AN ANALYSIS OF THE IMPACT OF RENEWABLE PORTFOLIO STANDARDS ON RESIDENTIAL ELECTRICITY PRICES

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ABSTRACT

A Renewable Portfolio Standard (RPS) has become a popular policy for states seeking to increase the amount of renewable energy generated for consumers of electricity. The success of these state programs has prompted debate about the viability of a national RPS. The impact that these state level policies have had on the price consumers pay for electricity is the subject of some debate. Several federal organizations have conducted studies of the impact that a national RPS would have on electricity prices paid by consumers. NREL and US EIA utilize models that analyze the inputs in electricity generation to examine the future price impact of changes to electricity generation and show marginal increases in prices paid by end users. Other empirical research has produced similar results, showing that the existence of an RPS increases the price of electricity. These studies miss important aspects of RPS policies that may change how we view these price increases from RPS policies.

By examining the previous empirical research on RPS policies, this study seeks to identify the controls necessary to build an effective model. These controls are utilized in a fixed effects model that seeks to show how the controls and variables of interest impact electricity prices paid by residential consumers of electricity. This study utilizes a panel data set from 1990 to 2014 to analyze the impact of these policies controlling for generating capacity, the regulatory status of utilities in each state, demographic characteristics of the states, and fuel prices.
The results of the regressions indicate that prices are likely to be higher in states that have an RPS compared to states that do not have such a policy. Several of the characteristics mentioned above have price impacts, and so discussing RPS policies in the context of other factors that contribute to electricity prices is essential. In particular, the regulatory status of utilities in each state is an important determinate of price as well as the amount of renewable energy generated in each state. There are several implications of this analysis that are relevant for policy makers who seek to gain the environmental benefits of these policies, but who are also concerned with the costs those polices may impose on consumers of electricity. First, allowing utilities as much time as possible to comply with the mandates of the RPS will mitigate the price increases associated with implementation of and compliance with the policy. Secondly, policy makers need not fear imposing high targets for their RPS as this is not associated with higher electricity prices. Finally, policy makers should be concerned with the bindingness of the policies they impose. States with non-binding policies tend to have higher electricity prices, likely due to the costs of early compliance. As such imposing interim targets may raise rates more than simply allowing compliance at a pace utilities can bear without substantially increasing prices.
The research and writing of this thesis is dedicated to several people who have been instrumental in my success.

To my advisor Jeff for his assistance in producing this work.
To my partner Rose for her constant love and support.
To my parents Mike and Terri without whom I would never have had the courage or opportunity to attend graduate school.

Thank you for all you’ve done for me.

Many thanks,
Andrew Larson
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CHAPTER 1
INTRODUCTION

Electricity is one of the most important drivers of developed economies, it powers industry, gives us modern conveniences, and keeps the lights on. The electricity sector has been undergoing major changes in recent years due a number of factors including scarcity of fuels and the changing economics of generation. Electricity in the United States has traditionally come from coal because of fossil fuels’ easy conversion to electricity through combustion. During the 1970s, nuclear energy became a prominent source of power for American electricity generation. During the 1990s, natural gas became a popular source of electricity generation due to its lower carbon impact and the maturity of the technology (EIA, 2015). More recently, renewable energy has become a popular means of meeting increased demand, and many new electricity generators are either wind or solar generators. Some of these changes are occurring due to the concerns of climate scientists about the impact that fossil fuels have on the climate, and some are merely a function of changing economics. Part of this transition to cleaner energy has resulted from the increased regulation of emissions from fossil fuels, EPA regulations like the National Ambient Air Quality Standards (NAAQS) and the Mercury and Air Toxics (MATS) standards have forced utilities to install emissions control technologies on dirty fossil fuel plants, making them less economically efficient. There have also been approaches that seek to change the sources of generation and not just reduce emission from current generators. Policies to reduce emissions and change generation exist at both a federal and state level, with some states choosing to forge a path for clean energy when the federal government is unable or unwilling to meet the environmental goals of the states. As a result of these policy changes and the changing economics of electricity generation technologies, the share of non-hydroelectric renewable
energy generating capacity has risen from just under 1% in 1990, to 6.1% in 2014 (EIA, 2015).

This, and emissions control regulations, have yielded a reduction in emissions from electricity generation from a peak of 2400 million metric tons of CO2 equivalents in 2005, to the current level of 2040 million metric tons in 2014 (EPA, 2015). Policy is a powerful tool in driving changes to electricity generation, and understanding its impact on the prices consumers pay for electricity can help sell the environmental benefits of such policies.

While policy is a useful tool in promoting clean energy, these policies are controversial due to their impact (both perceived and real) on electricity prices. Policies to promote clean energy are implemented at both the federal level (production and investment tax credits for renewable sources) and at the state level (System Benefit Charges which taxes utilities for every kilowatt hour they generate and uses the money to promote clean energy through research and development). One of the major policies states are choosing to employ to make this transition to clean energy is the renewable portfolio standard (RPS). RPSs are defined as a “regulatory mandate to increase production of energy from renewable sources such as wind, solar, biomass and other alternatives to fossil and nuclear electric generation” (NREL, 2015). These mandates are put in place because the goals of policy makers and environmentalists are not being met by the market, implying that renewable energies are not currently cost competitive with fossil generation or are at least not being pursued by utilities through the market. Forcing utilities to make changes to their generation means passing down those costs to consumers through the rates consumers pay for electricity in their homes and businesses. The price consumers pay for electricity has often been at the heart of policy debates surrounding the regulation of electricity generation because of the electoral significance of households and because these prices affect
every voter in a state. Given this, it is important to understand how these standards change the price that end users pay for electricity, and in particular, residential end users.

This thesis will explore the impact that Renewable Portfolio Standards (RPS) have on electricity prices paid by residential end users of electricity. By mandating utilities to make changes to their generating mix, an RPS might impact these prices. While previous research has been done on the price impact of RPS using a fixed effects model to measure if states with RPS have higher or lower prices than states without such a policy, that work has focused on the mere existence of an RPS. In some cases, the strength of the standards are considered, but their examination of this impact is incomplete. This paper instead seeks to determine the impact the strength of the standard has on electricity prices. In addition, it will explore how the bindingness of the standards impacts those prices. Bindingness is defined here to mean that the utilities have already complied with the mandates of the standards before the year the statute requires those standards to be met. This research is useful in helping state policy makers develop policies that promote clean energy but have a small impact on the prices consumers pay for electricity.

An understanding of how RPSs impact electricity prices is important for policy makers for a number of reasons. First, policy makers interested in reducing carbon emissions must make a choice of how to reduce those emissions. There are a number of policies that are available including direct subsidies of renewable energy, taxes on fossil fuels, or mandates that require the installation of emissions control technologies. Each of these options present a different cost to utilities, and each will then have a different impact on the price consumers pay. It seems reasonable that RPS policies have a smaller impact on price than taxes, but may have a larger price impact than a subsidy of renewable energy. If RPSs have a small impact on the price of
electricity, policy makers might be more willing to implement an RPS rather than another pollution reduction scheme, or even to adopt an RPS when they might otherwise leave emissions unregulated in their state. In addition, states may choose to adopt an RPS to facilitate meeting a new federal environmental regulation like the EPA’s Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units (EPA Clean Power Plan). By understanding which policies have higher or lower price impacts to consumers, state legislatures may choose different options to meet the environmental goals of their constituents or of federal mandates.

The paper will examine existing literature on the impact that RPS policies have on the price of electricity and will discuss the difference between those works and this study. Secondly, it will create a conceptual framework that will inform an econometric model and show the impact that various aspects of the state have on the price residential end users pay for electricity. From this conceptual framework will flow the final fixed effects model that will give us the impact that various aspects of electricity generation have on the price, as well as the impact of the policy intervention. This study will also identify its limitations, potential future corrections to those limitations, and suggest areas for future research to explore.
CHAPTER 2
LITERATURE REVIEW

In order to determine the effect an RPS policy might have on electricity prices, an examination of the existing literature is essential to understanding other determinants of price in order to control for those factors. The literature generally indicates that RPS policies increase prices, but there are several other important determinants of price that must also be explored as well. By reviewing previous work on RPS price impacts, we can build an econometric model that controls for the appropriate variables in order to isolate the impact of the standard, its strength, and its bindingness.

An RPS is a tool used by states to increase the amount of renewable energy generated in their state. This tool “requires electric utilities and other retail electric providers to supply a specified minimum amount of customer load with electricity from eligible renewable energy sources” (US EIA, 2009). Most states aim for a specific percentage of generation in a target year. Minnesota, for example, has mandated utilities operating in the state must generate 25% of their electricity from renewable generation by 2025. Others have provided interim targets that must be met along the way to the final target (California has targets at 2020, 2024, 2027 and a final target at 2030). There is a wide range of regulatory regimes that monitor and enforce the standards and the statues usually institute penalties on the utilities for failing to comply with the targets. In some states, utilities may purchase Renewable Energy Credits (RECs) from nearby utilities in other states to help them meet these targets. The first RPSs were adopted in the early 1990s, with Iowa being the first state to adopt a mandatory RPS after making their voluntary program mandatory in 1991. Several states have renewable portfolio goals, which are non-mandatory versions of an RPS and simply ask utilities to make an effort to meet the percentage
targets. In all, there are 29 states plus the District of Columbia that have implemented some kind of RPS as of 2015, with 21 and the District making those standards mandatory (DSIRE, 2015). These standards have been theorized to have an impact on the price consumers pay for electricity due to the requirements they place on utilities.

The price of electricity is determined by a number of factors that have been identified by previous studies and other research on the price of electricity. One of the more important factors for determining the price is the structure of the electricity market in each state. Electricity markets have traditionally been vertically integrated, meaning a utility owns the generators, the transmission infrastructure, and often the distribution network. Prices in these markets must be approved by state regulatory commissions (Public Utility Commissions or PUCs) to ensure utilities cannot institute monopoly pricing from their natural monopoly (Joskow, 2008). These kinds of electricity markets are generally referred to as regulated markets. Utilities are required to propose rates to these commissions based on the economics of their generating assets, and then the commission must approve those rates. The inverse of regulated markets is a market where different companies own the generation, transmission, and distribution infrastructures, and distributors (who set rates), must bid into a wholesale market (Joskow, 2008). These are generally referred to as deregulated markets, and people often refer to laws deregulating these markets as “consumer choice” laws. Customers usually have a choice of which supplier of electricity to purchase their power from, and generators of electricity must compete on price with other generators. Deregulated markets are better able to pass higher costs on to consumers since the market sets the prices for electricity. Regulated markets must wait to pass those costs onto
consumers and sometimes are unable to entirely depending on the rate cases and the PUC with which they must negotiate.

The literature suggests a second major determinant of electricity prices is the cost of generating electricity, as might be expected. This cost is influenced by the price of the fuels that power traditional plants, and the cost of operating and maintaining these plants (NREL, 2014). The price of electricity from renewables does not depend on a fuel per se, but instead relies on the resource (e.g. wind or solar resource). Some states have better “resources” for these kinds electricity generation, for instance states in the Southwest are more likely to be better solar resource states than cloudy states in the Pacific Northwest. This is where RPSs will have the greatest influence on the price of electricity, as they mandate a change in the generating mix present in a state. This paper addresses a source of price differences between states through changing the generating mix in each state. First, it will show the impact that different mandate strengths have different impacts on price. Secondly, it seeks to show that states with non-binding RPS policies (i.e. targets that have been met before the final year) impact electricity prices less than those that are binding.

There has been a lot of debate over how these kinds of standards impact the price consumers and industry pay for electricity in states with these standards. Many conservative politicians and industry analysts decry these standards as raising electricity prices, and hurting business (Furth, 2015). They rely on traditional conservative arguments about how government interference in markets raises prices in those markets by instigating changes from fossil to renewable fuels before the market is ready. Liberals on the other hand, suggest that they will lower electricity prices in the long run due to low fuel costs, and that these policies are worth the
price increase that may (or may not) be associated with these polices. There is some consensus that prices increase as a result of RPS implementation, but there is some debate as to how much they increase prices for residential consumers of electricity (Fischer, 2009 and Tra, 2009). There is even further debate that in the long run, these policies may lower electricity prices by reducing reliance on fossil fuels which are subject to price fluctuations which in turn impact the cost of generation (Fischer, 2009).

There are a number of forward looking studies that attempt to evaluate the impact RPSs have on prices in the future. In particular, the US Energy Information Agency (US EIA) conducted a study in 2009 using the National Energy Modeling Systems (NEMS) which attempts to evaluate the choices of the electricity industry in response to changes to the system (regulations, fuel price shocks, etc). This study evaluated the future impact of a national RPS of 25% by 2025, and showed a price increase of between 1% and 6% above the reference case in years 2025 to 2030 (US EIA, 2009). Additionally, Fischer conducted a study looking at various other papers discussing long term changes in electricity prices using models that project the impact to prices and found that for low percent mandates, prices actually decline. Fischer does not predict the point at which the change from increased to decreased prices occurs but notes the recent EIA analysis is consistent with these findings noting some chance of reduced prices by 2020 under a 10% RPS, but almost no chance of price reductions under the 20% RPS scenario (Fischer, 2009).

In 2015, the National Renewable Energy Laboratory (NREL), produced a report that summarized the incremental costs reported by utilities for implementing RPSs. This report measured the cost borne by utilities by these mandates, which should have an impact on the price
that end users pay (NREL, 2014). The impact to ultimate consumers was not analyzed by this report, but it can safely be assumed that at least some of those costs are passed onto consumers (at least in deregulated markets, but probably also in regulated markets as well). In addition to the NREL study, a research paper by Laura Lamontagne at Clemson University, showed a positive relationships between the implementation of an RPS and electricity prices using data from 1990 – 2010. She uses a number of control variables to attempt to isolate the impact that the standard has on electricity prices. She notes that “electricity prices increase by approximately 5% on average per year relative to states with no RPS” (Lamontagne, 2013).

Another study done a few years earlier by Constant Tra of UNLV, using a different methodology from utility level data, notes that prices increase by roughly .3% for every 1% increase in RPS requirement, with the effect increasing by .2% for every year after implementation (Tra, 2009).

All of these studies fall short in a few key ways that this study seeks to address. The NREL study falls short of showing the relationship between retail prices to consumers of electricity by only evaluating the impact to producers (utilities). The other major studies of price impact have only looked at RPSs as being in a binary state. Tra attempts to note an impact of increased stringency, but utilizes a different data set (utilizing prices for individual utilities as opposed to average state price) and methodology overall in which he controls for the type of utility, this impacts price in that only some kinds of utilities are covered under RPS policies (Tra, 2009). The Lamontagne study is lacking an examination of how the different stringencies of these states’ policies may impact retail prices and lacks an examination of the bindingness of these policies. Finally, Tra utilizes data that show the prices charged by each utility, instead of using state average prices. The Tra study also includes controls for the type of utility that
produces the power (whether it is an investor owned utility, a publicly owned power company or a rural electric cooperative). In Tra’s study, he attempts to determine the price impact but fails to evaluate the number of years until compliance is mandatory, and does not consider the bindingness of the standard. In addition to these problems Tra reviews data from 1990 to 2006, giving 8 additional years to see the impact of the standards. This study will utilize state average prices (a departure from Tra, but consistent with other studies) and will evaluate the impact that compliance time has on price as well as the impact that bindingness has on price.

This thesis will provide a threefold contribution to this literature base. First, none of the pre-existing research has incorporated more recent data into the debate. The data set used in this study includes price information from years 1990 to 2014, aggregated by US EIA. The most recent studies only include data through 2010, but data through 2014 is now available from US EIA. This new data may shed some light on long term impacts to electricity prices, and brings some states within a year of the first targets set by these standards, making them more likely to be in compliance or near compliance. Nearing the end of the compliance period may reduce prices for states as they may have to do little to get over the finish line. The expiration of the federal wind production tax credit also takes place during this time period, and may have an impact on the price of energy generated by wind sources and electricity prices in states with significant wind resources. Additionally, renewable energy generation technology has matured dramatically which may cause the cost of generation to fall in the additional years since previous studies. In those additional years, several states have utilities that reached their targets and are thus under non-binding policies (policies in which states have met their targets early).
The second contribution to this field is an attempt to determine the impact of the stringency of the regulation and how that affects the price. That is, the models in the Lamontagne study only specify the existence of an RPS, and not how stringent it is (Lamontagne, 2013). There is a wide range of requirements on these mandates, ranging from 10% of generation up to 50% of generation, so merely analyzing the existence of an RPS does not provide a complete picture of the price impact of this policy. It seems likely that a more stringent requirement would impact the price of electricity more if critics of these programs are to be believed. Tra captures this dynamic of the RPS, but falls short of examining the compliance time given to utilities (Tra, 2009). Not only are states imposing different percent mandates, but they also have different years in which the utilities must meet the mandates. In particular, it might be expected that mandating a higher amount renewables when they may not be economically efficient may increase prices. Further, states which impose mandates that end in earlier years may force the uneconomic changes faster, thereby increasing prices further. By adding these variables to my model, I hope to determine if high requirement states have a different change in electricity price than those with low requirements quality.

The final contribution this thesis seeks to make is to examine the impact that bindingness has on the price paid by residential end users. None of the other studies have examined this interesting hallmark of these policies. Some states have utilities that have reached their targets before the date the legislatures have set as the final target date, and some states are still in the process of meeting the mandated targets. This is an important contribution because it will show that the impact to price is the mandate and not the technology. In this study, if the utilities have met 99% to 100% of their requirements for 3 consecutive years they are considered to be under
non-binding policies. Non-binding targets should lower the price paid by end users because any additional capacity built to meet demand should not be influenced by the policy (i.e. the market is driving the change in generation, and not the policy). In addition, this builds the case that meeting mandates early (an important environmental goal) doesn’t harm prices more than the policy’s implementation. An examination of bindingness will show, to some degree, if the policy itself is driving change, or if market forces are propelling expansion of renewables.

The following sections in chapter 3 will discuss the theoretical justifications for which controls are utilized in the model, explore the model specifications, and sources of data that this model will utilize. Chapter 4 will show the results of the models including the areas in which previous literature has fallen short. The final section, Chapter 5, will demonstrate the importance of the findings and suggests areas for future researchers to explore for a more complete understanding of how RPSs impact residential electricity prices.
CHAPTER 3
HYPOTHESIS, MODEL, AND DATA

Hypothesis and Conceptual Model

The hypothesis explored in this paper is that the presence of the RPS policy will increase electricity prices to residential end users. This will be shown through a number of regressions that eliminate state characteristics that are time invariant, and allow characteristics of the state that vary over time to be used as controls. By specifying a fixed effects model, we remove the effect of time invariant factors that could confound the analysis, and instead focus solely on factors that vary over time. This model will help isolate the impact that the various factors of the policy (such as the percent of the mandate, and the number of years until compliance) have on price. This work will also seek to determine how the bindingness of these mandates may influence prices.

In addition to the mere existence of the RPS increasing electricity prices, there are several other variables of interest in this thesis. First, this paper focuses on the strength of the mandate. It does this through two variables and their interaction, the number of years until the target must be met, and the percent of generation that utilities must derive from renewables. It is expected that as the number of years until the mandate increases, the price impact will fall (as there are more years to comply) and as the percent of the mandate increases, the price should increase (as the standard is harder to meet). We would expect the interaction to potentially be either positive or negative, as which factor plays a larger role has yet to be explored by previous research.

Secondly, this analysis will determine if the bindingness of the standard matters for prices. It is expected that if the standard is binding, prices will be higher than in states where the standard is not binding. This is because the states that are mandated to build more renewable
energy should have higher compliance costs than states that are already building more than the mandated amount of renewable energy. These additional compliance costs would ostensibly be passed to the consumer in the form of higher prices.

The dependent variable of interest to this research is residential electricity prices in states over the years 1990 - 2014. There are three different end users that there is data available to analyze, residential, commercial and industrial. Each of these end users represent different markets for electricity and have different constraints on their prices. Residential consumers usually pay a set rate for their electricity and get all of their electricity from utilities. Commercial consumers of electricity tend to consume larger quantities of electricity and are different from residential end users because they are often charged different rates during peak demand and often have tiered pricing depending on usage. Industrial consumers are least likely to be affected by RPS policies because they often have on-site generators to fulfill the needs of their production (PG&E, 2007). This study will focus on residential consumers of electricity because they are most likely to be impacted by the standards since they primarily purchase electricity from covered sources (i.e. sources that are subject to the mandates of the RPS). The goal of this study is to evaluate the impact that the RPS policy has on residential end users in particular because they are often the center of the controversy about higher electricity prices. They are the central to the debate because they are the constituents and voting populations and are often the people who feel the largest impact of increased prices (especially low income households) (Febrizio, 2014). The following hypotheses explain how different inputs that affect the price of electricity to end users. The hypotheses about the different inputs to the model discussed in this section will inform the construction of the final econometric model and the
expected signs of the coefficients in the final regressions. By creating hypotheses about the coefficients we can ensure that the model is correctly specified through comparison of expected sign, and the sign given to these coefficients in the regression outputs.

One major influence on the price of electricity is the cost of generation. There are a number of inputs that affect the cost of generating electricity. One of the major components is the cost of input fuels that go into producing electricity at fossil fuel plants. Coal, natural gas, and to some degree oil are all used to generate electricity, and each has their own price that utilities must pay to combust them for electricity generation. In addition to fuel prices, there are capital costs associated with a generating facility which must be recuperated by utilities through higher energy prices charged to end users. In many instances, these capital costs were accrued well before the beginning of my price data set (usually for coal and some natural gas facilities) as these facilities were built well before 1990. This is not the case for most non-hydroelectric renewable energy sources because the technology has only begun to be useful in utility scale electricity generation (Zindler, 2015). In any case, these costs (capital and fuel) will drive up the cost of electricity in the state and so we expect to see a positive association between the cost of generation (contributed to by capital and fuel costs) and electricity prices. The data captures this through the use of variables that capture the percent of generating capacity installed in each state by fuel type and the price of natural gas.

As might be expected, many of the states with renewable portfolio standards have at least some portion of their generation from renewable energy. These renewable sources, almost definitionally, do not have a fuel cost associated with them. This means that an incremental kilowatt hour will cost very little for a wind plant relative to a coal or natural gas plant (EWEA,
Instead, the cost of capital, and operation and maintenance costs are what drives the cost of electricity generated by renewable sources. While these are the costs of renewables, often fossil fuel generators are subject to fuel costs to continue to produce electricity. We would expect these fuel costs to be positively associated with the price of electricity as fuel costs will incrementally increase the cost of an additional kilowatt hour of electricity generation.

Fuel costs are not the entire story when it comes to the costs utilities pass down to consumers through prices. Renewable resources are often considered more expensive than fossil fuel generation because of their high capital and maintenance costs, but also because of their intermittency (they are unable to produce electricity 24 hours a day in the same way that traditional electricity generators can). This intermittency issue raises the cost of renewable energy because storage technology is required to provide power during peak demand (although storage is rarely practiced at this stage because of the small amount of renewable generation utilized and the infancy of storage systems) or peaking generators (often natural gas) are required to be operated when the intermittency of renewable generators would hamper grid reliability. Usually, the higher costs are associated with other upgrades required of the grid to deal with intermittency. In particular, the introduction of net metering and transmission upgrades to deal with constantly changing sources of electricity generation (i.e. a natural gas plant that is run only when the renewables are not producing enough to meet demand) will increase costs for utilities operating costs (NREL, 2014). These changes will force utilities to raise rates to end users to recover those costs as an RPS policy would require utilities to raise rates to meet these needs as they come into compliance with the standards.
The strength of the economy of the state in which electricity prices are measured may also impact electricity prices. In general, the literature suggests that a stronger or larger state economy will increase electricity prices because of high willingness to pay, high property values (generating facilities generally quite large), and high demand for electricity (Jorgensen, 2012). Each of these factors mean that utilities can or must charge more for electricity. In addition, in years of slow economic growth, the change in demand for electricity will be smaller an economy experiences rapid growth, or may even shrink which would drive down electricity prices (since new capacity is not required). For the purpose of this research, GDP per capita will be used to measure the strength of a state economy as it captures most of these variations (high willingness to pay, and higher demand). We expect that GDP per capita would be positively associated with residential electricity prices.

An additional control utilized by this study is the population of the states in each year. States with larger populations may reasonably be expected to have higher electricity prices than states with small populations since there is less demand in smaller states. There are also fewer capital costs associated with distribution and fuel costs because of the lower demand. It may also be that states with small populations have higher prices since the costs are distributed among fewer consumers. Inclusion of population as a control variable also facilitates eliminating disproportionate impact from states with large generating capacities since population should mirror these effects.

Another factor that contributes to the price of electricity is the regulatory status of the electricity market in the state. Different states have different regulatory structures, but they are generally divided into two categories. Traditionally, electricity markets have been regulated,
where the utilities are vertically integrated. In these states, utilities are generally guaranteed a vertical monopoly by the state or simply occupy a vertical monopoly to keep electricity prices down through economies of scale. The prices they may charge for electricity are regulated by public utility commissions, where the utilities must make a case to the commission for the rates that they charge. These states tend to have lower electricity prices than deregulated states, and are less susceptible to price shocks to end users because rates are negotiated and there is minimal competition (Zummo, 2015). The alternative are deregulated markets, or competitive markets. These markets have had distribution, transmission and generation sectors broken apart so that no one company controls the entire flow of electricity. These markets often have higher electricity prices, and are susceptible to shocks in fuel markets much more than regulated industries because utilities must compete on price (Zummo, 2015). Market structure in this paper is determined by if a majority of the utilities in the state are subject to a particular market structure. The model here only notes the predominant characteristic of the electricity markets in the states, some states have regulated markets, as well as deregulated markets.

The types of generators used to generate the electricity in each state by utilities will affect the price of electricity in different ways. Higher use of coal will generally be associated with lower prices since there are minimal additional capital costs, but it is associated with changing fuel costs. Higher natural gas use should also generally be associated lower prices because natural gas generators have often been in existence since before the panel. Higher penetration of renewable energy will be associated with higher prices for reasons noted above in the discussion of fuel prices. These are represented in the model by including the total installed generating capacity of each type of generator.
The final and most important characteristics of the states that the model will account for are the different aspects of the policy itself. These variables will have a few impacts on some of the previously mentioned variables which will influence the end price paid by consumers. In particular, an RPS would increase the amount of renewables in a state and force greater integration into the grid of those generators. This means that the cost of generation and distribution increases with the introduction of more renewables and consequently the price of electricity increases as well. The RPS might exacerbate this issue because it is mandating additional integration that might not have occurred under normal market conditions. This is the impact that the model seeks to capture, the additional impact these policies have on prices when these other factors have been controlled for. In addition, the use of a dummy variable for the bindingness of the standard should show if states with in years where the policy is not binding have different prices than those who have binding standards (i.e. standards that are forcing utilities to make changes they would not normally).

All of these factors yield the following basic regression format for all of the analyses conducted in this thesis:

\[ \text{Price}_{st} = \beta_0 + \beta_1 \times \text{RPS}_{st} + \beta_2 \times \text{Generation}_{st} + \beta_3 \times \text{controls}_{st} + \beta_4 \times \text{regulatory status}_{st} + \beta_5 \times \text{Binding}_{st} + \epsilon \]

Prices are divided into three categories of end users (residential, commercial, and industrial), this analysis will focus on the price paid by residential consumers of electricity for a few reasons. First, RPS policies are most likely to affect residential consumers because they rarely have their own sources of generation compared to commercial (which may have some small facilities to generate electricity) or in particular industrial consumers (which often have
small generation facilities to meet some of their demand). Secondly, the price households pay for electricity probably has the greatest political impact since residential consumers are voters and can vote based on how the price they pay for electricity changes with policy. In this formula, the variable RPS indicates the presence of an RPS mandate in a given state (s) and year (t). Based on the above hypothesis the sign of this variable should be positive indicating the presence of the mandate will increase the price end users pay for electricity.

The generation variables are shown through installed capacity of different kinds of generators. This thesis breaks generation into five variables, generation from coal, gas, hydroelectric, non-hydroelectric renewables, and other sources (which includes oil, and biogas). Controls being utilized in this model include the GDP per capita of the state, and the price of natural gas. Finally, the regulatory status notes if the majority of a state’s market is regulated (that is a Public Utility Commission sets prices) or if the market is unregulated (where the market for electricity is competitive). Each of these have an impact on the price payed by residential consumers of electricity and their effect is noted in this section.

**Data Description**

Data has been drawn from a number of sources to complete this analysis. The source for the dependent variable (price) is drawn from the EIA form EIA-861 which tracks electricity prices by state over time. They have constructed a panel data set on electricity prices in the three major end use sectors (residential, commercial, and industrial) in the 50 states and the District of Columbia from 1990 to 2014 in nominal dollars. They also include overall energy prices, although this thesis will focus solely on price from electricity generators. These numbers have been inflation adjusted to real 2014 dollars to match other data which are presented in real
dollars. The variables of interest for the RPS have been drawn from the DSIRE data on RPS which provides the start year, end year, and strength of the policy.

The control variables for this analysis come from a number of other sources. The generation mix in each state is aggregated data from EIA form 860, which tracks generating capacity by generator and state. For this analysis the capacity is summed by generator type by state and year to get the total generating capacity by generator type in each state in each year. Finally, state economic indicators like GDP per Capita were drawn from the Bureau of Economic Analysis (BEA). This variable has a series break where the method of accounting for GDP per capita is different (BEA, 2016). This yields higher GDP per capita in 1997 than in 1998 because of these differences in accounting. This presents some problems for the regressions, but since it is the same in all states and is not unbalanced, the problem will simply be absorbed by the regression through inclusion of a dummy variable which is zero in years before the break, and one in years after the break. These values for GDP per capita and gas prices have both been inflation adjusted to be real 2014 dollars to provide a common unit of measurement. Population has been drawn from the US census bureau which tracks the population of states over the time examined in this panel data set.

Table 3.1 shows the descriptive statistics for the variables to be included in the model. The regression has data for 50 states (District of Columbia has been excluded due to the fact that the District has almost no generators and has been dropped from the regressions due to missing values) over 24 years, which yields n = 1250 in all cases.
<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Description</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>min</th>
<th>max</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>residential</td>
<td>Price in cents per kilowatt hour paid by residential consumers (Real 2014 Dollars)</td>
<td>12.51</td>
<td>3.758</td>
<td>7.028</td>
<td>38.46</td>
<td>US EIA</td>
</tr>
<tr>
<td>gdppercapita</td>
<td>Personal income in each state (Real 2014 Dollars)</td>
<td>46,788</td>
<td>10,102</td>
<td>25,723</td>
<td>78,578</td>
<td>BEA</td>
</tr>
<tr>
<td>population</td>
<td>Population of each state in a given year</td>
<td>5,747,000</td>
<td>6,262,000</td>
<td>453,401</td>
<td>38,800,000</td>
<td>Census</td>
</tr>
<tr>
<td>rps</td>
<td>Indicator variable showing the presence of an RPS policy</td>
<td>0.272</td>
<td>0.445</td>
<td>0</td>
<td>1</td>
<td>DSIRE</td>
</tr>
<tr>
<td>binding</td>
<td>Indicator variable showing the bindingness of an RPS policy in a given year</td>
<td>0.182</td>
<td>0.386</td>
<td>0</td>
<td>1</td>
<td>LBNL</td>
</tr>
<tr>
<td>regulated</td>
<td>Indicator variable showing the status of utility regulation in a state in a given year</td>
<td>0.194</td>
<td>0.396</td>
<td>0</td>
<td>1</td>
<td>US EIA</td>
</tr>
<tr>
<td>natgas</td>
<td>Installed natural gas generating capacity in Megawatts</td>
<td>5,883</td>
<td>9,664</td>
<td>0</td>
<td>74,692</td>
<td>US EIA</td>
</tr>
<tr>
<td>coal</td>
<td>Installed coal generating capacity in Megawatts</td>
<td>6,168</td>
<td>5,946</td>
<td>0</td>
<td>25,420</td>
<td>US EIA</td>
</tr>
<tr>
<td>nonhydro</td>
<td>Installed non-hydroelectric generating capacity in Megawatts</td>
<td>351.6</td>
<td>1,185</td>
<td>0</td>
<td>12,455</td>
<td>US EIA</td>
</tr>
<tr>
<td>hydro</td>
<td>Installed hydroelectric generating capacity in Megawatts</td>
<td>1,965</td>
<td>3,600</td>
<td>0</td>
<td>21,273</td>
<td>US EIA</td>
</tr>
<tr>
<td>other</td>
<td>Installed generating capacity not meeting the above (Nuclear, oil, etc) in Megawatts</td>
<td>1,192</td>
<td>1,728</td>
<td>0</td>
<td>10,542</td>
<td>US EIA</td>
</tr>
<tr>
<td>gasprice</td>
<td>Price of natural gas measured at the city-gate in Dollars per Thousand Cubic Feet</td>
<td>6.637</td>
<td>2.855</td>
<td>0.541</td>
<td>33.36</td>
<td>US EIA</td>
</tr>
<tr>
<td>RPSpercent</td>
<td>The final required percent of the RPS mandate</td>
<td>4.314</td>
<td>9.540</td>
<td>0</td>
<td>40</td>
<td>DSIRE</td>
</tr>
<tr>
<td>year_final</td>
<td>The number of years until a utility must comply with an RPS</td>
<td>2.596</td>
<td>5.56</td>
<td>0</td>
<td>29</td>
<td>DSIRE</td>
</tr>
</tbody>
</table>
This thesis will utilize a fixed effects model for determining the impact that the policy has on electricity prices given a host of controls mentioned above. This analysis will be done in several stages to track how the different features of the policy impact prices. First, this study will estimate an equation that mimics previous work by showing only the existence of an RPS, only adding the new years of data that are available (the differences between this specification have been noted above). This regression will have a variable that note the existence of an RPS as well as the controls mentioned in the hypothesis and model specification sections. The second regression will add variables that denote the strength of the standards, both the percent of the mandate, and also the final year of the standard. This regression will help capture the contours of how the different aspects of the policy impact electricity prices and help isolate which aspects are most important in determining price. Third, this study will examine the impact of the bindingness of the standard without regard to the strength of the standard to see how it may impact price which will help elucidate the impact that bindingness has without regard to the strength of the policy. Finally, the full model will evaluate both the strength of the standard and the bindingness of the standard to determine if bindingness matters in the face of differing standards.

The coefficients that are of interest for this analysis are the coefficients on RPS and the interaction terms between RPS and year, as well as the bindingness indicator variable. Based on the literature review, we expect to see a positive coefficient on the RPS term, showing electricity prices increase with the RPS intervention. The interesting thing about this paper is that it is unclear if the strength of the policy matters. Just as the literature talks about the addition of these resources increasing price because of grid changes, we might also expect larger renewables
penetration to be associated with higher prices because it would require more changes to the grid. Additionally, states set a deadline by which the standard must be met. As additional years are given to the states to make the transition to higher penetration of renewables, we may see a smaller price impact of the standard. The converse might also be true, at a certain level, maybe this price impact disappears as fuel costs become closer to zero for utilities and maintenance on old plants subsides. It may also be the case that additional renewable integration means that the costs of integrating additional renewables is lower.

The next section will describe the results of these model specifications and will seek to reconcile the outcomes with the hypothesis. In additional, it will identify the factors that most dramatically influence price.
CHAPTER 4
RESULTS

Descriptive Evidence

The descriptive evidence demonstrating higher electricity prices in states with RPS will focus on a series of graphs that demonstrate the impact the standards have on electricity generation and therefore the impact on prices end users pay for electricity. The graph 4.1 illustrates how the price for electricity has changed over the duration of the panel (excluding Hawaii because its uncharacteristically high rates skew the graph). It shows the range of residential prices by state over the course of the panel as well as the quartiles of those prices. This study focuses on these residential rates which have increased from 7.69 cents per kilowatt hour on average in 1990 to 13.08 cents per kilowatt hour on average in 2014. Much of this increase has occurred in the time period 2004 to 2014 which saw average rates increase from 8.94 cents per kilowatt hour on average to the high of 13.08 cents per kilowatt hour on average. Compared to the previous 10 years in which prices increased from only 8.31 cents per kilowatt hour on average in 1994 to 8.94 cents per kilowatt hour on average in 2004 (all prices data includes Hawaii). As we can see in graph 4.1, prices have generally increased over the period of observation, and the prices vary widely between states. The graph notes the maximum, minimum, mean, and interquartile range of prices over the panel.
Graph 4.2 demonstrates how the number of states that have adopted an RPS has changed over the course of the panel. Beginning in 1990 with the first RPS in Iowa the proportion of states with RPSs has increased from 2% to 58% in 2009 when Kansas and West Virginia adopted their policies. States that implement these policies tended to do so during the period when the federal government was doing little to promote green energy and electricity policy was viewed as either a state issue or as a market issue (and therefore not a policy issue at all). As you can see from these two graphs, the rise in electricity prices occurs somewhat concurrently with the increase in total proportion of states that have an RPS policy.

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*a Source: EIA, 2015*
The descriptive evidence grows stronger when you compare prices in states with the RPS and states without a policy. Graph 4.3 demonstrates this difference, with the green line showing states with the policy, and the black line showing states without such a policy. Merely by looking at the difference between prices for states with RPS and states without such a policy, one can see that there is some reason to believe that the policy might have an influence on price. This may be contributed to by several factors that will be analyzed in the analysis section, and have been spoken to in the preceding section. This graph does not provide the whole story as we the difference in the lines shows the difference between states that ever adopted the policy, and not the states that had the policy in each year. So while prices are higher in RPS states, it may simply be that states with higher prices simply tend to adopt the policy relative to states with low prices.

Source: DSIRE, 2015
There are other trends that might shed some light on the differences in prices between the states with RPS policies and those without such a policy. First, we can see from graph 4.4 that states with RPS policies have higher gas prices on average. We might expect this because it represents a reason a state might naturally pursue higher amounts of renewable energies (due to high costs of fossil generation). There is, however, minimal difference in gas price between states with the policy and those without, which indicates that fuel price may not play a particularly large role in states choice to adopt an RPS policy.

Source: DSIRE, 2015 and EIA, 2016
In graph 4.5 we can see that GDP per capita is higher on average in states with an RPS than those without. This may be because higher income is often associated with higher willingness to pay for environmental quality. It may also be the case that states with higher GDP per capita face higher electricity prices due to the purchasing power associated with higher incomes, or that those states have greater demand for electricity which makes providing sufficient electricity more expensive.

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Source: DSIRE, 2016 and EIA, 2016
Finally, we can see from graph 4.6 that states with non-binding RPSs are likely to have higher prices. We would expect the opposite to be true when thinking about how regulations are traditionally viewed. It would make sense to see that prices are higher in states that are not meeting their commitments. While not the expected sign relationship, this may make sense in that states that have high renewables penetration may simply be reacting to higher rates that existed before the enactment of the policy by building more renewables ahead of the mandates of the standard. It may also be the case that states with non-binding RPS policies are already experiencing the price increases associated with the implementation of the policy, while states that have not met their targets have yet to experience the price increase associated with the policy.

* Source: DSIRE, 2015 and EIA, 2016
The following section will be divided into four parts and each will examine a different model specification that should shed light on the reasons for price differences in states with RPS policies and those without. This section will examine the outcomes of various model specifications for the residential electricity prices. Each model progressively adds variables that contribute to understanding what about an RPS contributes to higher prices. The first model only includes a variable that notes the mere existence of an RPS, the second adds variables that show the impact of increasing the percent goal, the final year of the policy, and their interacted effect. The third investigates the influence of the bindingness of the standard. The last is the full model

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Source: LBNL, 2016 and EIA, 2015

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that includes both the strength variables related to the policy, and the bindingness of the standard.

This analysis will utilize a fixed effects model which captures the effects that vary between years, but will eliminate the impact of time invariant effects. This allows the analysis to focus on variables that change over time, and helps prevent omitted variable bias because any missing variables that do not vary over time will be purged from the model. This is a common technique for panel data sets as it only captures time varying effects. This technique is utilized by many of the previous studies examining the impact of RPS standards and serves the needs of this study as well. A major pitfall of panel data analysis is from omitted variable bias resulting from unobserved characteristics of the states being analyzed. Fixed effects is utilized in the literature because it eliminates this potential endogeneity from unobserved time-invariant characteristics of the states (Tra, 2009). Additionally, the models below have been corrected for potential heteroscedasticity by utilizing robust standard errors.
### Table 4.1: Residential Electricity Prices under Various Model Specifications

<table>
<thead>
<tr>
<th>Variables</th>
<th>(1) Basic FE</th>
<th>(2) Strength Only</th>
<th>(3) Bindingness Only</th>
<th>(4) Full Model</th>
</tr>
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<tbody>
<tr>
<td>rps</td>
<td>1.125***</td>
<td>1.776***</td>
<td>1.911***</td>
<td>2.653***</td>
</tr>
<tr>
<td></td>
<td>(0.367)</td>
<td>(0.346)</td>
<td>(0.664)</td>
<td>(0.588)</td>
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<td>population</td>
<td>-1.56e-07</td>
<td>-2.11e-07</td>
<td>-1.97e-07</td>
<td>-2.16e-07</td>
</tr>
<tr>
<td></td>
<td>(2.37e-07)</td>
<td>(2.49e-07)</td>
<td>(2.29e-07)</td>
<td>(2.34e-07)</td>
</tr>
<tr>
<td>gdppercapita</td>
<td>-7.67e-05</td>
<td>-7.87e-05*</td>
<td>-7.37e-05</td>
<td>-7.36e-05*</td>
</tr>
<tr>
<td></td>
<td>(4.82e-05)</td>
<td>(4.62e-05)</td>
<td>(4.57e-05)</td>
<td>(4.32e-05)</td>
</tr>
<tr>
<td>regulated</td>
<td>-1.207***</td>
<td>-1.175***</td>
<td>-1.293***</td>
<td>-1.215***</td>
</tr>
<tr>
<td></td>
<td>(0.386)</td>
<td>(0.388)</td>
<td>(0.420)</td>
<td>(0.392)</td>
</tr>
<tr>
<td>natgas</td>
<td>-5.23e-05</td>
<td>-3.17e-05</td>
<td>-4.20e-05</td>
<td>-2.67e-05</td>
</tr>
<tr>
<td></td>
<td>(7.69e-05)</td>
<td>(6.56e-05)</td>
<td>(7.12e-05)</td>
<td>(6.17e-05)</td>
</tr>
<tr>
<td>coal</td>
<td>-2.22e-05</td>
<td>2.09e-05</td>
<td>-7.49e-05</td>
<td>-4.13e-05</td>
</tr>
<tr>
<td></td>
<td>(0.000317)</td>
<td>(0.000291)</td>
<td>(0.000323)</td>
<td>(0.000295)</td>
</tr>
<tr>
<td>nonhydro</td>
<td>0.000401**</td>
<td>0.000287*</td>
<td>0.000386**</td>
<td>0.000300*</td>
</tr>
<tr>
<td></td>
<td>(0.000186)</td>
<td>(0.000153)</td>
<td>(0.000175)</td>
<td>(0.000151)</td>
</tr>
<tr>
<td>hydro</td>
<td>-0.000375</td>
<td>-0.000514</td>
<td>-0.000357</td>
<td>-0.000477</td>
</tr>
<tr>
<td></td>
<td>(0.000373)</td>
<td>(0.000405)</td>
<td>(0.000384)</td>
<td>(0.000396)</td>
</tr>
<tr>
<td>other</td>
<td>0.00219</td>
<td>0.00194</td>
<td>0.00216</td>
<td>0.00189</td>
</tr>
<tr>
<td></td>
<td>(0.00148)</td>
<td>(0.00133)</td>
<td>(0.00145)</td>
<td>(0.00129)</td>
</tr>
<tr>
<td>gasprice</td>
<td>0.234</td>
<td>0.229</td>
<td>0.236</td>
<td>0.231</td>
</tr>
<tr>
<td></td>
<td>(0.171)</td>
<td>(0.154)</td>
<td>(0.161)</td>
<td>(0.148)</td>
</tr>
<tr>
<td>year_final</td>
<td>-0.191***</td>
<td>-0.178***</td>
<td>-0.178***</td>
<td>-0.178***</td>
</tr>
<tr>
<td></td>
<td>(0.0633)</td>
<td>(0.0635)</td>
<td>(0.0635)</td>
<td>(0.0635)</td>
</tr>
<tr>
<td>RPSpercent</td>
<td>0.0250</td>
<td></td>
<td>-0.0133</td>
<td>-0.0133</td>
</tr>
<tr>
<td></td>
<td>(0.0516)</td>
<td>(0.0516)</td>
<td>(0.0455)</td>
<td>(0.0455)</td>
</tr>
<tr>
<td>yearbypercent</td>
<td>0.00402**</td>
<td></td>
<td>0.00542***</td>
<td>0.00542***</td>
</tr>
<tr>
<td></td>
<td>(0.00169)</td>
<td>(0.00169)</td>
<td>(0.00189)</td>
<td>(0.00189)</td>
</tr>
<tr>
<td>break</td>
<td>-1.082***</td>
<td>-1.040***</td>
<td>-1.100***</td>
<td>-1.080***</td>
</tr>
<tr>
<td></td>
<td>(0.233)</td>
<td>(0.241)</td>
<td>(0.222)</td>
<td>(0.228)</td>
</tr>
<tr>
<td>binding</td>
<td></td>
<td></td>
<td>-1.152**</td>
<td>-1.072**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.545)</td>
<td>(0.515)</td>
</tr>
<tr>
<td>Constant</td>
<td>14.53***</td>
<td>15.14***</td>
<td>14.91***</td>
<td>15.30***</td>
</tr>
<tr>
<td></td>
<td>(2.642)</td>
<td>(2.368)</td>
<td>(2.472)</td>
<td>(2.272)</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.303</td>
<td>0.339</td>
<td>0.327</td>
<td>0.355</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

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Models estimated in this table are all fixed effects models to eliminate potential endogeneity effects resulting from unobserved time invariant effects. Data for this analysis is drawn from EIA, DSIRE, LBNL and BEA.
The first column in table 4.1 shows the results of a basic fixed effect model in which the only indication of a RPS is a simple dummy variable in which states are given a value of one for the variable in years where the policy is active and assigned a value of zero in years where there is no RPS policy. The coefficient for this term shows the impact of the mere existence of the policy, and not any indication of the strength of the policy. From this regression we can tell that the presence of an RPS is associated with approximately a 1 cent per kilowatt hour increase in the price residential customers pay for electricity; this coefficient is significant at the 1% level. States with an RPS policy are expected to have prices that are 1.12 cents per kilowatt hour higher than states that do not have such a policy. This increase in price is what we expected from our pre-regression assumptions about the policy, and fits with the descriptive evidence. We expect utilities that have to make non-market decisions about their sources of electricity generation to pass that cost on to their customers in both regulated (through PUC rate cases) and unregulated electricity markets (through the market mechanism). These choices are reflected in the positive and significant coefficient on RPS.

Regression 2 in table 4.1 demonstrates the effect of policies of increasing strength and decreasing years until finalization of the targets. It also contains an interaction term for these as they both should be related to the final price of electricity as discussed above. The effect of the mere existence of an RPS policy in this specification increases from just over 1 cent per kilowatt hour to 1.77 cents per kilowatt hour. This increase is due to the inclusion of the strength variables. From model 2, we can see that as the number of years until the target must be achieved increases, the price of electricity falls by .19 cents per kilowatt hour; this variable is significant at the 1% level. This coefficient meets with our expectation that more years to
comply with a policy will allow for a smoother transition to renewable energies and avoid passing some of those costs to consumers. The coefficient on percent of electricity from renewables is insignificant in this model specification, possibly because of the inclusion of the interaction term which captures the effect of higher mandated renewable generation. The sign is as we expected from our hypothesis: a higher percent mandated should increase prices more than lower mandates. Finally, we can see from the interaction term that for a given final year, an increase in the percent of the requirement will increase electricity prices by .004 cents per kilowatt hour (although to get the full amount of the increase one would have to add the insignificant, un-interacted coefficient for the percent term). Even when combining terms, the price increase as a result of the increase in percent of the policy is very small. Which may demonstrate that given adequate time to comply with an RPS policy, the costs to consumers should be quite low, and so policy makers designing an RPS may be able to justify increasing the percent of the mandate given that they allow utilities more years to comply with the policy.

Regression 3 in table 4.1 shows the effect of the bindingness of the policy and only includes the dummy variable for RPS indicating the presence of the policy in a state in a given year. In this model specification, the cost of the policy itself is 1.9 cents per kilowatt hour, higher than in the model specification for strength. This is because the states with binding standards have lower prices and that coefficient will reduce the price impact when added to determine the full price. We can see that the coefficient on the bindingness variable is significant at the 1% level, and shows that if the policy is non-binding, the price of electricity will be 1.15 cents per kilowatt hour higher than in states where the policy is binding. This does not hold with our understanding of how these policies might work, since we would expect states
that are naturally building more than the required amount of renewable energy (i.e. making their policies non-binding) would have lower compliance costs than states that are actively being mandated to build renewable generation. This is because generally utilities are making the economically efficient choice to comply instead of being forced to build to be in compliance with the policy. The sign shown in regression 3 does make some sense despite the original hypothesis. A state with naturally higher prices may choose to build more renewable generation naturally and so comply earlier than states where utilities are seeking to keep rates low and choosing to delay their compliance until costs for renewables fall further. It may also be that states that have already complied with their standards have already experienced the price increase from their compliance with the policy. In either case, prices in states with binding targets are statistically more likely to have higher rates for residential end users than states with a policy that is not binding.

Regression 4 in table 4.1 shows a full model that contains variables that account for both the strength of the policy, and its bindingness in a given year. In this regression, the variables having to do with the strength of the policy retain their significance from model two, the number of years until the final year and the interaction terms are significant, but the percent requirement remains insignificant. In this model specification the mere existence of the policy is associated with prices that are higher by 1.47 cents per kilowatt hour. Each additional year until the standard must be met reduces prices by .18 cents per kilowatt hour. The interaction term here demonstrates that for a fixed final year of the policy, an additional percent increase in the mandate will increase prices by .005 cents per kilowatt hour. Bindingness remains a significant predictor of electricity price in the model as well, demonstrating a higher price in states that have
non-binding RPS policies. This may be the case for a number of reasons including the fact that those states may have already experienced the price increase associated with coming into compliance with the policy, or because utilities who offer low rates are choosing to delay implementation of the policies because they want to keep rates low for their customers.

**Robustness Checks**

The robustness check for this analysis is the use of random assignment on states in which all years have RPS equal to zero. By randomly assigning states which do not have an RPS policy in a given year (N=910) with a fake RPS policy, we can check if the policy is in fact the driving force behind differences in price. The result of this check should result in the coefficient on this fake policy being zero, or close to it. This is because we would expect the RPS to be a significant predictor if it was what created higher prices, and not a significant predictor if it was a result of random variation. The fake RPS variable is expected to also not be a significant predictor of electricity prices since it is randomly assigned.

Table 4.2 shows the results of the fixed effects model of states in which there is no RPS policy in a particular year, but they have been randomly assigned a fake RPS policy based on random number generation. We can see from these results that the policy is actually increasing electricity prices (i.e. the coefficient in the models from table 4.1 is picking up the appropriate variation). The RPS variable has lost significance and the coefficient is much closer to zero than in the regression in which the policy was real. This means the model passes the robustness check and the variation in RPS is actually associated with the increased prices, and is not due to random variation in price and the appearance of the policy. The sign of the other variables
remains the same as regression 1 in table 4.1, and the magnitudes change very little
demonstrating there to be little bias associated with the original models.

Table 4.2: Robustness Check

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>Robustness Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>fakerps</td>
<td>-0.0784</td>
</tr>
<tr>
<td>population</td>
<td>-1.13e-07</td>
</tr>
<tr>
<td>gdppercapita</td>
<td>-5.71e-05***</td>
</tr>
<tr>
<td>regulated</td>
<td>-1.246***</td>
</tr>
<tr>
<td>natgas</td>
<td>5.40e-05***</td>
</tr>
<tr>
<td>coal</td>
<td>0.000121</td>
</tr>
<tr>
<td>nonhydro</td>
<td>0.000445***</td>
</tr>
<tr>
<td>hydro</td>
<td>-0.000771***</td>
</tr>
<tr>
<td>other</td>
<td>-0.000493*</td>
</tr>
<tr>
<td>gasprice</td>
<td>-0.0302*</td>
</tr>
<tr>
<td>break</td>
<td>-0.766***</td>
</tr>
<tr>
<td>Constant</td>
<td>16.68***</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.506</td>
</tr>
</tbody>
</table>

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Note: Models estimated in this table are all fixed effects models to eliminate potential endogeneity effects resulting from unobserved time invariant effects. Data for this analysis is drawn from EIA, DSIRE, LBNL and BEA. Fake RPS has been randomly assigned using a random number generator.
Chapter 5
Limitations and Conclusions

Limitations and Areas for Future Study

There are several limitations of this study that must be discussed. This discussion highlights areas for improvement in future studies that seek to further understand the contours of electricity prices in the context of RPS policies. Some aspects are related to the controls used in this study (or controls that may be relevant but were unavailable for various reasons), and others are related to the design of RPS policies (which are beyond the scope of this study). By adding these data to the regression models, it is possible to gain a better understanding of how RPS policies impact residential electricity prices in future studies.

First, a more robust exploration of the impact that fuel prices have on the price end users pay for electricity might help capture more of the variation in electricity prices. EIA lacks the necessary data for a full examination of this effect. Given a data set that has prices that vary by time and by state for the duration of the panel, we may see different impacts to electricity prices for the gas price variable, but also possibly the RPS variables. This thesis has used the city-gate price of natural gas (the price of natural gas paid by natural gas utilities as they receive it from pipelines) as a proxy for the price of natural gas to producers of electric power because of the completeness of that data set and because these prices of natural gas (while not absolutely the same) follow similar patterns. This was utilized because the data for natural gas price paid by electric power producers was missing data in a number of years and states and was unbalanced. A similar problem arose for coal, but there was no sufficient proxy and was consequently excluded from this study. A researcher more adept at data science might be able to impute missing values for the cost of coal and natural gas delivered to electric power producers in order
to have a complete data set of fuel price inputs. Data on coal price for electricity generators was also only available from EIA for years 2001 to 2014 and by including fuel price for coal, this study would have missed valuable years of variation that might help understand price differences. As EIA adds coal price data for additional years, this data on coal prices may be included without hurting the size of the panel.

Second, this study could be improved by better capturing aspects of RPS policies that were left unexamined by this study. Some states have different percentage mandates for different electric power producers in the state. There are number of different utility structures which have different mandates for the RPS in some states and not others. As noted in the literature review, RPS policies in some states present different requirements for rural electric cooperatives, public power providers, and large investor owned utilities. Tra’s research included controls for these different power producers, and so controls for this variation in mandate by utility type, but leaves out some of the work undertaken by this study (Tra, 2009). Future researchers may seek to reconcile these studies and control for strength, bindingness, and the type of utility under the mandate and examine the price differences that better capture the differing mandates imposed on different utilities under each state’s RPS.

There are also areas that are unexamined by this study, but that may be of use in better understanding better the price impact that these standards may have. Future studies may wish to examine the impact that tradable permits (RECs) have on states with RPSs (in which states can purchase credits for renewable power from neighboring states to offset their generation from fossil fuels). Additionally, there are some states that have unique sub-mandates for their standards. These include things like targets for solar energy alone (called carve-outs), mandating
that utilities generate a certain percentage from solar resources which may or may not contribute to the utilities meeting the larger mandate. Some states allow solar power to count for more when determining a utility’s compliance with the RPS. Each of these differences may produce higher or lower electricity prices since they mandate or change incentives for different generation mixes relative to states with simple overall mandates (DSIRE, 2015 and LBNL, 2016).

**Conclusions**

These results have a number of implications for policy makers who may seek to design a policy that will promote alternative energies while not driving up the price of electricity to residential end users. The first aspect to consider when designing an RPS policy is the percent of the mandate that states will require utilities to produce. This study suggests states seeking to minimize the price impact of an RPS policy need not pay very much attention to the size of the mandate. This may prove to be different at high percent mandates because the maximum percent mandate is only 40% in this study, and the effect may be different as the mandates approach 100%. It is worth noting that in 2015, Hawaii amended its RPS policy to mandate 100% of electricity be generated from renewable sources by 2045. This analysis does not capture this change, as utilities were operating under the assumption of the previous standard during the years captured by the panel. Because of this change additional research in future years may seek to identify if this very robust standard in Hawaii has different impacts than the lower standards studied here. The finding that the percent mandate has a minimal price impact bodes well for environmentalists because states need not fear high prices if they implement high standards for
their utilities. When policy makers are choosing to design these policies, they can credibly show utilities and consumers that the costs are small even for large mandates.

The next aspect of design to consider is the number of years policy makers choose to give utilities to comply with the regulation. States that seek to minimize the impact the policy has on prices paid by residential electricity customers should consider giving utilities as many years as possible to comply with the mandate. If however, states seek to maximize the environmental benefits of the policy, they may wish to push the deadline up to maximize the number of years in which utilities are generating electricity from renewable sources. This study highlights this trade off and can help policy makers with designing policies that mitigate the fears of various stakeholders about high costs and high electricity prices. They may choose to give more years for compliance to assuage industry and consumers fears of high electricity prices. This tradeoff highlights the different bargaining chips each side of the environmental regulation debate may use. Environmentalists may be able to lobby for high percent mandates in exchange for additional years for compliance (a feature favored by industry).

Finally, this study shows that utilities who wish to meet the mandates of the standards early may end up causing higher prices for consumers of electricity. Utilities may choose to only comply incrementally as they near their final target to avoid raising the cost to consumers more quickly than if they had decided to reach their targets early. Utilities that already have high costs of generation may seek to reach the targets early since their costs are already higher and may demonstrate that renewable energy is cost competitive in high cost states. It may also be that states meeting targets early simply have already experienced higher electricity prices as a result of their switch to higher renewable generating sources. This finding is less relevant for policy
makers crafting RPSs in their states, but may contribute to the ongoing push and pull of environmentalists versus industry when negotiating the mandates of an RPS.

The price of introducing a renewable portfolio standard is relatively small relative to the total cost per kilowatt hour. An average household uses 10,932 kilowatt hours of electricity annually (US EIA, 2016). From the analysis, we can see that the average household pays roughly 181 dollars a year (just over 15 dollars a month) more for electricity than a household in a state without an RPS policy for states in which the target is non-binding. The costs are lower in states that have not reached their targets early, at approximately 71 dollars a year (just under 6 dollars a month) more for state in which the targets are considered binding. This is a relatively small increase in price for electricity for a typical American household, but is a much larger increase for low income households. Policy makers may find this a price they are willing to impose on consumers of electricity for the environmental benefits of the introduction of additional renewable energy, or they may find this increase to be too burdensome. This study will hopefully help elucidate the choices policy makers face in choosing to implement an RPS policy and allow them greater understanding of the costs the will impose on their constituents.
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