12-2017

Regulation and Energy Poverty in the United States

Michael C. Jensen
Utah State University

REGULATION AND ENERGY POVERTY IN THE UNITED STATES

by

Michael C. Jensen

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Economics

Approved:

William F. Shughart II, Ph.D. Major Professor	Randy Simmons, Ph.D. Committee Member
Chris Fawson, Ph.D. Outside Member	Mark McLellan, Ph.D. Vice President for Research and Dean of the School of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2017

ABSTRACT

Regulation and Energy Poverty in the United States

by

Michael C. Jensen, Master of Science

Utah State University, 2017

Major Professor: Dr. William F. Shughart, II.
Department: Economics & Finance

An affordable utility bill is considered to represent six percent of household income. According to recent research, however, energy costs now represent 20 percent or more of income for many American families. A discussion of energy poverty largely is missing from the debate about America's future, as the call to address climate change by reducing greenhouse gas emissions, at any cost, influences policymakers strongly. For families on fixed incomes, rising energy prices mean that the gap between what they can afford to pay and what they are paying for electricity is widening. Our research evaluates the regressive effects of regulation by studying how such regulation impacts residential energy expenditures, and therefore the household energy burden.

(91 pages)

PUBLIC ABSTRACT

Regulation and Energy Poverty in the United States

Michael C. Jensen

Energy poverty is a topic often neglected in the discussion about global climate change. Apocalyptic prophecies about the negative future effects of climate change ignore the suffering of people around the globe whose lives could be drastically improved with access to reliable sources of energy. Though energy poverty from a global perspective is much more serious than energy poverty from a domestic perspective, high home energy bills are a serious cause for concern for many Americans.

This research examines the relationship between regulation, the prices of electricity and natural gas, and the household energy burden, which is the ratio of household energy expenditures to household income. Where the household energy burden exceeds six percent of household income, households are at the brink of living with a high household energy burden. High household energy burdens can become a generational poverty trap, so understanding what contributes to a high household energy burden may help decision makers determine how to proceed when shaping energy-related and poverty-related policy.

ACKNOWLEDGMENTS

I would like to thank the following individuals for their mentorship and for their help in developing my research and thesis: William F. Shughart II, Ph.D., Randy Simmons, Ph.D., and Chris Fawson Ph.D., James Harrigan, Ph.D., Ryan Yonk, Ph.D., and Patrick McLaughlin, Ph.D.

I give special thanks to my classmates who patiently answered my questions and tutored me throughout my graduate experience, and also to my husband for being patient and supportive as I finished my thesis. I am blessed to have such good people in my life.

I would also like to acknowledge the authors of the USU School of Graduate Studies' *Publication Guide* for their dedication to the craft of creating incredibly annoying and undeniably unnecessary hoops for graduate students to jump through in order to graduate. I have many positive things to say about the time I spent at USU, and so it is unfortunate that one of the final emotions associated with my USU experience is unadulterated loathing. Had Donald Trump run on a platform of eliminating the jobs of those who wrote the *Publication Guide*, rather than those of the poor people around the world willing to outcompete American labor, I'd have been first in line to vote for him.

Michael Jensen

CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

On August 3, 2015, President Barack Obama and the U.S. Environmental Protection Agency announced the final version of the Clean Power Plan, a regulation designed to limit carbon dioxide emissions from power plants. This first-of-its-kind regulation was highly controversial, and the Clean Power Plan quickly became the "most litigated environmental regulation ever, with 39 separate lawsuits filed against it in the D.C. Circuit by 157 different petitioners" (Small 2016).

Supporters of the Clean Power Plan argued that the regulation would result in substantial human health benefits, and that it was a necessary step in combating climate change. Opponents argued that the regulation would kill jobs, actually do little to prevent climate change, and that the burden of complying with the regulation would fall most heavily on low- and middle-income American households.

As I researched and wrote about the Clean Power Plan, I became interested in understanding how energy and environmental regulation affect American households. In particular, I began to explore the relationship between regulation and household energy expenditures, which led me to the topic of energy poverty.

Energy Poverty

Energy poverty is "a lack of [household] access to … electricity and clean cooking facilities," where clean cooking facilities are defined as "fuels and stoves that do not cause air pollution in houses" (International Energy Agency 2017). The International Energy Agency estimates that 1.1 billion people, approximately fifteen percent of the world's population, do not have household access to electricity and that 2.8 billion people, approximately forty percent of the world's population, lack clean cooking facilities (Ibid. 2017). The agency further estimates that a lack of clean cooking facilities leads to 3.5 million people dying prematurely every year, due to "household air pollution resulting from the traditional use of solid fuels, such as fuelwood and charcoal" (Ibid. 2016, 14).

Though my research is not focused on global energy poverty, understanding global energy poverty is necessary to properly frame energy poverty in the United States. Owing to high living standards, the discussion of American energy poverty has been expanded to include more than mere access to electricity and clean cooking facilities. Instead, the discussion of American energy poverty focuses on the percentage of household income spent on household energy (electricity and natural gas, primarily). Thus, it is important to distinguish between energy poverty in the United States, where energy is accessible though perhaps expensive, and global energy poverty, which is truly a poverty of energy.

Because energy poverty in the United States is in most cases not truly a poverty of energy, it is more appropriate to speak in terms of a person or household's energy burden. Energy burden is the ratio of energy expenditures to income. Individuals or households with a large energy-expenditure-to-income ratio have a high energy burden. People with high energy burdens are generally the people discussed when lobbyists and policymakers talk about energy poverty in the United States. As I will discuss later, household energy prices in the United States have been, on average, stable over the past thirty years, so it is ironic that energy poverty has become an increasing public policy issue at a time when energy is becoming cheaper.

Summary of Findings

The relationship between regulation and household energy burden is not clear. The empirical evidence is not supportive of my expectation that an increase in regulation affecting the price of energy would increase both the household energy burden and the number of households with a high energy burden. In my thesis, I propose several explanations for this unexpected finding.

ENERGY POVERTY IN THE UNITED STATES

As mentioned in the introduction, energy poverty in the United States is in most cases not truly a poverty of energy. The number of U.S. households that meet the International Energy Agency's definition of living in energy poverty (no electricity and no clean cooking facility) is small enough that in the United States the term energy poverty is instead used to describe people who have access to electricity, but who pay large percentages of their incomes for that access. Thus, describing such households as being in energy poverty can be misleading. It is more accurate to instead discuss the high energy burden of low-income households, and I will therefore use "high energy burden" in place of "energy poverty" for the remainder of this thesis.

Energy Burden

Energy burden is the ratio of household energy expenditures to household income. At the household level, several types of energy burden exist: residential energy burden, transportation energy burden, and total energy burden. Residential energy burden is the ratio of residential energy expenditures to household income, where residential energy expenditures are the amounts spent to provide energy to a residence, such as for keeping the lights on, the refrigerator running, and heating or cooling the home. Transportation energy burden is the ratio of transportation energy expenditures to household income, where transportation energy expenditures are the cost of using energy to travel to workplaces or shopping centers, such as paying for gasoline or to charge an electric vehicle’s battery. The total energy burden is the sum of residential and transportation energy burdens.

Each type of energy burden mentioned above can be measured in at least two ways, using a household energy burden or a group energy burden approach. In this paper, I am concerned only with the residential energy burden, so I will leave study of the transportation and total energy burden for future research, but the following discussion on the household and group approaches to measuring the energy burden applies to all three types of energy burdens.

The Division of Energy Assistance of the U.S. Department of Health and Human Services (2016, 90) outlines two ways of computing energy burden, using a household or group approach, explained as follows:

Household Energy Burden

The household energy burden (sometimes referred to in the energy burden literature as the individual energy burden) is the ratio of household energy expenditures to household income. It is “the burden placed on household incomes by the cost of residential energy” (Ibid. 2016, 89).

Thus, for example, a household with $2,000 in annual residential energy expenditures and an annual household income of $40,000 would have a household residential energy burden of five percent.

The household energy burden can be aggregated to find its central tendency for a given population. Consider a population of four households with energy with energy burdens of, respectively, four, five, seven, and eight percent. The mean (and median) household energy burden for that population would be six percent (Ibid. 2016, p. 90).

Group Energy Burden

Though household-level data provide a more accurate understanding of the range and central tendency and range of energy burdens, such data may not be available. When household-level data are not available, but group-aggregated information is, the group approach to studying the energy burden is appropriate.

The group energy burden, which is the average energy burden for each household or individual in the group, is the ratio of the group's total residential energy expenditures to the group's total income (Ibid.).

For example, consider a population of four households for which information about how much each household spends on energy or how much each household earns each year is not available. The researcher is, however, able to access information indicating that the combined energy bill of the four households is $4,000 and that total income for the four households is $100,000. The group energy burden for this population of houses would then be four percent. (Ibid.).

The group approach to studying the energy burden offers a way around unavailable household-level data, but the group approach suffers from the problem inherent to studying averages: it tells us little about what is happening within a population. Thus, when the group energy burden approach is the only method available because of data availability issues, critical analysis is handicapped.

Low-Income Households and High Energy Burdens

Again, given an understanding of energy poverty from a global perspective, broadly categorizing Americans who allocate larger percentages of their household incomes to heating and cooling as being in energy poverty is an abuse of language. A more appropriate way to describe such households is to state that they face heavy residential energy burdens. Doing so appropriately differentiates people who have access to energy sources, such as electricity and natural gas, from people who do not have access to such energy sources, and who therefore are truly energy impoverished.

Still, American energy poverty is not merely on the list of #firstworldproblems. A survey of U.S. households that receive help paying home energy bills through the federal Low-Income Home Energy Assistance Program (LIHEAP), for example, demonstrates how a large home energy bill, as a percentage of income, exacerbates the problems associated with a low household income: 24 percent of surveyed LIHEAP recipients reported going without food for at least one day, 37 percent went without medical or dental care, and 19 percent had someone in the home who became sick because the home was too cold (National Energy Assistance Directors' Association 2011, iii). Though a high energy bill isn't the only problem low-income households face, a high energy bill may mean that, on the margin, people are choosing between eating and keeping the house warm (Bhattacharya, DeLeire, Haider, and Currie 2003).[1]

---

[1] This is, of course, only one example of the many tradeoffs low-income individuals may make when choosing how to allocate their money to meet their needs. The heart of the question I'm interested in asks how the choices made by policymakers limits or expands the choices people are

Furthermore, in a 2007 study on homelessness in Colorado, researchers from the University of Colorado at Denver stated that the high cost of utilities was one of the most commonly cited reasons for homelessness (O'Brien, Appelbaum, Velez-Badar, and Buck 2007). Thus, not only do high household energy costs make life difficult for low-income American households, but high costs can contribute to people losing access to a house, electricity, and clean cooking facilities—pushing them out of their homes and into energy poverty.

Additionally, the need to maintain a supply of energy to a household in the face of mounting utility expenses can result in an intergenerational debt transfer. When parents are unable to pay the utility debt down, they may choose to open accounts with the utility company in their child's name. And when those parents unable to pay the utility bills transfer debt to their children in order to keep energy coming into the home, they create "involuntary debt traps for minors and other household members" (Hernandez and Bird 2016).

Government housing policies are intended to "create and maintain opportunities for low-income families to live in affordable rental housing" (Ibid.). However, these policies distort the cost of rental housing, and the housing subsidies may draw in tenants who would otherwise be unable to afford to live on their own. This then creates a problem of high residential energy burden for such tenants because they mistook the subsidy as a signal that housing was affordable. On the margin, such housing policies may increase the number of low-income households living with a high energy burden.

---

able to make when deciding how to allocate "scarce resources which have alternative uses" (Sowell 2014).

The same government housing policies that subsidize housing, and therefore allow more low-income individuals and households to live separately, create a situation known as the "split incentive problem" (Ibid.). Almost 80 percent of the nearly 40 million households eligible for federal heating assistance pay the utility bills for the units they rent (Ibid.). This means that neither the landlords nor the renters have a vested interest in improving the energy efficiency of the home—the landlords because they don't capture the benefits of energy savings, and the renters because they tend to not live in the unit long enough to make the investment in energy efficiency pay off (Ibid.). Thus, low-income households are drawn into housing and residential energy burdens that they struggle to afford. In effect, such subsidies nudge people into living with a high energy burden.

There is no universally-recognized percentage of income spent on residential energy that defines whether or not a household has a high energy burden. Economist Roger Colton, however, indicates that six percent of household income is a benchmark for an affordable energy burden (Fisher Sheehan & Colton 2016), and the Applied Public Policy Research Institute for Study and Evaluation suggests that eleven percent of household income be the benchmark for households living with a high energy burden (2007, iv).

Another way to approach the discussion of high energy burden is to discuss what does not constitute an unreasonable energy burden. In the U.S. Department of Health and Human Services' LIHEAP Home Energy Notebook: For Fiscal Year 2014, the Division of Energy Assistance estimated mean and median residential energy burden for four household categories: all U.S. households, U.S. non-low-income households, U.S. low income households, and LIHEAP recipient households (2016, 97-98). As Table 1 shows, in every region, non-low-income households had a mean burden of between 2% and 4% and a median burden of between 2% and 3% (Ibid.). Low income households had a mean burden ranging from 11% to 21% and a median burden of 5% to 11%, LIHEAP recipient households were similar to the low-income households (Ibid.).

Table 1: U.S. Department of Health and Human Services FY 2014 Household Residential Energy Burden

	Mean Residential Household Energy Burden	Median Residential Household Energy Burden
US Non-Low Income Households	3.3%	2.8%
US Low Income Households	18.4%	8.9%
US LIHEAP Recipient Households	18.8%	9.5%
Northeast Non-Low Income Households	3.8%	3.3%
Northeast Low Income Households	20.8%	11.1%
Northeast LIHEAP Recipient Households	18.7%	10.9%
Midwest Non-Low Income Households	3.3%	2.8%
Midwest Low Income Households	18.9%	9.2%
Midwest LIHEAP Recipient Households	21.5%	9.6%
South Non-Low Income Households	3.6%	3.1%
South Low Income Households	20.5%	9.9%
South LIHEAP Recipient Households	20.0%	9.9%
West Non-Low Income Households	2.3%	2.0%
West Low Income Households	11.8%	5.5%
West LIHEAP Recipient Households	9.8%	6.3%

(U.S. Department of Health and Human Services 2016, 97-98)

Low Income Home Energy Assistance Program (LIHEAP)

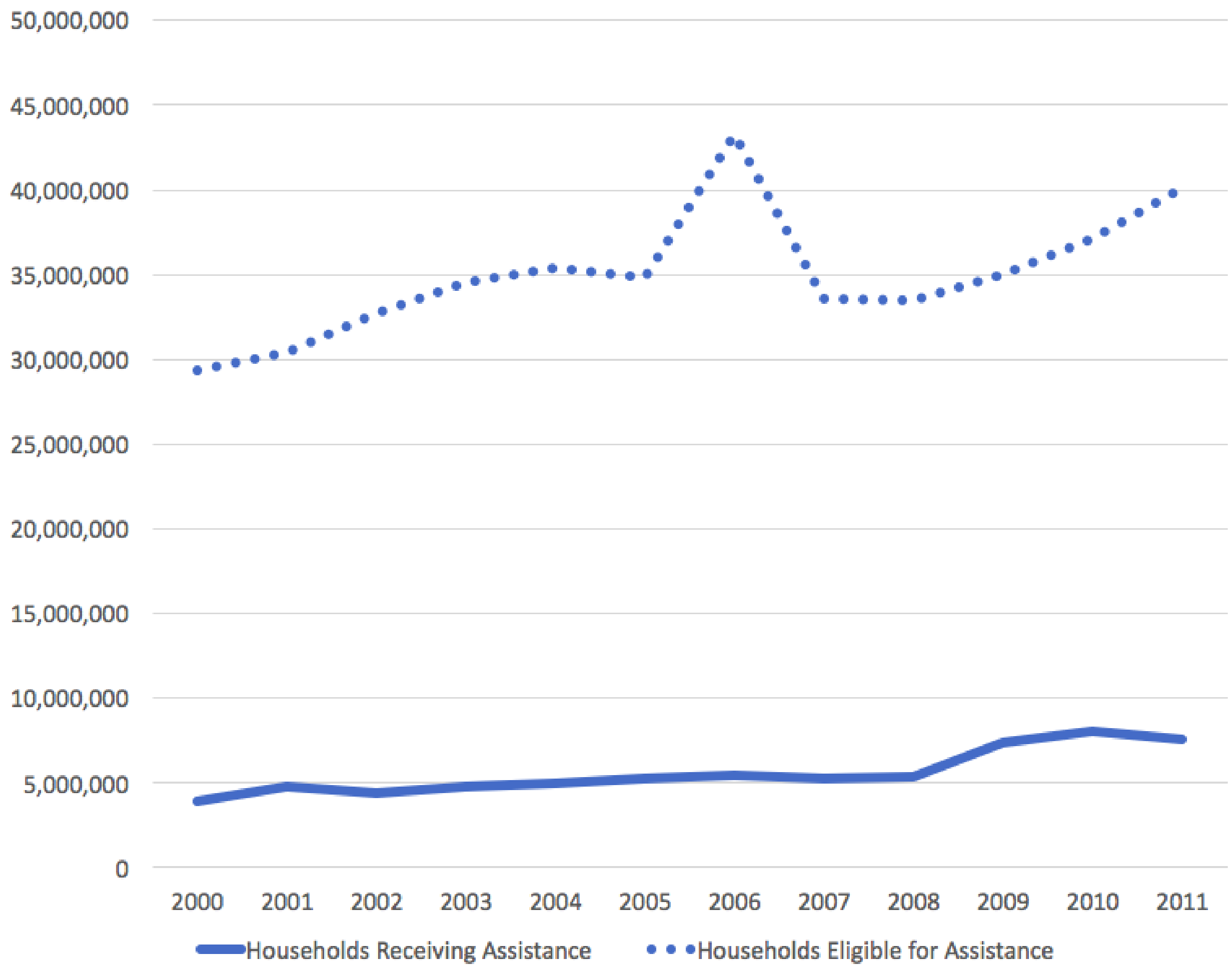
In order to alleviate the burden of high energy costs for low income households, every year Congress appropriates funding for the Low-Income Household Energy Assistance Program (LIHEAP). Funding is then apportioned to the 50 states and the District of Columbia, 153 Native American tribes, and five U.S. territories (collectively called the grantees) to “operate home energy assistance programs for low-income households" (Perl 2015, Summary). LIHEAP funding primarily is used to help households pay their heating and cooling bills (Office of Community Services 2016).

Authorized by the Omnibus Budget Reconciliation Act of 1981, the Low-Income Home Energy Assistance Program (LIHEAP) is "a block grant program administered by the U.S. Department of Health and Human Services" (Division of Energy Assistance n.d., i). The program's purpose is "to assist low-income households, particularly those with the lowest incomes, that pay a high proportion of household income for home energy, primarily in meeting their immediate home energy needs" (Ibid.).

Federal law requires that states and other LIHEAP grantees use two methods for determining whether a household is eligible to receive LIHEAP aid: eligibility based on income and eligibility based on receipt of other benefits (Perl 2015, 4). Eligibility based on income requires that states and other LIHEAP grantees set eligibility at no more than "150% of the federal poverty income guidelines or, if greater, 60% of the state median income," and must not declare ineligible any household with income "below 110% of the poverty guidelines" (Ibid.). Eligibility based on receipt of other benefits allows states and other LIHEAP grantees to qualify "any household of which at least one member is a recipient of Temporary Assistance for Needy Families (TANF), Supplemental Security Income (SSI), benefits under the Supplemental Nutrition Assistance Program (SNAP, formerly Food Stamps), or certain needs-tested veterans' programs" (Ibid.). Furthermore, 42 U.S.C. §8624(b)(3) requires that grantees reach out to low income households with high energy burdens (U.S. Government Publishing Office).

Although the law requires that LIHEAP funding be used to help low income households with high energy burdens, LIHEAP is not an entitlement program. Financial aid is awarded on a first-come, first-served, basis and the National Energy Assistance Directors' Association (NEADA) indicates that about only 20% of LIHEAP-eligible households receive financial aid before funding runs out (2017). Figure 1 shows for the years 2000-2011 the number of households eligible for LIHEAP funding and the number of households that actually received LIHEAP assistance, for the years 2000-2011 (Perl 2015, p. 9).

Figure 1: LIHEAP Recipients FY 2000-2011



(Perl 2015, p. 9)

Congress grants two types of LIHEAP funding: regular funds (also called block grant funds) and emergency funds. While emergency funds are awarded "at the discretion of the Secretary of the Department of Health and Human Services based on emergency need," regular funds are allocated by formula (Perl 2015, Summary). The formula used to allocate funding for LIHEAP is a composite of what are known as the "old" and "new" formulas (Ibid.).

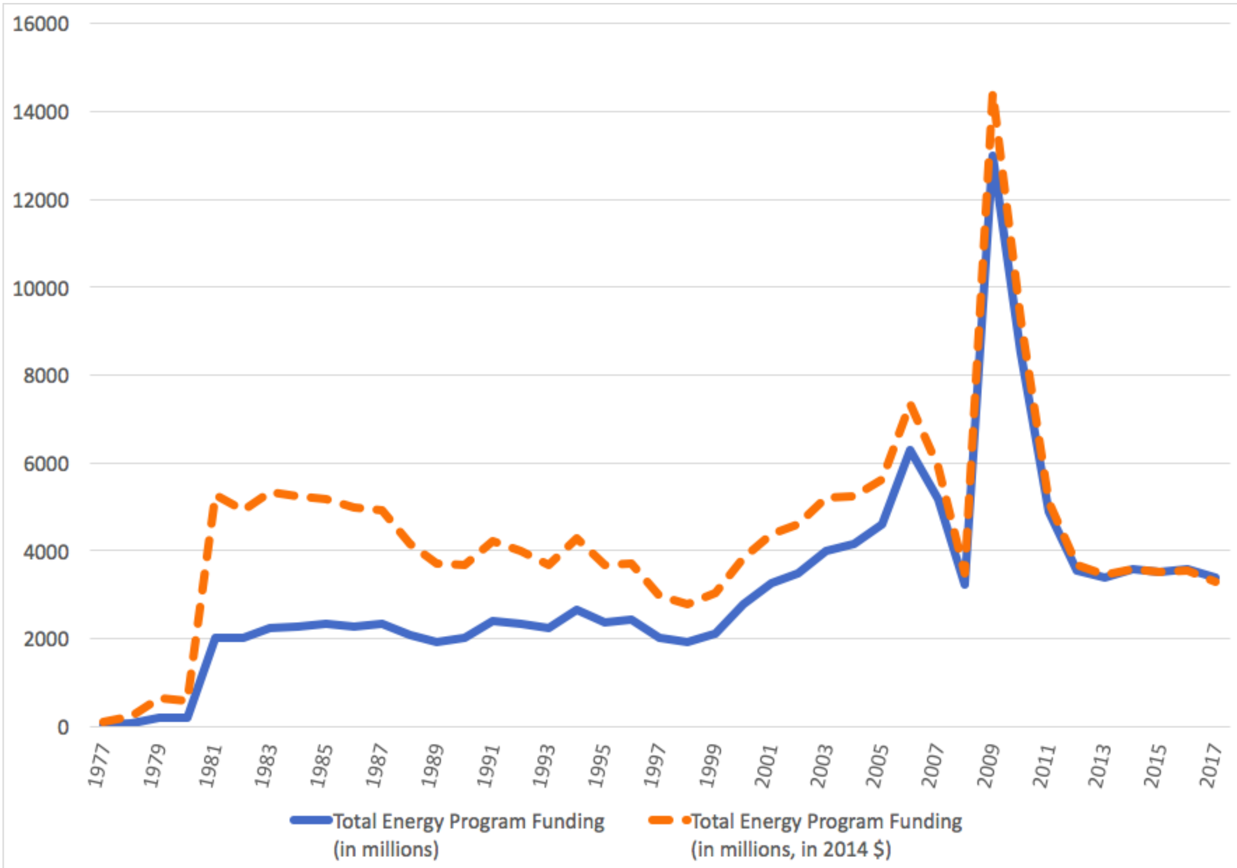
When Congress enacted LIHEAP in 1981, the program replaced the Low-Income Energy Assistance Program (LIEAP) but adopted the same formula used for LIEAP to determine how funds would be allocated to the states. Under LIEAP, cold-weather states benefitted over warm-weather states, as the funding primarily was meant to aid in heating homes, rather than cooling them. This allocation method is known as the old formula.

In 1984, Congress reauthorized LIHEAP and changed the allocation formula to more equally benefit warm-weather states more equally. Congress also included two hold-harmless provisions that would prevent LIHEAP funds from being unduly awarded to warm-weather states at the expense of the funding historically awarded to cold-weather states (Ibid.). This allocation method is known as the new formula, and the amount of money allocated for LIHEAP every year determines which formula is used to determine how LIHEAP funding is allocated across states (Ibid.).[2]

Although LIHEAP is not the only federal energy assistance program, it comprises the most significant portion of federal funding for home energy assistance programs. Figure 2 shows the total funding allocated for home energy assistance programs from FY 1977 through 2017. Figure 2 also shows the significant increase in funding for home energy assistance programs in 1981 when Congress created LIHEAP. (LIHEAP Clearinghouse n.d.). Figure 3 shows the total funding allocation for LIHEAP only, from FY 2007 to 2014 (Perl 2015, p. 33).

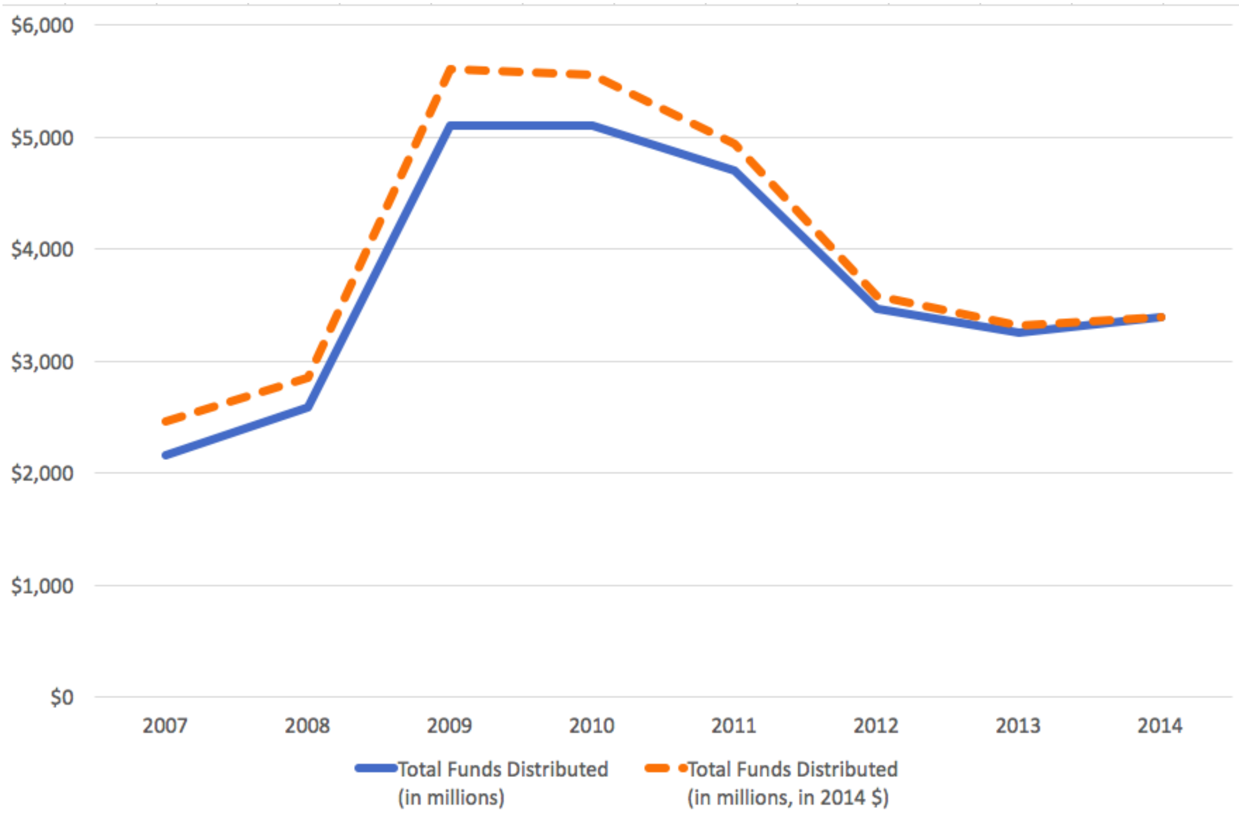
[2] The new formula was used to allocate funds in FY 1985, FY 1986, FY 2006, and FY 2008 (apparently mistakenly). From FY 2009 to at least FY 2015, Congress has allocated funds using both the old and the new formulas, dictating that certain amounts be allocated according to the old formula and certain amounts allocated according to the new formula (Perl 2015, Summary).

Figure 2: Total Home Energy Assistance Funding FY 1977-2017



(LIHEAP Clearinghouse n.d.)

Figure 3: Total LIHEAP Funding FY 2007-2014



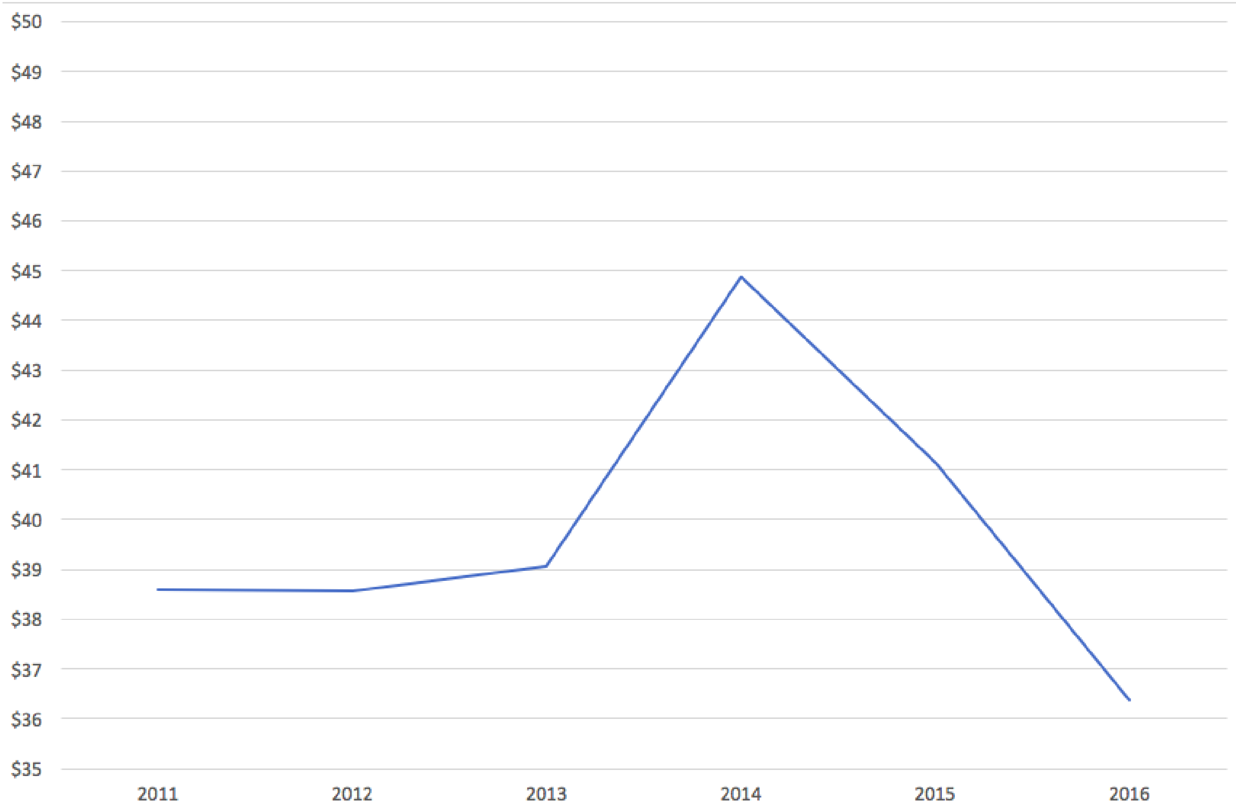
(Perl 2015, p. 33)

Home Energy Affordability Gap

In 2003, economists from Fisher, Sheehan & Colton (FSC) "introduced a model that calculated the dollar amount by which 'actual' home energy bills exceed 'affordable' home energy bills on a county-by-county basis" for the United States (FSC 2016). They called the gap between actual and affordable home energy bills the Home Energy Affordability Gap (HEAG). Figure 4 shows HEAG from 2011 to 2016 (FSC 2017).[3]

[3] Owing to a change in data sources and an update to methodology, the Home Energy Affordability Gap data prior to 2012 is not comparable to the data in 2012 and later. Fisher, Sheehan & Colton use a calculation for

Figure 4: Home Energy Affordability Gap 2011-2016 (in billions)



(FSC 2017)

Each year, FSC calculates the household energy burden for each state, plus the District of Columbia. Table 2 shows Utah's residential energy burden for years 2012-2016, for households up to 200% of Federal Poverty Level.[4] The table indicates that the group energy burden for households between 100% and 200% of Federal Poverty Level ranges from 4% and 7%. To calculate the Home Energy Affordability Gap, FSC relied on data from the following sources: U.S. Census, American Community Survey, fuel-

---

the Gap in 2011 as the base year to compare 2012 and later HEAG calculations against.

[4] FSC use a group energy burden approach.

specific information from the Energy Information Administration, federal poverty lines, allocations from the Low-Income Home Energy Assistance program, the U.S. Department of Energy's Residential Energy Consumption Survey, weather information from the National Weather Service's Climate Prediction Center, and price information from the Petroleum Administration for Defense Districts.

Table 2: Utah Residential Energy Burden 2012-2016

	Residential Energy Burden				
Federal Poverty Level	2012 Burden	2013 Burden	2014 Burden	2015 Burden	2016 Burden
Below 50%	20%	20%	21%	22%	20%
50-100%	11%	11%	11%	12%	11%
100-125%	7%	7%	8%	8%	7%
125-150%	6%	6%	6%	6%	6%
150-185%	5%	5%	5%	5%	5%
185-200%	4%	4%	4%	5%	4%

(FSC 2017)

As mentioned earlier, no uniform definitions for affordable and unaffordable household energy burdens exist. FSC, however, uses a threshold for an affordable home energy burden of 6% of household income (FSC 2016), and researchers from the Applied Public Policy Research Institute for Study and Evaluation (APPRISE) propose 11% of income as the threshold for a high energy burden (APPRISE 2007). For Utah residents, during 2012-2016, then, those definitions suggest that households at or below Federal Poverty Level live with high household energy burdens.

FSC's work on the Home Energy Affordability Gap, which includes calculating residential energy burdens, is some of the most extensive work available, and, in the domestic energy poverty literature, perhaps the most widely relied upon. That work, along with the calculations of energy burden produced by the U.S. Department of Health and Human Services' Division of Energy Assistance (addressed in the section on LIHEAP), are models for further research on residential energy burdens.

Energy Efficiency

Though total household energy expenditures for low income households were less than for non-low-income households (Division of Energy Assistance 2016, p. 24), residential energy burden is used to show that low income households pay a higher proportion of their household incomes on energy. This measure is used by many groups to advocate for aid in helping low income households pay their energy bills. But advocating for help paying for energy bills isn't the only use to which measures of household energy burden have been put. Energy burden statistics are also used to advocate for programs that increase household energy efficiency.

In a report on energy burden for the American Council for an Energy Efficient Economy, Ariel Drehobl and Lauren Ross (2016, 3) reached the unremarkable conclusion that demographic groups that are associated with low income also have higher energy burdens than average households. Their contribution to the energy burden discussion, however, is to indicate that while low-income households have lower energy bills in absolute terms, they pay relatively more per square foot of housing space than non-low-income households (Ibid.). Furthermore, Drehobl and Ross (Ibid.) concluded that "for low-income households and for multifamily low-income households, bringing housing stock up to the efficiency of the median household would eliminate 35% of excess energy burden, reducing energy burden from 7.2% to 5.9%."

The U.S. Department of Energy (DOE) operates the Weatherization Assistance Program (WAP), which helps low income households increase their homes' energy efficiency. WAP provides services to about 35,000 homes each year, at an average weatherization cost of $4,695 per household unit (DOE 2017, 1). DOE indicates that the energy burden for low income households is about 16% of annual income (recall that APPRISE proposes a threshold of 11% as an indicator of a high energy burden), compared to a household energy of 3.5% for other households, and that this difference means that low-income households must often "cut back on healthcare, medicine, groceries, and childcare to pay their energy bills" (Ibid.).

DOE funds weatherization services, such as "insulation and air sealing, HVAC systems, lighting, and appliances," credited with an average annual energy cost savings of $283 per household (Ibid.). DOE also states that WAP can reduce household heating costs in cold weather states by an average of 30%, that the program "returns $2.78 in non-energy benefits for every $1" invested in WAP, and that these benefits lower out-of-pocket medical expenses by an average of $514 per weatherized household (Ibid.).

In addition to understanding the role government plays in alleviating the burden of high energy bills for low-income families, it is important to understand why the need for alleviating that burden exists in the first place. Consider again the energy burden ratio: energy burden = energy expenditures / income.

Most research on energy poverty in the United States focuses on discovering to what degree it exists, what it means for low-income households, and how to lighten the energy burden of low-income households. That is, the question that most current research tries to answer is "Given the price of energy and a low household income, how can government alleviate the problem of a high energy burden?" This question looks at the inputs—energy prices and household income—and seeks an answer ex post facto that fixes the identified problem of high energy burdens. Solutions then come in the form of welfare programs like LIHEAP and WAP.

Of the two components of the energy burden ratio, the most significant is household income. Household energy expenditures do fluctuate from household to household, but not so extremely that energy expenditures (the numerator) is the key determinant of a household having an affordable or a high energy burden. Unsurprisingly, then, a high energy burden goes hand-in-hand with having a low income, and increasing a household's income is the surest way of reducing the household energy burden.

The question of how to increase household income is the central problem of the high energy burden discussion, and is the same problem discussed since at least Adam

Smith's Wealth of Nations, first published in 1776. That is, what conditions give rise to wealth and prosperity, for individuals and for nations?

The question of how to increase household income, and alleviate the burden of having a low-household income, is broadly discussed and frequently debated. I leave that discussion to others, acknowledging that it is the more significant component of addressing high household energy burdens. In my research, I instead focus on understanding the admittedly smaller and less significant, and therefore less-discussed question of the determinants of energy prices. That is, what happens in the market and in politics that affects how much people pay for household energy? As mentioned earlier, most research takes the energy prices and household income as given, and then works to find ways to solve the problem. In this thesis, I've attempted to explore the question of high energy burden by looking at what affects the price of energy. That is, I attempt to approach the problem of energy burden from the foundation of understanding what affects the price of energy. Understanding the factors that increase the price of energy offers another way for policymakers to address the issue of high energy burdens, and my research is meant to help start, and contribute to, that discussion.

The Story of the American Energy Market

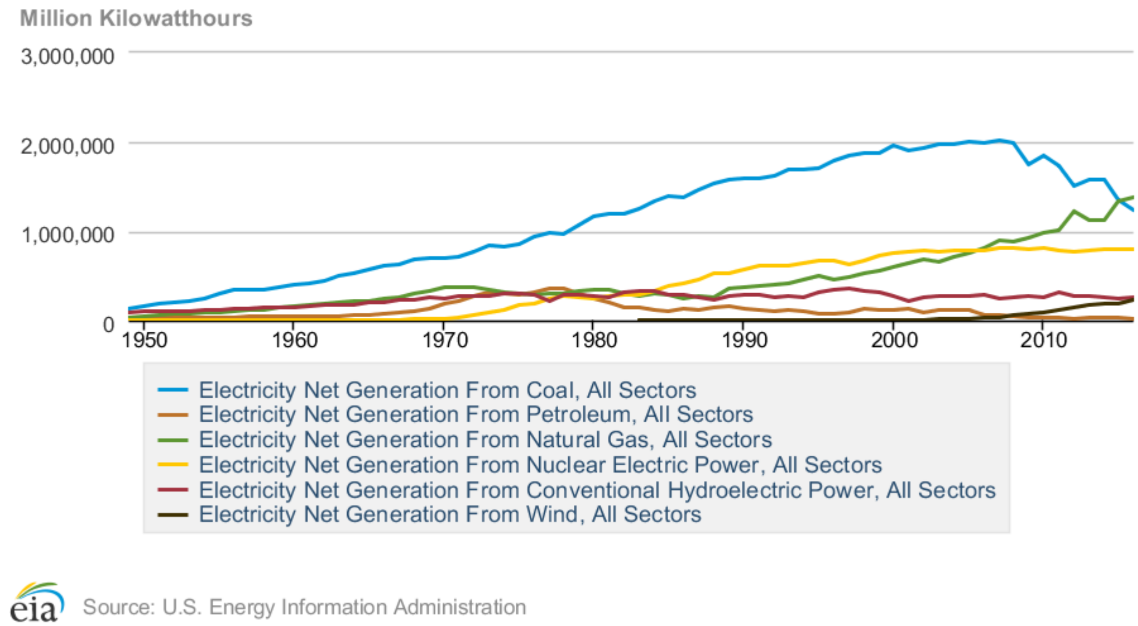
Over the course of America's history, its inhabitants have moved from relying on wood as a primary energy source to using coal, petroleum products, nuclear energy, and natural gas. Recent technological developments have allowed people to harness energy from sunlight, wind, and the ocean's tides. Of the energy sources currently available, "the three major fossil fuels—petroleum, natural gas, and coal, which together provided 87%

of total U.S. primary energy over the past decade—have dominated the U.S. fuel mix for well over 100 years … [and] the predominance of these three energy sources is likely to continue into the future" (EIA 2013).

According to the Energy Information Administration (EIA), "in all but 14 of the years from 1949 to 2007, energy consumption increased over the previous year. Total U.S. energy consumption reached its highest level in 2007" (EIA 2017). The recession in 2009 significantly reduced energy consumption, and "total U.S. energy consumption in 2016 was about 4% less than consumption in 2007" (EIA 2017).

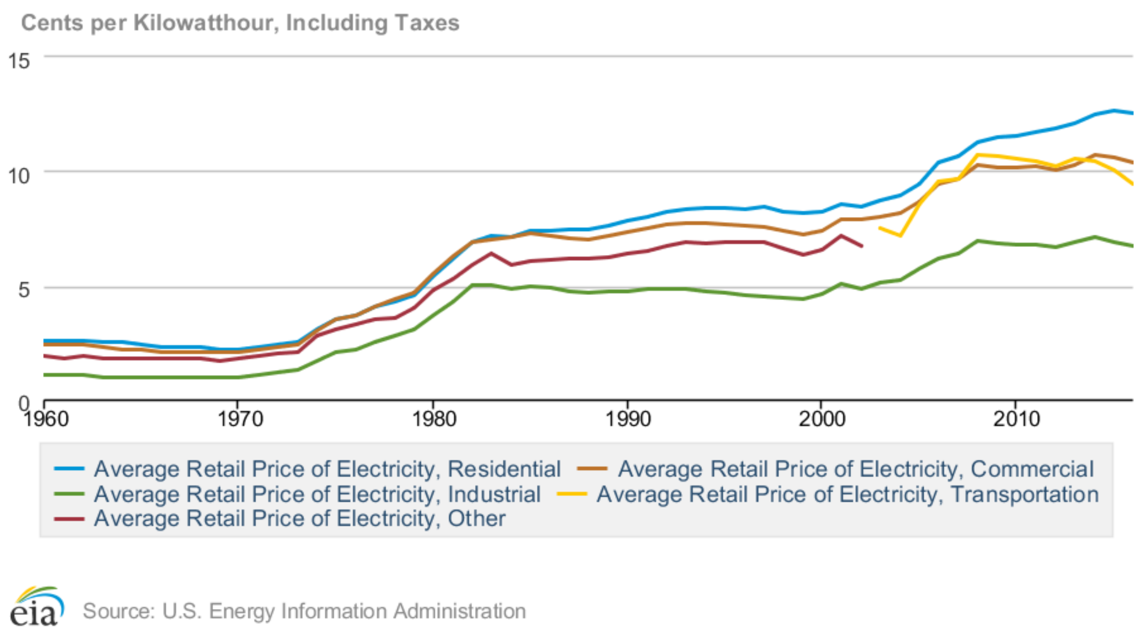
By far, given its abundance, coal has been the largest contributor to electricity generation in the United States, with natural gas increasing over the previous decades to overtake coal in 2015 (see Figure 5). As Figures 6 and 7 show, the nominal prices of electricity and natural gas have risen over time.

Figure 5: U.S. Electricity Net Generation



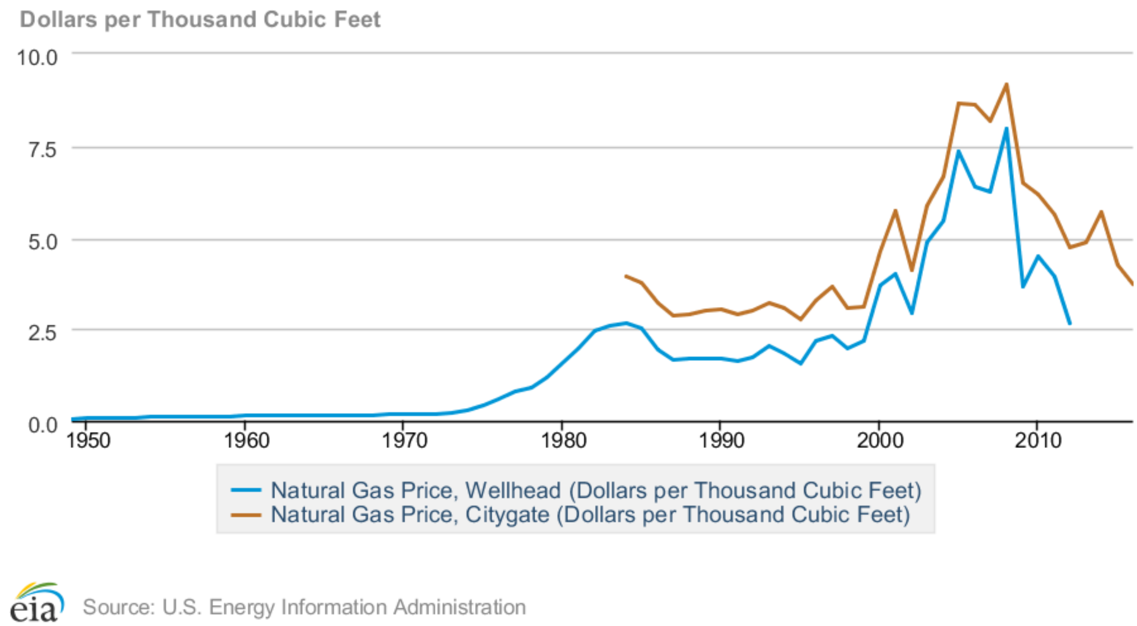
(EIA 2017)

Figure 6: U.S. Average Retail Prices of Electricity



(EIA 2017)

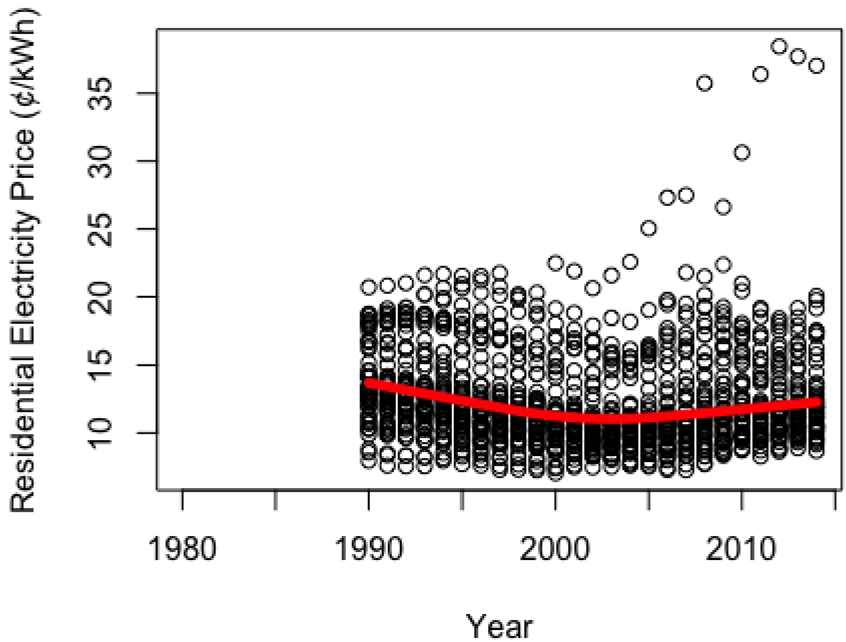
Figure 7: U.S. Average Retail Prices of Natural Gas



(EIA 2017)

Though Figures 6 and 7, downloaded from EIA's website, indicate that prices have increased over time, looking at the data another way tells a different story. When EIA's data are broken down into state-level data, it appears that high prices in a few states (Hawaii, in particular) have caused the average cost of electricity and natural gas to increase rather than there being a general increase in cost across all states. After analyzing the data at the state-level, and putting the price of energy in constant 2015 dollars, my analysis shows that the prices of electricity and natural gas have either fallen slightly or stayed about the same over the past few decades (see Figures 8 and 9). This begs the question, "Why?"

Figure 8: State Residential Price of Electricity



Note that each circle represents a data point for each year, for each state. The outlier is Hawaii.

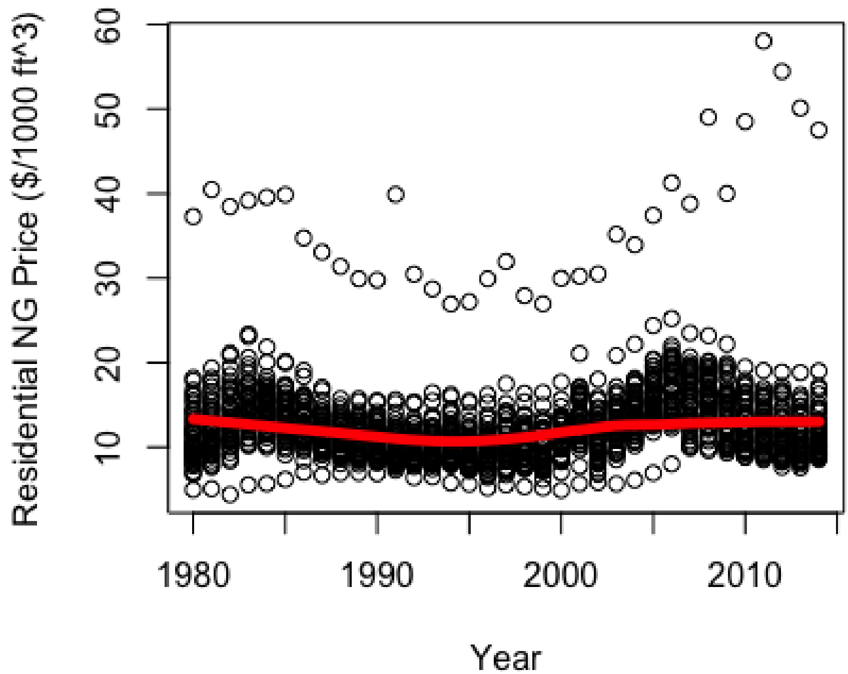
Amounts are inflation-adjusted and in 2014 dollars.

Data adapted from EIA's State Energy Data System (EIA 2017)[5].

---

[5] EIA's State Energy Data System (SEDS) provides comprehensive state energy statistics. The database is very large, and I stitched together a smaller data set using the variables I needed for my research. The dataset I built is available upon request.

Figure 9: State Residential Price of Natural Gas



Note that each circle represents a data point for each year, for each state. The outlier is Hawaii.
Amounts are inflation-adjusted and in 2014 dollars.
Data adapted from EIA's State Energy Data System (EIA 2017).

What Affects the Price of Energy?

In order to understand the numerator of the energy burden ratio (energy expenditures), it is necessary to understand the determinants of the price of energy. In the context of residential energy burden, then, it is necessary to understand what affects the price of electricity and natural gas, as they "are the most-consumed energy sources in U.S. homes" (U.S. Energy Information Administration 2013).

According to the Energy Information Administration (EIA), the factors affecting electricity and natural gas prices include: per unit cost of fuel; power plant construction, maintenance, and operating costs; transmission and distribution costs; weather conditions (because extreme temperatures increase demand); type of customer (residential, commercial, industrial, or transportation); geographic location; federal and state regulations (such as the prices set by Public Service or Public Utility Commissions); and variations in the amount of natural gas production, imports and exports, and storage (EIA 2016 and 2016).

In addition to the above-mentioned factors, regulation affecting everything from the process of extracting and harnessing energy to the system of delivering that energy to consumers will also affect the retail energy prices. The U.S. Environmental Protection Agency (EPA) acknowledges that causal chain in its regulatory impact analyses of various Clean Air Act-related regulations. In its “Regulatory Impact Analysis for the Clean Power Plan Final Rule,” for example, EPA reported the results of its use of the Integrated Planning Model to project the impact of the Clean Power Plan, a regulation affecting carbon dioxide emissions from power plants (EPA 2015, 3-1).

EPA predicts that the Clean Power Plan will affect the price of natural gas and coal, but because those fuel sources are “important inputs to the production of other goods and services,” this increase in price will also lead to “changes in the quantities and/or prices of the goods or services produced” elsewhere (Ibid., 5-3). That is, regulation affects the price of fuel sources needed to generate electricity and other inputs used to support other goods and services demanded by consumers. Regulation, therefore, is like the proverbial stone tossed into a pond—it ripples through the whole system and has anticipated and unanticipated consequences.

Though there is much to study on the topic of the determinants of energy prices, and of electricity and natural gas in particular, my immediate interest is in EPA’s analysis of the impact of its regulation on the economy. I am interested in understanding how energy and environmental regulations affect the prices of the electricity and natural gas people use in their homes. Furthermore, I'm interested in extending that understanding to the effect of higher energy prices on residential energy burdens. If, as EPA claims, regulation increases the costs of the basic energy inputs of the economy, then understanding what the resulting higher prices mean for low-income households is an important element of the discussion of poverty in general and energy burden in particular.

REGULATION IN THE UNITED STATES

The economic growth experienced since the Industrial Revolution vaulted millions of people out of poverty and raised their standards of living. But the increase in quality of life has not been free of consequences. Concern for the pollution generated by such economic growth has propelled people to pursue solutions through government action.

Yet the push to regulate the energy sources that have revolutionized the economy has not been free of consequences either. From a global perspective, seeking to limit carbon dioxide producing energy sources, like coal, means that millions (if not billions) of people are being held back from more comfortable lifestyles because they lack access to cheap and reliable energy. From a U.S. perspective, regulating energy sources like coal and natural gas, and therefore increasing the price of basic inputs to the economy, raises the cost of living for all. When this happens, it isn't the wealthy who bear the heaviest burden of the regulation, but rather those who lack the financial resources to insulate them from the shock of higher prices.

A relevant study is by Terry Dinan and Diane Lim Rogers, in the June 2002 issue of the National Tax Journal. They modeled the distributional effects of a proposed cap on U.S. carbon-dioxide emissions. In their analysis, they stated that "carbon-intensive consumption—defined here as expenditures on electricity, natural gas, fuel oil and coal, and gasoline and oil—makes up larger fractions of the total expenditures of lower-income households" (210). Thus, a policy limiting carbon emissions may have a regressive effect, and low-income households would bear the heaviest burden of complying with the policy unless the "government sought to offset the regressivity of the policy-induced price increases by providing lump-sum rebates" (Ibid., 219). As it relates to my research, this conclusion suggests a positive relationship between more regulation and more energy poverty, unless actions are taken to moderate the burden on low-income households.

Inasmuch as energy and environmental regulation aims to internalize the external cost of pollution, regulation is a roundabout way to tax energy production without actually calling the intervention a tax. Thus, the literature on the effects of a carbon dioxide tax is relevant to my research.

Andrea Baranzini, Jose Goldemberg, and Stefan Speck, in their 2000 paper published in Ecological Economics, summarized the results of several studies showing that "carbon taxes are generally regressive, but less than first expected" (404). They concluded that "the distributional impacts of carbon tax are quite complicated, since they depend on at least four factors:" household expenditure patterns, the degree to which the burden of the tax is passed on from producers to consumers, the distribution of benefits resulting from improved environmental quality, and how revenues generated from the tax are used to reduce the regressive impact of the tax (Ibid., 404). Inasmuch as regulation can be considered a method of taxation, this research indicates that I should expect to see that regulation is regressive, meaning that more regulation has a positive correlation with higher energy burdens, but that the relationship may be weaker than I would expect at first, given the four considerations mentioned.

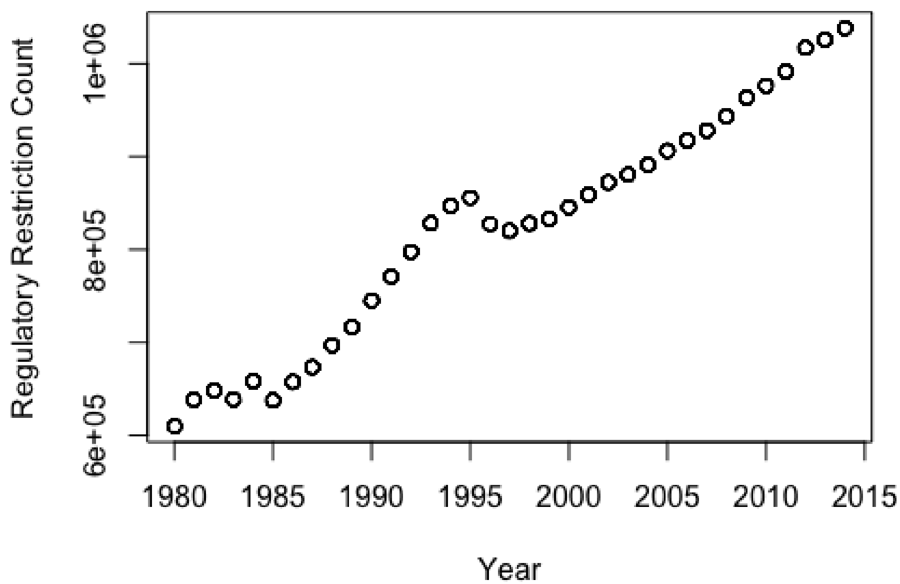
Gbadebo Oladosu and Adam Rose, in a study published May 2007 in Energy Economics, examined the distributional impacts of a proposed carbon tax in the Susquehanna River Basin and concluded that the tax would be mildly progressive, in contrast to most of the literature suggesting that a carbon tax is mildly regressive. They state that their study indicates that, despite the progressivity of the carbon tax, “lower income groups [will] spend relatively more of their income on Food, Housing, and Health Services than prior to the imposition of the tax,” (536) and conclude by refraining from the suggestion that the study’s finding of carbon tax progressivity is generalizable to “all other regions” (Ibid., 538).

Two working papers, “Regressive Effects of Regulation” by Diana Thomas and “How Do Federal Regulations Affect Consumer Prices?” by Dustin Chambers and Courtney Collins, informed my early research of the regressive effects of regulation. Specifically, Chambers and Collins found that “a 10 percent increase in total regulations leads to a 0.687 percent increase in consumer prices (Chambers and Collins 2016, 4); Thomas concluded that “regulation reflects the preferences of high-income households and effectively redistributes wealth from the poor to the middle class and the rich” (Thomas 2012, abstract). Together, these papers assert that regulation tends to reflect the preferences of middle- and higher-income households, but that the burden of regulation tends to fall disproportionately on lower-income households.

The findings by Thomas, Chambers, and Collins indicate support for the public choice school of thought: people are people, whether they are making a choice in the marketplace or in the voting booth. Rather than voting in “the public interest,” self-interested human beings vote and act to promote their own well-being in the political environment. Though individuals may not implement policy with the express purpose of harming lower income groups, their personal preferences result in policies that benefit themselves at the expense of others. Those groups that can mobilize and exert influence on the political system are able to take advantage of groups that are not able to do so, and low-income households appear to be the ones bearing the brunt of the policy preferences of wealthier households.

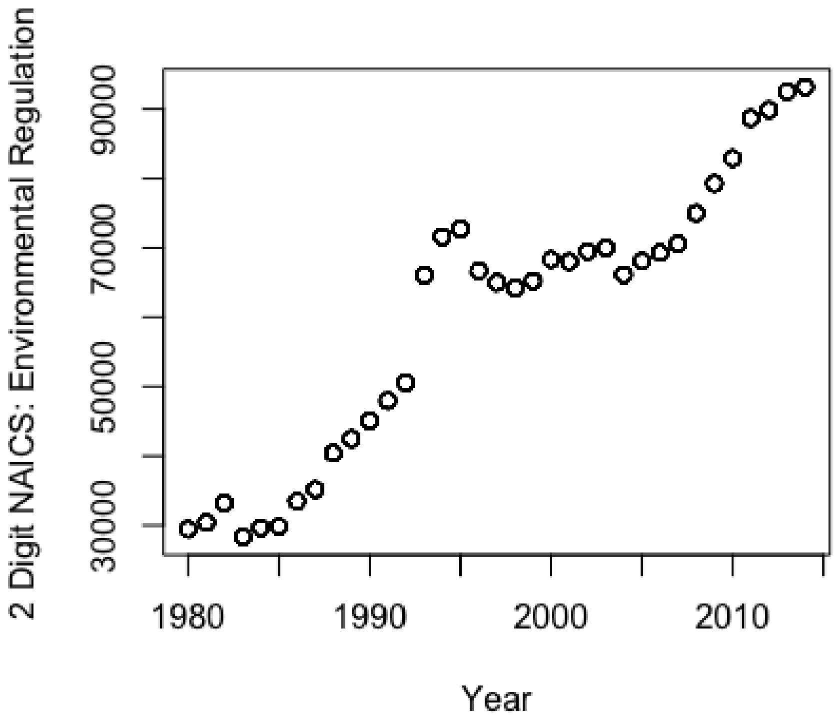
As mentioned earlier, the prices of electricity and natural gas general decline or stay constant over time (see Figures 8 and 9). Data from the Mercatus Center, however, shows that regulation over the past several decades has grown markedly, and Figures 10 and 11 show the rise in regulation since 1980. Figure 10 shows the growth in regulatory restrictions overall, and Figure 11 shows the growth in energy and environmental regulatory restrictions.

Figure 10: Regulatory Restriction Count



(Al-Ubaydli and McLaughlin 2017)

Figure 11: Energy and Environmental Regulatory Restriction Count



(Al-Ubaydli and McLaughlin 2017)

Following the Mercatus Center's definition, the regulatory restriction count is the number of words like "shall" and "must" that indicate a requirement to comply. The creators of the Mercatus Center's regulation database write that counting the restrictions, rather than overall word or page counts, is a more accurate indicator of the regulatory burden "because some regulatory programs can be hundreds of pages long with relatively few restrictions, while others only have a few paragraphs with a relatively high number of restrictions" (Al-Ubaydli & McLaughlin 2017).

Because I am interested specifically in energy and environmental regulation, not just overall regulation, I used Al-Ubaydli and McLaughlin's classification of the regulation data in order to count the number of energy and environmental regulatory restrictions since 1980 (as mentioned, shown in Figure 11). The same trend applies as with regulation in general: a significant increase since 1980.

As Figures 8, 9, 10, and 11 indicate, the idea that regulation increases the price of energy seems to not have been borne out as theory anticipated. Regulation is rising, while inflation-adjusted energy prices either remain constant or are falling. What explains this surprising observation?

There is, of course, the tempting correlation-causation answer: contrary to expectation, regulation reduces energy prices. But the correlation between regulatory growth and declining or constant energy prices does not indicate causation—at least not without further exploration.

Questions and Hypotheses

As mentioned earlier, the price of energy is affected by many factors. Because I am interested in the relationship between regulation and residential energy burden, and the relationship between energy and environmental regulation and residential energy burden, in particular, I must break my research question down into smaller components. In order to explore how regulation affects the residential energy burden, I must ask:

1) How does regulation, and energy and environmental regulation, in particular, affect the prices of electricity and natural gas?[6]
2) How does regulation and the prices of electricity and natural gas affect the household residential energy burden?

[6] Though energy sources other than electricity and natural gas are used to provide energy to households, electricity and natural gas are the two largest sources used in households.

Given my expectations after reading the literature, and despite my initial finding that increasing regulation does not seem to have led to higher energy prices, my directional hypothesis is that an increase in regulation, and an increase in energy and environmental regulation in particular, raises the prices of electricity and natural gas, which in turn raise the residential energy burden.

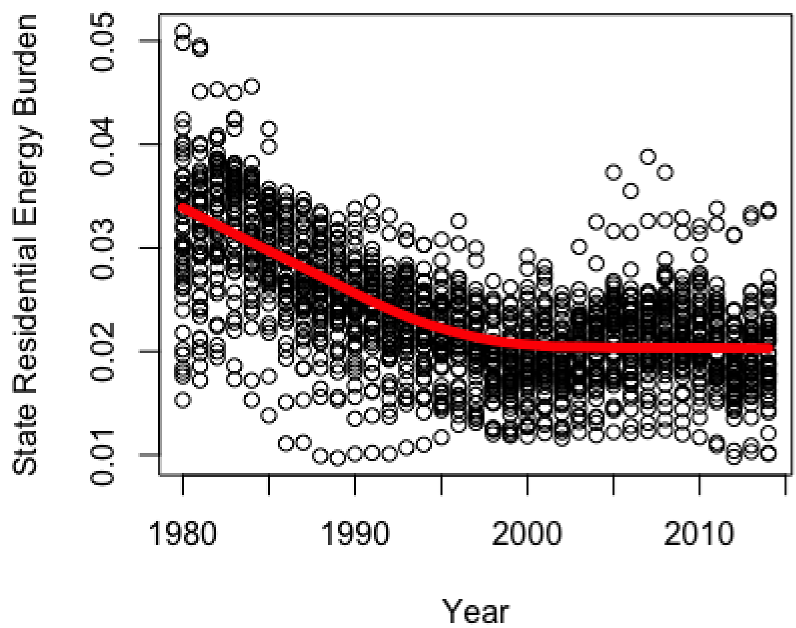
My non-directional hypothesis is than an increase in regulation, and an increase in energy and environmental regulation in particular, affects the prices of electricity and natural gas, which in turn affects the residential energy burden.

In order to account for the possibility of no relationship, my null hypothesis is that no causal relationship exists between an increase in regulation, of any kind, and the prices of electricity and natural gas. In other words, an increase in regulation has no second-order effect on the residential energy burden.

Testing the Correlations

As presented earlier, Figure 8 shows the inflation-adjusted price of residential electricity and Figure 9 shows the inflation-adjusted price of residential natural gas. As Figures 8 and 9 also show, the prices of electricity and natural gas fluctuated over the past several decades, but not wildly so. Figure 12 shows the historical residential energy burden at the state level, and the figure also shows that from 1980 to 1995, the residential energy burden declined from about 3.5 percent to 2 percent, leveling off thereafter.

Figure 12: State Residential Energy Burden



Note that each circle represents a data point for each year, for each state.
Amounts are inflation-adjusted and in 2014 dollars.
Data adapted from EIA's State Energy Data System (EIA 2017).

In contrast to the relatively stable historical prices of residential electricity and natural gas, and the general reduction in the state residential energy burden, Figures 10 and 11 show the steady increase of regulatory restrictions since 1980. As mentioned earlier, the term "regulatory restrictions" counts words like "must" and "shall" in regulations published in the U.S. Code of Federal Regulations, which indicate mandatory constraints on industry and which we can therefore expect to result in some sort of compliance cost. Figure 10 shows the increase in all regulatory restrictions in the Code of Federal Regulations and Figure 11 shows the increase in regulatory restrictions that relate to energy and environmental regulation, using the two-digit North American Industry Classification System (NAICS) adopted by federal agencies when working with statistical data as a means of identifying regulations falling into the energy and environmental regulation category.

Comparing Figures 8 and 9 to Figures 10 and 11 calls into question the validity of my hypothesis that more regulation, and, in particular, more energy and environmental regulation, leads to higher electricity and natural gas prices and therefore raises the household residential energy burden. Table 3 shows the correlations between regulation and electricity prices, natural gas prices, and state residential energy burdens.

Table 3: Correlation Matrix

	2 Digit NAICS: Energy & Environmental Regulatory Restrictions	All Regulatory Restrictions
Price of Electricity	-0.02	-0.02
Price of Natural Gas	-0.005	0.05
State Residential Energy Burden	-0.60	-0.58

The correlations shown in Table 3 indicate a negative and weak relationship between the prices of electricity and natural gas and the number of regulatory restrictions (both energy and environmental restrictions and total restrictions), with a positive and weak relationship between the number of total regulatory restrictions and the price of natural gas.

Though my hypothesis, based on the literature summarized earlier, indicates that I should expect to see positive correlations, the relationship shown in Table 3 is the opposite of what I expected, with the exception of the correlation between all regulatory restrictions and the price of natural gas, which is positive, but very weak. Controlling for other factors, then, is important for illuminating this puzzle.

Modeling Regulation and Energy Prices

Appendix A, which includes Tables 4, 5, 6, and 7, shows the results of my attempt at an empirical test of my research question. Though I do find, in some instances, evidence that an increase in regulation does affect the residential energy burden, I can conclude only that there is no evidence is found that more regulation has a direct and strong effect on the residential energy burden in either direction.

My first attempt at an empirical analysis of my research question indicates more work must be done in order to understand what is going on. Despite theory, and pronouncements from regulators themselves (such as EPA), more regulation does not have the clear effect on residential energy burden that I expected it to have. In order to further understand this puzzle, it will be necessary to specify several additional models to study this puzzle, including supply- and demand-side models explaining the variations in energy prices over time.

Though I leave further research to others, I suggest such a model be built by expanding the models I used for my empirical analysis (and which are described in Appendix A). I used a two-part model, which reflected the two parts of my research question:

1) How does regulation, and energy and environmental regulation in particular, affect the prices of electricity and natural gas?

2) How does regulation and the prices of electricity and natural gas affect the household residential energy burden?

To answer question one, it will be necessary to run separate regressions on electricity price and natural gas price, with the price of energy on the left-hand side and the factors affecting the price of energy, such as regulation, weather, and other economic factors, on the right-hand side. Example models, using the price of electricity and the price of natural gas as the left-hand side variables, are as follows:

Electricity Price = β0

+ β1 Energy & Environmental Regulatory Restrictions

+ β2 All Other Regulatory Restrictions

+ β3 Presence of EPA's Mercury & Air Toxics Standards Rule (dummy)[7]

+ β4 Presence of EPA's Clean Air Interstate Rule (dummy)

+ β5 Presence of EPA's Cooling Water Intake Structures Rule, Phase 1 (dummy)

+ β6 Presence of EPA's Cooling Water Intake Structures Rule, Phase 2 (dummy)

+ β7 Presence of EPA's Cooling Water Intake Structures

---

[7] Specific regulations, such EPA's Mercury and Air Toxics Standards, could be added to the regression in order to determine whether specific regulations, rather than regulation in general, have greater and statistically significant effects on the prices of energy. If individual regulations were added, it is important to note that they would be double-counted—both as a regulatory restriction and as a dummy variable for the years the regulation is in effect.

Rule, Phase 3 (dummy)

+ β8 Presence of a State RPS (dummy)

+ β9 Presence of a National Recession (dummy)

+ β10 Weather variable (perhaps number of heating or cooling days)

Natural Gas Price = β0

+ β1 Energy & Environmental Regulatory Restrictions

+ β2 All Other Regulatory Restrictions

+ β3 Presence of EPA's Mercury & Air Toxics Standards Rule (dummy)

+ β4 Presence of EPA's Clean Air Interstate Rule (dummy)

+ β5 Presence of EPA's Cooling Water Intake Structures Rule, Phase 1 (dummy)

+ β6 Presence of EPA's Cooling Water Intake Structures Rule, Phase 2 (dummy)

+ β7 Presence of EPA's Cooling Water Intake Structures Rule, Phase 3 (dummy)

+ β8 Presence of a State RPS (dummy)

+ β9 Presence of a National Recession (dummy)

+ β10 Weather variable (perhaps number of heating or cooling days)

The results of these first regressions would then inform the results of the second-stage regression, which will look something like:

Residential Energy Burden = β_0

+ β_1 Environmental Regulatory Restrictions
+ β_2 All Other Regulatory Restrictions
+ β_3 Presence of EPA's Mercury & Air Toxics Standards Rule (dummy)
+ β_4 Presence of EPA's Clean Air Interstate Rule (dummy)
+ β_5 Presence of EPA's Cooling Water Intake Structures Rule, Phase 1 (dummy)
+ β_6 Presence of EPA's Cooling Water Intake Structures Rule, Phase 2 (dummy)
+ β_7 Presence of EPA's Cooling Water Intake Structures Rule, Phase 3 (dummy)
+ β_8 Presence of a State RPS (dummy)
+ β_9 Presence of a National Recession (dummy)
+ β_{10} State Poverty Rate
+ β_{11} Price of Residential Electricity (cents/kWh)
+ β_{12} Price of Residential Natural Gas (dollars/thousand cubic feet)

As I discuss in Appendix A, one of the problems I ran into is a lack of data at the household level, meaning that I was not able to get a sample of individual household energy consumption and income data. Instead, I gathered aggregated household energy consumption and income data—recall this is the method described in the group approach to studying energy burden. Though this method was useful in describing the group energy burden in each state and for the nation, it had limited value because much of the variation in energy burden was lost in the state and national averages. Thus, such an approach did not allow me to see whether the energy burden was or was not increasing on the margin.

ANALYSIS

As mentioned earlier, a glance at Figures 8 and 9 shows that inflation-adjusted electricity and natural gas prices have remained fairly constant over time, even as regulation has been increasing almost exponentially. Furthermore, the correlations and the results of my first-attempt at an empirical test of my research question do not indicate support for the idea that regulation increases energy prices or, in turn, affects the residential energy burden.

Acknowledging that the answer to my research question may simply be that there is no relationship between regulation and energy prices or residential energy burden, I expect that if theory is in fact correct, supply- and demand-side factors that explain why there appears to be no relationship when a relationship may actually exist. I suspect that the explanation for my findings of no relationship lie in understanding how the demand for and supply of energy has circumvented or mitigated the effect of increasing regulation.

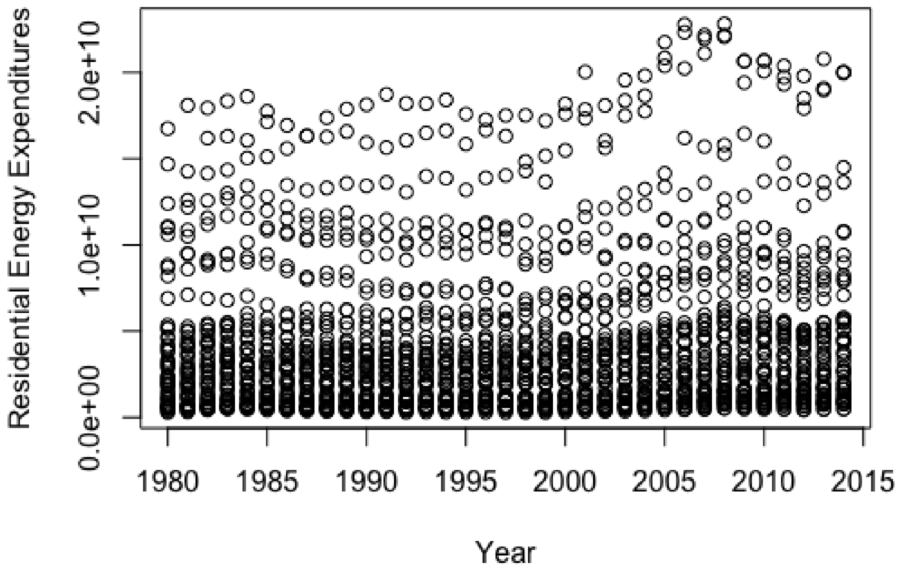
Competition-Driven Innovation

Competition spurs innovation. As an example, consider OPEC's price war on American hydraulic fracturing. When OPEC agreed to drive down oil prices in an effort to strangle American fracking, entrepreneurs responded with innovation that made fracking more cost-effective, allowing American fracking to compete even more strongly with OPEC. OPEC's effort to strangle American fracking through a price war backfired.

Taking the theory that regulation is burdensome and therefore that more regulation would increase the cost of providing a good or service, competition similar to the OPEC-American fracking conflict could offset the burden of regulation to the degree that it appears as though regulation had no effect on costs or prices. Such may be the case with American residential energy expenditures.

As shown in Figure 13, inflation-adjusted residential energy expenditures have remained fairly constant since 1980. The U.S. Energy Information Administration (EIA) indicates, however, that “energy use for air conditioning has doubled since 1980,” that households “plug in more appliances and electronics at home than ever before,” and that “ownership of appliances such as microwaves, dishwashers, and clothes washers and dryers has increased over the past 30 years” (2013). Thus, despite technological innovation over the past almost-four decades, the proliferation of energy-using devices has not resulted in a corresponding increase in energy expenditures.

Figure 13: State Residential Energy Expenditures, 1980-2014



Note that each circle represents a data point for each year, for each state. The outlier is Hawaii.
Amounts are inflation-adjusted and in 2014 dollars.
Data adapted from EIA's State Energy Data System (EIA 2017).

It is likely that energy efficiency is increasing as entrepreneurs improve the devices that have now become a part of daily living. Thus, although the total number of energy-consuming devices has grown over time, the ability to provide electricity for those devices and improve those devices to be more energy efficient likely has offset the otherwise expected increase in energy expenditures. EIA (2012) supports the accuracy of such reasoning to be accurate, stating that the results of the 2009 Residential Energy Consumption Survey indicate that "despite increases in the number and the average size of homes plus increased use of electronics, improvements in efficiency for space heating, air conditioning, and major appliances have all led to decreased consumption per household."[8]

It is also possible that energy prices have actually have risen significantly, but that the price of energy is obscured by how the electricity is paid for. That is, if the price of energy is subsidized in any manner, the amount households pay for energy, as reflected on their energy bills, may not reflect how much that energy actually costs.[9]

Regulation-Driven Innovation

Few things are as regulated as much as energy is, and yet the prices of energy do not appear to be as heavily impacted by regulation as theory would predict. To the contrary, it appears as though more regulation is commensurate with increasing innovation in the energy market. It may be that regulation, in a manner similar to OPEC's intention to strangle American fracking through a price war, is a catalyst for forcing innovation.[10] Such would be the case with the regulatory War on Coal, which may have helped spur the development of technology that contributed to the now-apparent substitution of natural gas for coal as the largest source of electricity generation in the United States.

---

[8] Note that some of the energy efficiency improvements are due to regulations requiring increased efficiency. See the summary conclusion of EIA's February 2015 study, "Drivers of U.S. Household Energy Consumption, 1980-2009" (2015).

[9] Such costs are explored in the research done by Institute of Political Economy at Utah State University in the *Unseen Costs of Electricity* series.

[10] Particular thanks to one of my thesis committee members, Chris Fawson, for this insight.

This is likely due to the high demand for energy. As technology is increasingly available to more and more people, and as more and more households obtain energy-consuming devices, the demand for energy increases. It may be that regulation meant to metaphorically plug a hole in a leaking dam causes innovators to find new ways to get around the dam, to the effect that technological development swamps the burdensome effect of regulation.[11]

[11] In the literature on the effects of regulation on the economy, this proposition may appear heretical, but it is worth considering.

CONCLUSION

As mentioned earlier, the surprising finding of my research is that an increase in regulation does not have the direct effect on electricity prices or on residential energy burden that I expected it to have. This finding does not mean that theory is wrong and that the relationship does not exist, but rather that further research is needed to determine whether theory is borne out in reality.

My research resulted in some additional surprising findings. The first indicates that federal subsidies for low-income housing may distort the housing market so that, on the margin, families that are unprepared to shoulder the cost of living on their own are incentivized to do so, and then become trapped in a cycle of poverty because they struggle to pay for their energy bills and end up living with a high energy burden.

The second additional finding is that, in at least some instances, regulation may spur innovation. The fairly constant prices of electricity and declining natural gas prices, despite increasing regulation and an increase in the number of devices using energy, indicate that something is happening to keep the price of energy stable when the demand for it is rising. Whether that is a result of competition-driven innovation, a result of regulation-driven innovation, or a combination of the two and some other factors, is yet to be determined.

REFERENCES

Al-Ubaydli, Omar, and Patrick McLaughlin. 2017. “RegData: About.” *regdata.org*. Mercatus Center at George Mason University. 2017. http://regdata.org/about/.

Al-Ubaydli, Omar, and Patrick McLaughlin. 2017. “RegData: A numerical database on industry-specific regulation for all United States industries and federal regulations, 1997-2012.” Regulation & Governance, doi: 10.1111/rego/12107. http://regdata.org.

Applied Public Policy Research Institute for Study and Evaluation and Fisher, Sheehan, and Colton. 2007. “Ratepayer-Funded Low-Income Energy Programs: Performance and Possibilities.” July 2007. http://www.appriseinc.org/reports/NLIEC%20Multi-Sponsor%20Study.pdf.

Baranzini, Andrea, Jose Goldemberg, and Stefan Speck. 2000. “A future for carbon taxes.” Ecological Economics. Volume 32, Issue 3. March 2000. 395-412. ISSN 0921-8009. Accessed online through the Utah State University Library April 21, 2017.

Bhattacharya, Jayanta, Thomas DeLeire, Steven Haider, and Janet Currie. “Heat or Eat? Cold-Weather Shocks and Nutrition in Poor American Families.” *American Journal of Public Health* V. 93(7). July 2003. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1447925/.

Chambers, Dustin, and Courtney Collins. 2016. “How Do Federal Regulations Affect Consumer Prices.” *Mercatus Center at George Mason University*. February 2016. https://www.mercatus.org/system/files/Chambers-How-Regs-Affect-Prices-v2.pdf.

Dinan, Terry, and Diane Lim Rogers. 2002. “Distributional Effects of Carbon Allowance Trading: How Government Decisions Determine Winners and Losers.” National Tax Journal. 55, no. 2: 199-221. Accessed online through the Utah State University Library April 21, 2017.

Division of Energy Assistance. 2016. “LIHEAP Home Energy Notebook For Fiscal Year 2014.” *U.S. Department of Health and Human Services*. June 2016. https://www.acf.hhs.gov/sites/default/files/ocs/hen_final_508_compliant_fy14.pdf.

Division of Energy Assistance. n.d. “Low Income Home Energy Assistance Program: Report to Congress for Fiscal Year 2014.” *U.S. Department of Health and Human Services*. https://www.acf.hhs.gov/sites/default/files/ocs/fy14_liheap_rtc_final.pdf.

Drehobl, Ariel and Lauren Ross. 2016. "Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low Income and Underserved Communities." *Energy Efficiency for All*. April 2016. http://energyefficiencyforall.org/sites/default/files/Lifting%20the%20High%20Energy%20Burden_0.pdf.

Fisher Sheehan & Colton. 2016. "Introduction." *homeenergyaffordabilitygap.com*. Accessed December 6, 2016. http://www.homeenergyaffordabilitygap.com/index.html.

Fisher Sheehan & Colton. 2017. "The Data: Affordability Gap Data." homeenergyaffordabilitygap.com. Accessed October 10, 2017. http://www.homeenergyaffordabilitygap.com/03a_affordabilityData.html.

International Energy Agency. 2016. "Energy and Air Pollution." *iea.org*. https://www.iea.org/publications/freepublications/publication/WorldEnergyOutlookSpecialReport2016EnergyandAirPollution.pdf.

International Energy Agency. 2017. "Energy Access." *iea.org*. http://www.iea.org/energyaccess/.

International Energy Agency. 2017. "Glossary." *iea.org*. http://www.iea.org/about/glossary/e/.

Gould, William. n.d. "What is the between estimator?" *STATA*. Accessed April 25, 2017. http://www.stata.com/support/faqs/statistics/between-estimator/.

Hernandez Diana and Stephen Bird. 2016 "Energy Burden and the Need for Integrated Low-Income Housing and Energy Policy." American Journal of Public Health. April 4, 2016. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4819257/#FN1.

LIHEAP Clearinghouse. n.d. "Low-Income Energy Programs Funding History 1977-2016." *U.S. Department of Health and Human Services*. Accessed September 30, 2017. https://liheapch.acf.hhs.gov/Funding/energyprogs_hist.htm#three.

National Energy Assistance Directors' Association. "2011 National Energy Assistance Survey Summary Report." November 2011. http://neada.org/wp-content/uploads/2013/05/FINAL_NEADA_2011_Summary_Report1.pdf.

National Energy Assistance Directors' Association. 2017. "Statement in Response to the Administration's FY 2018 Budget Proposal." *neada.org*. March 17, 2017. http://neada.org/wp-content/uploads/2013/03/PressReleaseFY18Budget.pdf.

O'Brien, Tracey, Laura Appelbaum, Christine Velez-Badar, and Beverly Buck. 2007. "Colorado Statewide Homeless Count." *University of Colorado at Denver and Health Sciences Center*. February 2007. http://www.ucdenver.edu/academics/colleges/SPA/researchandoutreach/Buechner%20Institute%20for%20Governance/Centers/CEPA/Publications/Documents/HomelessExecutive%20Summary-FINAL-2-27-07.pdf

Office of Community Services. 2016. "LIHEAP Frequently Asked Questions for Consumers: What is LIHEAP and how can LIHEAP help me?" U.S. Department of Health and Human Services. January 19, 2016. https://www.acf.hhs.gov/ocs/resource/consumer-frquently-asked-questions#Q12.

Oladosu, Gbadebo, and Adam Rose. 2007. "Income distribution impacts of climate change mitigation policy in the Susquehanna River Basin Economy." Energy Economics. Volume 29, Issue 3. May 2007. 520-544. ISSN 0140-9883. Accessed through the online Utah State University Library April 21, 2017.

Perl, Libby. 2015. "LIHEAP: Program and Funding." *Congressional Research Service*. July 29, 2015. http://neada.org/wp-content/uploads/2015/09/CRS-LIHEAP-Program-and-Funding.pdf.

Perl, Libby. 2015. "The LIHEAP Formula." *Congressional Research Service*. June 26, 2015. http://neada.org/wp-content/uploads/2015/09/CRS-LIHEAP-Formula.pdf.

Small, Laura. 2016. "Diving into the Legal Action Against the Clean Power Plan (Part 1)." *Environmental and Energy Study Institute*. March 2, 2016. http://www.eesi.org/articles/view/diving-into-the-legal-action-against-the-clean-power-plan.

Sowell, Thomas. "Basic Economics: A Common Sense Guide to the Economy." Blackstone Audio, Inc. *audible.com*. 5th edition.

Thomas, Diana. 2012. "Working Paper: Regressive Effects of Regulation." Mercatus Center, George Mason University. November 2012. https://www.mercatus.org/system/files/RegressiveEffects_Thomas_v1-0.pdf.

U.S. Bureau of Economic Analysis. "Regional Data: SA1 Personal Income Summary: Personal Income, Population, Per Capita Personal Income." *bea.gov*. Accessed February 21, 2017. https://www.bea.gov/itable/iTable.cfm?ReqID=70&step=1#reqid=70&step=30&isuri=1&7022=21&7023=0&7033=-1&7024=non-industry&7025=0&7026=xx&7027=2016,2015,2014,2013,2012,2011,2010,2009,2008,2007,2006,2005,2004,2003,2002,2001,2000,1999,1998,1997,1996,1995,1994,1993,1992,1991,1990,1989,1988,1987,1986,1985,1984,1983,1982,1981,1980&7001=421&7028=-1&7031=0&7040=-1&7083=levels&7029=21&7090=70.

U.S. Bureau of Labor Statistics. n.d. "Local Area Unemployment Statistics: County Data." *bls.gov*. Accessed January 20, 2017. https://www.bls.gov/lau/#tables.

U.S. Department of Energy. 2017. "Weatherization Assistance Program." *energy.gov*. August 2017. https://energy.gov/sites/prod/files/2017/05/f34/wap_factsheet_08.2017.pdf.

U.S. Energy Information Administration. 2017 "State Energy Data System (SEDS): 1960-2014 (complete)." *eia.gov*. June 29, 2017. https://www.eia.gov/state/seds/seds-data-complete.php?sid=US.

U.S. Energy Information Administration. "Drivers of U.S. Household Energy Consumption, 1980-2009." eia.gov. February 2015. https://www.eia.gov/analysis/studies/buildings/households/pdf/drivers_hhec.pdf.

U.S. Energy Information Administration. 2016. "Electricity Explained: Factors Affecting Electricity Prices." *eia.gov*. Last reviewed: November 25, 2016. https://www.eia.gov/energyexplained/index.cfm?page=electricity_factors_affecting_prices.

U.S. Energy Information Administration. 2013. "Energy sources have changed throughout the history of the United States." *eia.gov*. July 3, 2013. https://www.eia.gov/todayinenergy/detail.php?id=11951.

U.S. Energy Information Administration. 2013. "Energy Use in Homes." *eia.gov*. February 5, 2013. https://www.eia.gov/energyexplained/index.cfm/data/index.cfm?page=us_energy_homes.

U.S. Energy Information Administration. n.d. "Natural Gas." *eia.gov*. Accessed January 2017. https://www.eia.gov/naturalgas/data.php#prices.

U.S. Energy Information Administration. 2016. "Natural Gas Explained: Factors Affecting Natural Gas Prices." *eia.gov*. Last updated: August 29, 2016. https://www.eia.gov/energyexplained/index.cfm?page=natural_gas_factors_affecting_prices.

U.S. Energy Information Administration. "RECS data show decreased energy consumption per household." eia.gov. June 6, 2012. https://www.eia.gov/consumption/residential/reports/2009/consumption-down.php.

U.S. Energy Information Administration. n.d. "Total Energy: Table 7.2a Electricity Net Generation: Total (All Sectors)." *eia.gov*. Accessed September 5, 2017. https://www.eia.gov/totalenergy/data/browser/?tbl=T07.02A#/?f=A.

U.S. Energy Information Administration. n.d. "Total Energy: Table 9.8 Average Retail Prices of Electricity." *eia.gov*. Accessed September 5, 2017. https://www.eia.gov/totalenergy/data/browser/?tbl=T09.08#/?f=A.

U.S. Energy Information Administration. n.d. "Total Energy: Table 9.10 Natural Gas Prices." *eia.gov*. Accessed September 5, 2017. https://www.eia.gov/totalenergy/data/browser/?tbl=T09.10#/?f=A.

U.S. Energy Information Administration. 2017. "Use of Energy in the United States Explained." *eia.gov*. June 1, 2017. https://www.eia.gov/energyexplained/index.cfm?page=us_energy_use.

U.S. Environmental Protection Agency. 2015. "Regulatory Impact Analysis for the Clean Power Plan Final Rule." *epa.gov*. October 23, 2015. https://www.epa.gov/sites/production/files/2015-08/documents/cpp-final-rule-ria.pdf.

U.S. Government Publishing Office. 2016. "Applications and requirements." 42 *U.S. Code* Sec. 8624(b)(3), Accessed November 11, 2017. https://www.gpo.gov/fdsys/pkg/USCODE-2016-title42/pdf/USCODE-2016-title42-chap94-subchapII-sec8624.pdf.

Wooldridge, Jeffrey M. 2012. *Introductory Econometrics: A Modern Approach 5th Edition*. Ohio: South-Western CENGAGE Learning.

APPENDICES

Appendix A: Sample Models & Results

Modeling Regulation and State Energy Burden

To explore the puzzle of relatively constant energy prices and increasing regulation, I used the group energy burden approach to create a variable for state residential energy burdens. This variable does not allow me to explore how regulations affect the energy burden of households in different income groups, but does allow me to understand how regulations affect the residential energy burden at the state level aggregation. As a reminder, state energy burden = state residential energy expenditures / state aggregated personal income.

The Model

My research question has two parts:

1) How does regulation, and energy and environmental regulation in particular, affect the prices of electricity and natural gas?
2) Given the answers to my first question, how does regulation affect the state residential energy burden?

In order to understand the relationship between regulation and the prices of electricity and natural gas, and the relationship between regulation and the state residential energy burden, I controlled for additional variables that I believe affect the dependent variables. In addition to creating two variables for regulation—energy and environmental regulatory restrictions and all other regulatory restrictions—I added dummy variables indicating if and when a state instituted a Renewable Portfolio Standard (RPS), when the nation was in recession, and the presence of three EPA regulations: the Mercury and Air Toxics

Standards rule, the Clean Air Interstate Rule, and phases 1-3 of the Cooling Water Intake Structures rule.

In part one of this two-stage regression, I estimated the following:

Electricity Price = β0

+ β1 Energy & Environmental Regulatory Restrictions

+ β2 All Other Regulatory Restrictions

+ β3 Presence of EPA's Mercury & Air Toxics Standards Rule (dummy)

+ β4 Presence of EPA's Clean Air Interstate Rule (dummy)

+ β5 Presence of EPA's Cooling Water Intake Structures Rule, Phase 1 (dummy)

+ β6 Presence of EPA's Cooling Water Intake Structures Rule, Phase 2 (dummy)

+ β7 Presence of EPA's Cooling Water Intake Structures Rule, Phase 3 (dummy)

+ β8 Presence of a State RPS (dummy)

+ β9 Presence of a National Recession (dummy)

+ β10 Weather variable (perhaps number of heating or cooling days)

Natural Gas Price = β0

+ β1 Energy & Environmental Regulatory Restrictions

+ β2 All Other Regulatory Restrictions

+ β3 Presence of EPA's Mercury & Air Toxics Standards

Rule (dummy)

+ β4 Presence of EPA's Clean Air Interstate Rule (dummy)

+ β5 Presence of EPA's Cooling Water Intake Structures

Rule, Phase 1 (dummy)

+ β6 Presence of EPA's Cooling Water Intake Structures

Rule, Phase 2 (dummy)

+ β7 Presence of EPA's Cooling Water Intake Structures

Rule, Phase 3 (dummy)

+ β8 Presence of a State RPS (dummy)

+ β9 Presence of a National Recession (dummy)

+ β10 Weather variable (perhaps number of heating or

cooling days)

In step two of this regression analysis, I moved the electricity price and natural gas price variables to the right-hand side of the equation and used the state residential energy burden as the dependent variable:

State Residential Energy Burden = β0

+ β1 Environmental Regulatory Restrictions

+ β2 All Other Regulatory Restrictions

+ β3 Presence of EPA's Mercury & Air

Toxics Standards Rule (dummy)

+ β4 Presence of EPA's Clean Air Interstate

Rule (dummy)

+ β5 Presence of EPA's Cooling Water

Intake Structures Rule, Phase 1 (dummy)

+ β6 Presence of EPA's Cooling Water Intake Structures Rule, Phase 2 (dummy)

+ β7 Presence of EPA's Cooling Water Intake Structures Rule, Phase 3 (dummy)

+ β8 Presence of a State RPS (dummy)

+ β9 Presence of a National Recession (dummy)

+ β10 State Poverty Rate

+ β11 Price of Residential Electricity (cents/kWh)

+ β12 Price of Residential Natural Gas (dollars/thousand cubic feet)

Description of Variables and Summary Statistics

State Residential Energy Burden

As described earlier, the State Residential Energy Burden is equal to state residential energy expenditures divided by state aggregated personal income, where the state residential energy expenditure data are taken from the U.S. Energy Information Administration's State Energy Data System (2017) and the state aggregated personal income data are from the U.S. Bureau of Economic Analysis (n.d.).

The mean level of residential energy expenditures relative to income is two percent, with a standard deviation of one percent, and a minimum and maximum energy burden of one percent and five percent, respectively. Remember that the measure of an affordable residential energy bill I have chosen to use is six percent of income. This measure shows that, as a group, residents in each state have affordable energy bills. What this measure does not reveal, however, is how many households in each state pay more than an affordable measure of six percent of income. Thus, this variable is helpful in the energy poverty discussion, but does not provide a complete picture of the residential energy needs of those who are in energy poverty. See Table 4 for summary statistics.

Regulation

Omar Al-Ubaydli and Patrick McLaughlin, researchers from the Mercatus Center at George Mason University, developed a database called RegData (Al-Ubaydli and McLaughlin 2015) in order to improve the "measurement of regulations and the regulatory process" (Mercatus 2017). RegData measures the federal regulatory burden in two ways: (1) by word counts, and (2) by the number of explicit restrictions, which count the number of words in a regulation like "must" and "shall" that indicate a binding constraint on activity. Because a regulation can be wordy but not be particularly restrictive, I use the regulatory restriction data from RegData to measure the burden of regulation over time.

Al-Ubaydli and McLaughlin categorize regulation in two ways: (1) by agency, and (2) by the North American Industry Classification System (NAICS). NAICS is used by federal statistical agencies when "classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy" (U.S. Census 2017).

RegData uses the North American Industry Classification System to categorize the industries that a particular regulation is likely to affect. I created two variables for regulation using RegData: (1) regulatory restrictions relating to NAICS codes 21 (Mining, Quarrying, and Oil and Gas Extraction) and 22 (Utilities), and (2) all other regulatory restrictions. This was the most convenient method of classifying regulation as either falling into an "energy and environmental regulation" category or an "other regulation" category.

Because the regulatory restriction data I have is for federal regulation, and which I have therefore applied equally across each state, the mean and standard deviation summary statistics are not useful. Since 1980, the minimum number of regulatory restrictions was 28,327 for energy and environmental regulation and 416,558 for all other regulations. The maximum number of regulatory restrictions was 93,160 for energy and environmental regulation and 781,882 for all other regulations. See Table 4 for summary statistics.

Table 4: Summary Statistics

	Mean	Std. Deviation	Min	Max
State Residential Energy Burden	0.02	0.01	0.01	0.05
Environmental Regulatory Restrictions (2-Digit NAICS)	59962	19932	28327	93160
All Other Regulatory Restrictions (2-Digit NAICS)	572436	113673	416558	781882
MATS Implemented	0.11	0.32	0	1
CAIR Implemented	0.29	0.45	0	1
CWIS Phase 1 Implemented	0.4	0.49	0	1
CWIS Phase 2 Implemented	0.14	0.35	0	1
CWIS Phase 3 Implemented	0.26	0.44	0	1
State RPS	0.19	0.39	0	1
National Recession	0.23	0.42	0	1
Poverty Rate	0.13	0.04	0.03	0.27
Electricity Price (¢/kWh)	12.5	3.73	7.03	38.46
Natural Gas Price ($/1000 ft^3)	12.66	4.82	4.39	58.04

Specific Regulations

Even though I created variables to measure the burden of regulation using the regulatory restrictions count from the Mercatus Center's RegData, I was interested in seeing how particular regulations affected the dependent variables. I created dummy variables for the following regulations issued by the Environmental Protection Agency: the Mercury and Air Toxics Standards rule, the Clean Air Interstate Rule, and phases one through three of the Cooling Water Intake Structures rule.

In addition to the three regulations issued by EPA, it was important to account for regulations at the state level. As there is not currently a RegData-like database for regulations at the state level, I created a dummy variable for states that have a renewable portfolio standard (RPS) and turned the dummy variable on in the year that the RPS was implemented.

The summary statistics for these variables, presented above in Table 4, are not particularly useful, other than to note that my data set includes several decades of data before any of these regulations are implemented. With respect to RPS, over half of the states have had an RPS at some time, although not all states that previously had an RPS currently have one. States that have a non-mandatory RPS are not included as having an RPS.

National Recession

Because of the significance of the Great Recession, it seemed prudent to account for the effects of a recession on the residential energy burden. Recall that the energy burden is a ratio of energy expenditures to income. If energy expenditures remain constant, or fell only slightly, but income drops significantly, then the residential energy burden will increase significantly. This change in energy burden would, of course, not be a result of energy and environmental regulations but instead a loss of income. I used data from the National Bureau of Economic Research (2017).

Though the summary statistics for this variable are presented above in Table 4, they are not particularly useful. From 1980 to 2014, the United States had four recessions, the most significant of which was of course the Great Recession which began in 2008.

Poverty Rate

Though I used the national recession dummy variable to account for changes in income during a national recession, it is also important to account for the variation in economic activity that occurs within each state. For this, I chose to use the state poverty rate. When this variable is entered on the right-hand side of the equation for which the state residential energy burden is the dependent variable, it would make sense for this variable to have a positive and significant relationship with the state residential energy burden. If energy expenditures don't change commensurately with a decline in income, then an increase in the poverty rate would result in an increase in the residential energy burden, and therefore an increase in the number of people living in energy poverty. I used data from the U.S. Bureau of Labor Statistics (n.d.).

The mean poverty rate in the United States from 1980 to 2014 was 13 percent, with a standard deviation of four percent. The minimum poverty rate was three percent, for New Hampshire in 1986, and the maximum poverty rate of 27 percent occurred in Mississippi during 1988. See Table 4 (above) for summary statistics.

Prices of Electricity and Natural Gas

These two variables are both a dependent and an independent variable. In part one of my two-stage regression, I use both of these as dependent variables in order to understand the relationship between regulatory restrictions and the price of electricity and natural gas. In part two, I use these as independent variables in order to see how the relationship between regulatory restrictions and the prices of electricity and natural gas may carry through to the residential energy burden. Electricity price is measured in cents per kilowatt-hour and the price of natural gas is measured in dollars per thousand cubic feet. Data comes from the U.S. Energy Information System's State Energy Data System (2017).

As Figures 8 and 9 show, the residential prices of electricity and natural gas have been fairly constant since 1990, for electricity, and 1980, for natural gas. As Table 4 shows, the mean price of electricity was 12.5 cents/kWh, and the minimum and maximum prices were 7.03 and 38.46 cents/kWh, respectively. The mean price of natural gas was $12.66/thousand cubic feet, and the minimum and maximum prices were $4.39 and $58.04/thousand cubic feet, respectively.

Regulation and the Price of Electricity

Table 5 shows the results of the regression on electricity price outlined above.

Table 5: Electricity Price as the Dependent Variable

	Pooled OLS	Fixed	Between	Random
Intercept	24.5276 ***		10.9174 ***	21.6000 ***
	3.0383		0.6234	1.2995
Energy & Environmental Regulatory Restrictions (2 Digit NAICS)	0.0000 ^	0.0000 **		0.0000 **
	0.0000	0.0000		0.0000
All Other Regulatory Restrictions (2 Digit NAICS)	0.0000 ***	0.0000 ***		0.0000 ***
	0.0000	0.0000		0.0000
Mercury & Air Toxics Standards Rule	1.5173 ***	1.3934 ***		1.3953 ***
	0.4561	0.1827		0.1834
Clean Air Insterstate Rule	0.3948	0.7328 **		0.7276 **
	0.6169	0.2473		0.2483
Cooling Water Intake Structures Rule: Phase 1	-0.2026	-0.2854		-0.2841
	0.5617	0.2249		0.2258
Cooling Water Intake Structures Rule: Phase 2	-0.1119	-0.1415		-0.1410
	0.3500	0.1401		0.1407
Cooling Water Intake Structures Rule: Phase 3	1.2439 *	1.3640 ***		1.3621 ***
	0.6064	0.2428		0.2438
Renewable Portfolio Standard	3.0623 ***	0.5183 ***	6.0242 ***	0.5574 ***
	0.2628	0.1434	1.7120	0.1435
National Recession	0.1904	0.3079 *		0.3061 *
	0.3378	0.1353		0.1359
R^2	0.13	0.21	0.20	0.21

Significance Levels: ***: 0.001, **: 0.01, *: 0.05, ^: 0.1. N = 1275

The first regression is a pooled OLS model. In order to have consistent estimators in this model, however, any unobserved state effect must be uncorrelated with the regression explanatory variables (Wooldridge 2012, 460). If this is not true, the model will have "bias caused from omitting a time-constant variable" (Ibid.). Wooldridge also notes, however, that it can be helpful to estimate the model using pooled OLS, fixed effects, and random effects in order to "determine the nature of the biases caused by leaving the unobserved effect … entirely in the error term (as does pooled OLS) or partially in the error term (as does the RE transformation)" (Ibid., 494). Thus, I've used all three approaches Wooldridge mentions, plus the between effects approach, to analyze the data.

It is difficult to assert that any unobserved state effect is uncorrelated with the explanatory regression variables, especially in the case of whether a state has a renewable portfolio standard. Thus, it seems best to rely on the fixed, between, and random regression models to understand the effect of regulation on electricity price.

I use the fixed effects model to remove the unobserved state effects and get insight into the effect of an explanatory variable when that variable changes within a U.S. state (Gould n.d.). When the unobserved effects are removed, the fixed effects model uses a pooled OLS approach on "the time variation … within each cross-sectional observation" (Wooldridge 2012, 485). As long as the explanatory variables are strictly exogenous, "the fixed effects estimator is unbiased" and the error term "should be uncorrelated with each explanatory variable across all time periods" (Ibid., 485).

Figure 5 shows the results of using the fixed effects model when electricity price is the dependent variable. In this model, the explanatory variables that have a significant relationship to the price of electricity are: energy and environmental regulatory restrictions (0.01 significance), all other regulatory restrictions (0.001 significance), EPA's Mercury and Air Toxics Standards (MATS) rule (0.01 significance), EPA's Clean Air Interstate Rule (CAIR) (0.01 significance), phase three of EPA's Cooling Water Intake Structures (CWIS) rule (0.01 significance), a state renewable portfolio standard (RPS) (0.001 significance), and a national recession (0.05 significance).

In each instance that a variable is statistically significant at the 95 percent confidence level or higher, the relationship is positive. This indicates that, after removing the unobserved state effects, as regulation increases in a state, we can expect that the price of electricity will increase as well. The two-digit North American Industry Classification System code regulatory restrictions have a significant and positive, but very small association with an increase in the price of electricity (so small to be almost zero).

Specific regulations, however, rather than a count of all energy and environmental regulatory restrictions or all other regulatory restrictions, matter more than a count of regulatory restrictions. The implementation of MATS is associated with an increase in the price of electricity of 1.39¢/kWh, the implementation of CAIR with an increase in the price of electricity of 0.73¢/kWh, the implementation of phase three of CWIS with an increase in the price of electricity of 1.36¢/kWh, and the implementation of a state RPS with an increase in the price of electricity of 0.52¢/kWh.

The between estimation allows me to obtain OLS estimators "on the cross-sectional equation[s]" (Wooldridge 2012, 485) and provides insight into the effect of an explanatory variable when that variable changes between states (Gould n.d.). Wooldridge cautions, however, that though between estimation provides insight into the cross-sectional variation, it "ignores important information on how the variables change over time" and will be biased when the unobserved state effects are correlated with the explanatory variables (2012, 485). Still, the between effects results shown in Table 5 indicate that states with an RPS have associated electricity prices that are 6.02¢/kWh higher than states without an RPS. Though the between estimation may be biased, the direction and magnitude of the result suggest that state energy and environmental policies are a significant component of electricity price.

If I assume that the unobserved state effects are "uncorrelated with each explanatory variable in all time periods," (Ibid., 492) then I can use the results of the random effects estimation included in Table 5. Wooldridge notes that random effects estimation has an advantage over the fixed effects approach because it "assumes that the unobserved effect is uncorrelated with all explanatory variables, whether the explanatory variables are fixed over time or not" (Ibid., 493).

In the random effects estimation, the energy and environmental regulatory restrictions variable and the all other regulatory restrictions variable are significant at 0.01 and 0.001, respectively, and are positive but so small as to almost be zero. As with the fixed effects estimation, it appears that the implementation of specific regulations matter more than the total regulatory burden: MATS is associated with an increase in the price of electricity of 1.4¢/kWh, CAIR with an increase of 0.73¢/kWh, phase three of the Cooling Water Intake Structures rule with an increase of 1.36¢/kWh, and a state RPS with an increase of 0.56¢/kWh.

The story most consistent with the observations from the regressions in Table 5 is that an increase in regulations is associated with an increase in the price of electricity, but that some regulations matter more than others.

Regulation and the Price of Natural Gas

Table 6 shows the results of the regression on natural gas price outlined above.

Table 6: Natural Gas Price as the Dependent Variable

	Pooled OLS	Fixed	Between	Random
Intercept	19.9349 ***		11.8217 ***	18.7852 ***
	2.7858		0.8065	1.2544
Energy & Environmental Regulatory Restrictions (2 Digit NAICS)	0.0000	-0.0001 ***		-0.0001 ***
	0.0000	0.0000		0.0000
All Other Regulatory Restrictions (2 Digit NAICS)	0.0000	0.0000 *		0.0000 *
	0.0000	0.0000		0.0000
Mercury & Air Toxics Standards Rule	-1.7353 ***	-1.7274 ***		-1.7275 ***
	0.4793	0.1920		0.1921
Clean Air Insterstate Rule	2.3953 **	2.6653 ***		2.6629 ***
	0.7748	0.3107		0.3110
Cooling Water Intake Structures Rule: Phase 1	3.3813 ***	3.4369 ***		3.4364 ***
	0.6235	0.2497		0.2499
Cooling Water Intake Structures Rule: Phase 2	0.7702 ^	0.7029 ***		0.7035 ***
	0.4059	0.1626		0.1627
Cooling Water Intake Structures Rule: Phase 3	0.6294	0.7769 ***		0.7757 **
	0.7434	0.2979		0.2981
Renewable Portfolio Standard	1.4365 ***	-0.2590	4.3980	-0.2443
	0.3286	0.1650	2.9640	0.1649
National Recession	-0.4442	-0.4409 ***		-0.4410 ***
	0.2860	0.1145		0.1146
R^2	0.15	0.51	0.04	0.51

Significance Levels: ***: 0.001, **: 0.01, *: 0.05, ^: 0.1. N = 1275

The analysis of the effect of regulation on the price of electricity generally carry over to the effect of regulation on the price of natural gas, but with some important differences. As Table 6 shows, a pooled OLS estimation approach indicates that total regulatory restrictions, either in the energy and environmental category or the all other category, don’t have a significant relationship to the price of natural gas.

The implementation of MATS, however, has a significant and negative relationship to the price of natural gas: -$1.74/thousand cubic feet. This is likely explained by two factors: (1) MATS and other EPA regulation that made coal more expensive facilitated demand for natural gas, and (2) the development of fracking technology that greatly increased the accessible supply of natural gas.

The fixed and random effects estimations are very similar and so I discuss them concurrently. Energy and environmental regulatory restrictions are significant at 0.001 and have a very small and negative association with the price of natural gas. This is likely, as mentioned in the preceding paragraph, a result of regulation that targeted coal, and therefore facilitated demand for natural gas, and the exogenous influence of the increase in natural gas supply due to the fracking boom.

CAIR and phases one through three of the CWIS rule have significant and positive associations with the price of natural gas, with a corresponding increase in the price of natural gas from as low as $0.70/thousand cubic feet to as high as $3.44/thousand cubic feet. Additionally, and in contrast to the regressions using the price of electricity as the dependent variable, a state RPS is not significantly associated with the price of natural gas. This likely has to do with the design of an RPS—it is meant to encourage the development of renewable and alternative energies, and natural gas is not directly targeted in the regulation and so is unaffected.

Regulation and the State Residential Energy Burden

Table 7 shows the results of the regression on state residential energy burden, outlined above.

Table 7: State Residential Energy Burden as the Dependent Variable

	Pooled OLS	Fixed	Between	Random
Intercept	0.0376 ***		0.0205 ***	0.0293 ***
	0.0038		0.0036	0.0016
Energy & Environmental Regulatory Restrictions (2 Digit NAICS)	0.0000 ^	0.0000 ***		0.0000 ***
	0.0000	0.0000		0.0000
All Other Regulatory Restrictions (2 Digit NAICS)	0.0000 ***	0.0000 ***		0.0000 ***
	0.0000	0.0000		0.0000
Mercury & Air Toxics Standards Rule	0.0002	0.0002		0.0002
	0.0006	0.0002		0.0002
Clean Air Insterstate Rule	0.0036 ***	0.0024 ***		0.0024 ***
	0.0007	0.0003		0.0003
Cooling Water Intake Structures Rule: Phase 1	0.0021 **	0.0016 ***		0.0016 ***
	0.0007	0.0002		0.0002
Cooling Water Intake Structures Rule: Phase 2	0.0006	0.0005 **		0.0005 **
	0.0004	0.0001		0.0001
Cooling Water Intake Structures Rule: Phase 3	0.0009	0.0002		0.0003
	0.0007	0.0003		0.0003
Renewable Portfolio Standard	-0.0014 ***	0.0008 ***	-0.0045 ^	0.0008 ***
	0.0003	0.0001	0.0024	0.0001
National Recession	0.0009 *	0.0007 ***		0.0007 ***
	0.0004	0.0001		0.0001
Poverty Rate	0.0099 **	0.0198 ***	0.0015	0.0199 ***
	0.0033	0.0024	0.0181	0.0024
Electricity Price	0.0003 ***	0.0006 ***	0.0003	0.0006 ***
	0.0000	0.0000	0.0002	0.0000
Natural Gas Price	-0.0002 ***	0.0000 ^	-0.0002	0.0000
	0.0000	0.0000	0.0002	0.0000
R^2	0.13	0.59	0.09	0.57

Significance Levels: ***: 0.001, **: 0.01, *: 0.05, ^: 0.1. N = 1275

Part two of my analysis was to use the state residential energy burden variable as the dependent variable and move the electricity price and natural gas price variables to the right-hand side of the equation. I did this to understand, first, how regulations affect the prices of the electricity and natural gas used for residential energy and, second, how regulations and the prices of electricity and natural gas affect the energy burden.

The pooled OLS estimation results in Table 5 indicate that regulatory restrictions and specific regulations are significantly associated with changes in the state residential energy burden. Of more interest, however, are the results of the fixed and random effects estimations.

Both the fixed and random effects estimations indicate a significant (0.001) and positive relationship between an increase in the number of regulatory restrictions, energy and environmental and all other, but that, as seen in Tables 5 and 6, the estimate is so small as to be almost zero. This means that though I find that the direction of my hypothesis is correct—energy and environmental regulation and all other regulation does have a positive relationship with the energy burden—the magnitude is very small. I conclude that regulatory restrictions are associated with an increase in the state residential energy burden, but that at the group level the increase is so small that it does not appear to be economically significant.

Though MATS had a significant relationship on the prices of electricity and natural gas, it does not have a significant relationship with the state residential energy burden. MATS, therefore, may only have a significant relationship to the state residential energy burden through the prices of electricity and natural gas.

CAIR has a significant relationship (0.001) with the state residential energy burden, but its implementation is associated with a small increase in the state residential energy burden of 0.24 percent.

Where phase three of the CWIS rule had a significant relationship with the prices of electricity and natural gas, it has no significant relationship to the state residential energy burden. Rather, phases one and two have significant relationships (0.001 and 0.01, respectively) and the implementation of each phase of CWIS is associated with an increase in the state residential energy burden of less than one percent.

A state RPS and a national recession are associated with similar changes in the state residential energy burden (0.08 and 0.07 percent, respectively).

Though regulations are associated with an increase in the prices of electricity and natural gas, only the price of electricity has a significant (0.001) relationship to the state residential energy burden in both the fixed and random effects estimations. Natural gas is significant (0.05) in the fixed effects estimation but not the random estimation. Electricity price is associated with a small, but positive, change in the state residential energy burden of 0.06 percent and, in the fixed effects model, natural gas price is associated with a small, almost zero, but positive change in the state residential energy burden.

Modeling Regulation and Group Household Energy Burden

In my empirical analysis, I developed three measures of energy burden: state energy burden (discussed above), group household energy burden, and group household energy burden using national income quintiles.

I've previously discussed the results of my econometric analysis of regulation, electricity and natural gas prices, and the state energy burden. The regression estimates for the group household energy burden and the group household energy burden using national income quintiles are so similar to the econometric analysis of the state energy burden that discussing the conclusions here would be unnecessarily repetitive. I will, however, briefly explain the additional measures of energy burden I developed before concluding.

Group Household Energy Burden

As an additional approach to measuring residential energy burden, I used a group approach, where I assumed that residential energy expenditures are distributed equally across all households within each state and that each household had an income equal to the state median income. As is quickly apparent, such assumptions don't describe the reality of households living with high energy burdens.

I calculated the group household energy burden as follows: I calculated the household residential energy burden by setting it equal to household residential energy expenditures divided by state median income, where household residential energy expenditures were equal to state residential energy expenditures divided by the number of households in the state.

Group Household Energy Burden (using National Household Income Quintiles)

Because the group household energy burden I described above, by nature of the calculation, erases the variability of household energy burden, I used an additional measure to show the energy burden for households at different incomes levels. Like the measure I described above, this measure also assumes that residential energy expenditures are distributed equally across all households within a state, but the household income is divided into the average household income for each income quintile (from national quintile data).

Though this measure doesn't reflect actual individual household energy burden, it is intuitively a more meaningful measure than the group household energy burden approach above. Using this measure, the residential energy burden for households at the lowest income quintile is 15-20 percent of household income, while less than one percent of household income for those in the highest quintile.

Recall that an affordable measure of household energy burden is six percent of household income and a measure for a high energy burden is eleven percent of household income. This approach then indicates that households in the lowest income quintile live with high energy burdens and households in the second lowest income quintile have burdens that put them above the six percent threshold.

I calculated the group household energy burden, using national income quintiles, as follows: I calculated the household energy burden for each income quintile by setting it equal to household residential energy expenditures divided by household income at the given income quintile, where household residential energy expenditures equals state residential energy expenditures divided by the number of households in the state.

Conclusion

Though I used three measures of group energy burden in my regression analyses, each with different strengths and weaknesses, the results were consistent and so I did not include the results for the second two measures.

Taken together, the regression results shown in Tables 5, 6, and 7 suggest that an increase in regulation is associated with an increase in the price of electricity, an increase in regulation is sometimes associated with an increase in the price of natural gas, an increase in the price of electricity is associated with a small increase in the state residential energy burden, the price of natural gas does not appear to have an economically significant association with the state residential energy burden, and that an increase in regulation has a small but positive association with an increase in the state residential energy burden.

Additionally, the regressions indicate that though regulation as a whole is associated with a very small, almost zero, increase in the state residential energy burden, some regulations are more burdensome than others. Thus, it may be more helpful to say that certain energy and environmental regulations are significantly associated with increases in the energy burden rather than to say that energy and environmental regulations as a combined whole significantly affect energy burden.

These conclusions are of limited usefulness, however, and their real value is in indicating that the relationship between regulation, energy prices, and energy burden is complicated. Further research is needed.

Appendix B: Further Research

My research resulted in more questions than answers. Because few economists have studied energy poverty, an opportunity exists for someone, or a handful of people, to have significant influence in this intersection of poverty, regulatory policy, and energy and environmental policy. The following is a list of research ideas I thought of while exploring my research question.

State regulation and household energy burden

Although I controlled for the presence of a state Renewable Portfolio Standard using a dummy variable that I switched on in the year the RPS was enacted, I did not explore how state energy and environmental regulations may affect energy burdens. Such an analysis would be a valuable addition to the study of regulation and energy poverty, mostly because the state-by-state variation could be captured more adequately. It may be helpful to begin with case studies of states with many energy and environmental regulations, such as California, and compare them to states that depend heavily on coal, such as Wyoming or West Virginia.

Household transportation energy burden

I restricted my analysis of the household energy burden to residential energy expenditures (electricity and natural gas). Residential energy expenditures are not the only component of a household's total energy burden, however, and so studying the energy burden for households in the transportation sector may be a fruitful avenue for research.

Household total energy burden

Total household energy burden is the household energy burden in the residential and transportation sectors. Understanding how households choose to allocate resources to residential versus transportation energy needs may shed light on how regulations affect consumer behavior.

Low-Income Housing Energy Assistance Program (LIHEAP)

Studying the history of LIHEAP and how and when funds are allocated to the states may be interesting research, especially from a Public Choice viewpoint. Research might include identifying the states that tend to receive the most funding and how logrolling in Congress affects funding amounts and allocations.

Additional research might include studying the efficiency of LIHEAP allocations and whether the program is operating as originally intended.

Effect of wind and solar energy growth on household energy burdens

Running a regression like I've done above, but doing so by state (or utility system), with yearly data points for total state (or utility) megawatts of wind and solar, relative to annual average transmission and distribution charges on consumer bills, may show a strong relationship.[12]

---

[12] This suggestion came from Steve Lomax, Director of Environmental Affairs at Koch Industries, Inc. I was put in contact with him after I spoke to someone asking for help understanding how regulation affects utilities.

Energy efficiency

Energy Efficiency for All claims that "low-income households, renters, African-American households, and Latino households paid more for utilities per square foot than the average household, indicating that they reside in less efficient housing" (Drehobl and Ross 2016, 4). The relationship between energy efficiency and energy poverty may be worth pursuing.

The masking effect of subsidies

Another area of research that would be helpful, though challenging, is working to understand how subsidies distort price signals. Understanding the magnitude of subsidies awarded to the energy sector and how those subsidies, as a hidden cost, disguise the real cost of any given energy source would be useful in the energy and environmental policy discussion. This research ties into energy poverty and the regressive effect of regulation literature if it shows that consumers pay more (through energy bills and taxes) and thus have less buying power.[13]

In addition to the effect of subsidies to the energy sector, another line of research would pursue the effect of subsidized housing programs on home energy burdens. If, for example, housing policies that lower the cost of rent are not commensurately accompanied by policies that subsidize the price of residential energy, then drawing more

[13] This idea is akin to research published by the Institute of Political Economy at Utah State University on the hidden costs of wind-, solar-, coal-, and natural-gas generated electricity.

people into housing they would otherwise not be able to afford would lead to an increase in the number of households living with a high energy burden.[14]

[14] This idea was spurred by Hernandez and Bird's section on the split incentive problem in their 2016 publication "Energy Burden and the Need for Integrated Low-Income Housing and Energy Policy."