.150)		(-0.334)	(1.481)
Deregulation Indicator				-0.106***	-0.106***	-0.0901***
				(-3.908)	(-3.891)	(-3.051)
Constant	2.241***	2.380***	2.243***	2.368***	2.265***	2.038***
	(488.4)	(161.7)	(39.47)	(180.2)	(36.34)	(21.98)
Time trend	N	Y	Y	Y	Y	Y
Time trend^2	N	Y	Y	Y	Y	Y
Time *Division	N	Y	Y	Y	Y	Y
Time^2 *Division	N	Y	Y	Y	Y	Y
State FE	Y	Y	Y	Y	Y	Y
Year FE	N	N	N	N	N	Y
Serial correlation adjusted	Y	Y	Y	Y	Y	Y

N	1,034	1,034	1,034	1,034	1,034	1,034
R2	0.024	0.398	0.400	0.467	0.468	0.516
No. of State id	47	47	47	47	47	47

*** p<0.01, ** p<0.05, * p<0.1