THE REGIONAL GREENHOUSE GAS INITIATIVE: A THREE-ARTICLE STUDY ON THE DECISION TO JOIN AND THE IMPACTS OF A CAP AND TRADE MARKET

by

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ABSTRACT

BRIAN KENNETH JONES. The Regional Greenhouse Gas Initiative: A Three-Article Study on the Decision to Join and the Impacts of a Cap and Trade Market (Under the direction of Dr. SUZANNE LELAND)

This dissertation takes an interdisciplinary view of the Regional Greenhouse Gas Initiative (RGGI) carbon dioxide cap and trade market. Specifically, I analyze both the factors contributing to state participation within the Initiative and the multilevel impacts of the policy on specific outcomes. In the first article, I examine the factors that explain a state's decision to opt into the voluntary carbon market. I conduct the analysis using both Cox proportional hazards and longitudinal logistic models. The results demonstrate a complex array of factors affecting this decision. First, I find a non-monotonic relationship between per-capita gross state product and the likelihood to join. Results show diminishing effects on the linear term, and positive effects on the quadratic term, creating a relationship between affluence and environmental protection demonstrated by the environmental Kuznets curve. Next, states with more liberal elected state-level officials are more likely to opt into the market. Finally, the likelihood of membership decreases significantly as distance from the policy inventor (New York) increases.

In the second article, I identify the impact of participation in the RGGI on state-level carbon emissions from the power sector. I use a longitudinal panel fixed effects OLS model, and use states with deregulated electricity markets for comparison. I find that participation alone does not lead to lower emissions relative to the comparison group.

Instead, only member states with more liberal government ideologies will see a diminishing in annual emissions.

In the final article, I examine the impacts of participation in the RGGI on the adoption of an array of emission abatement strategies. I identify these impacts using longitudinal panel fixed effects and negative binomial regression models. I find evidence that power plants covered by the RGGI are no more likely to invest in heat-rate improving technology than their comparison group counterparts. I do find evidence that power plants covered by the RGGI are switching away from coal and toward other fuel sources at a higher rate than the comparison group. Finally, I find evidence that power plants covered by the RGGI are no more likely to close coal-fired generating units than the comparison group. I conclude that while the implementation of a cap and trade market is seen by many as a means to attenuate further contributions to global climate change, the impacts of the policy on adaptation strategies within the power sector are weaker than expected.

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DEDICATION

I dedicate this dissertation to the people who, simply put, got me here. Each one of these people embodies all of the things, both tangible and intangible, giving meaning to the word ‘family.’ First, to my wife, Sarah: thank you all of your patience, love, and understanding as I navigated the ups and downs of graduate school. Next, to my parents, Jeff and Debbie: you instilled a love of learning in all of three boys, one that will continue beyond our decades in school. Finally, to my brothers, Curt and Dave: the progress that both of you are making as adults continues to be an inspiration for me.

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INTRODUCTION

Climate Change Policy

The problem of anthropogenic, or human-caused, climate change is a problem facing the entire human population, and one that partially results from a failure of private markets to account for the full social costs of activities that generate greenhouse gases. In 2014, the Intergovernmental Panel on Climate Change (IPCC) released its fifth assessment report in which it contends that continued expulsion of anthropogenic carbon dioxide into the atmosphere at current rates will drive the mean global temperature up 2° Celsius or higher from pre-industrial levels (IPCC, 2014). According to the long-run models, this elevated temperature will result in an accelerated pace of glacial melt and regional climate shifts, among other effects, and will ultimately generate steep costs for human populations. Some of these effects are already observable today. [1] Among the more prominent are an increased occurrence of heat wave-related death, malnutrition caused by shifting agricultural production, and spreading patterns of infectious disease (Patz et al., 2005). Estimates of the economic costs of climate change impacts range anywhere from $55 - $140 billion annually to the US alone

[1] Changes in global ocean currents and rising sea levels are believed to have had direct effects on regional fish populations (Mooney, 2015).

(Nordhaus and Boyer, 2000). While studies of the current impacts of climate change continue, the majority of concern over the impacts of climate change is fixed on the future (Dasgupta et al., 2013; Wheeler and von Braun, 2013). The gradual pace of sea-level rise threatens lower lying countries, as does the intrusion of salt water into drinking water sources. Climate scientists almost unanimously argue that current human emissions of CO_2 need to diminish significantly in order to prevent a more accelerated change. In response to these dire warnings, policymakers have begun implementing policies designed to reduce emissions related to human activity.

The impetus for establishing climate policy began at the international level with the First World Climate Conference (FWCC) of 1979. Instead of a meeting of world leaders, the FWCC brought together scientists concerned about the effects that climate change would have on human living conditions (UNFCC, 2014). Over the course of the next decade, these concerns from the scientific community began to bleed into the public's consciousness and ultimately the international narrative, as evidence that the emission of chlorofluorocarbons was creating a hole in the ozone layer became a prominent feature in news cycles (Bodansky, 2001). Per Daniel Bodansky:

> By the end of 1988, global environmental issues were so prominent that *Time* magazine named endangered Earth "Planet of the Year."

These findings, coupled with increased public worry on the issue, sparked the international community into action from the late 1980s on. In 1990, the United Nations' Intergovernmental Panel on Climate Change (IPCC) released its first report on the current and expected impacts of a warming global climate. These reports would soon become the primary means through which the scientific community would nudge governmental leaders toward the development of climate policy. Around the same time as the first IPCC report, the member countries of the United Nations (UN) established the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC/FCCC). This group was tasked with drawing up a framework for addressing contributions to climate change upon which the UN member countries would agree. The work accomplished by this group ultimately led to the initiation of the formal United Nations annual climate change conferences, the first of which met in Berlin in 1995. The ultimate achievement from the first four climate conferences, referred to as Conferences of the Parties (CoPs), was the Kyoto Protocol, which was adopted in 1997. The protocol established country-specific emission targets, as well as provided mechanisms by which developing countries could fit into the system.[2]

While the Kyoto Protocol outlined commitments for all of the members of the United Nations, the effectiveness of the Treaty rested on the participation of the largest developed countries, primarily the United States and the European Union (Kahn, 2002). While the Clinton Administration signed the Treaty in 1998, the Senate refused its ratification. In 2001, the Bush Administration officially rejected the Treaty. According to President Bush:

> "As you know I oppose the Kyoto Protocol because it exempts 80 percent of the world, including major population centers such as China and India, from compliance, and would cause serious harm to the U.S. economy."

At this point, the Kyoto Protocol with the participation of the United States was dead. Other countries, including the European Union, began work to achieve reductions in

[2] http://unfccc.int/kyoto_protocol/items/2830.php

greenhouse gas emissions as outlined in the Protocol, but the United States was left with no federal plan.

It was at this point that state-level policymakers within the United States, frustrated with the decision of the Bush Administration to reject the Kyoto Protocol and the continued lack of enthusiasm at the federal level to address climate change, began developing and implementing climate policy (Revkin and Lee, 2003). In 2003, New York Governor George Pataki took the first steps towards establishing a regional emission-trading program by inviting the governors of other northeastern and mid-Atlantic states to participate (Huber, 2013). By 2005, governors from Vermont, New Jersey, New York, Delaware, Maine, Connecticut, and New Hampshire had signed onto what was called the Regional Greenhouse Gas Initiative (RGGI). Maryland, Massachusetts, and Rhode Island joined in 2007.

In order to establish a climate compact in the area, RGGI member states needed to unanimously agree on a single policy mechanism. The array of climate policy mechanisms available to the member states included renewable portfolio standards, land use regulations, energy efficiency standards, fuel economy standards, emission taxes, emission trading, and subsidies for green industries. The desired outcome from these policies is not simply a reduction in emissions, but also an eventual transition away from carbon-intensive (i.e. coal, petroleum, and natural gas), and toward renewable sources of energy (Shogren and Toman, 2000). Of these policies, economists and policy analysts tend to support emission trading as a means of controlling greenhouse gas emissions (Stavins, 2008). Emission trading is based on the logic of the Coase Theorem, which states that as long as transaction costs are negligible, problems of negative externalities can be solved without extensive governmental intervention by allocating and enforcing property rights (Coase, 1960). When property rights are clearly defined, deals can be made between parties to pay for either the reduction or cessation of the externality or for the right to continue generating the externality. Within an emission-trading program, property rights are typically reserved for the government, while emitting entities pay for the right to continue emitting greenhouse gases (Stavins, 2008). From a theoretical perspective, efficient regulation of greenhouse gas emissions involves setting the limit at the point where the marginal benefits of reducing emissions equal the marginal cost of abatement (Keohane and Olmstead, 2007). This point is demonstrated in Figure 1.

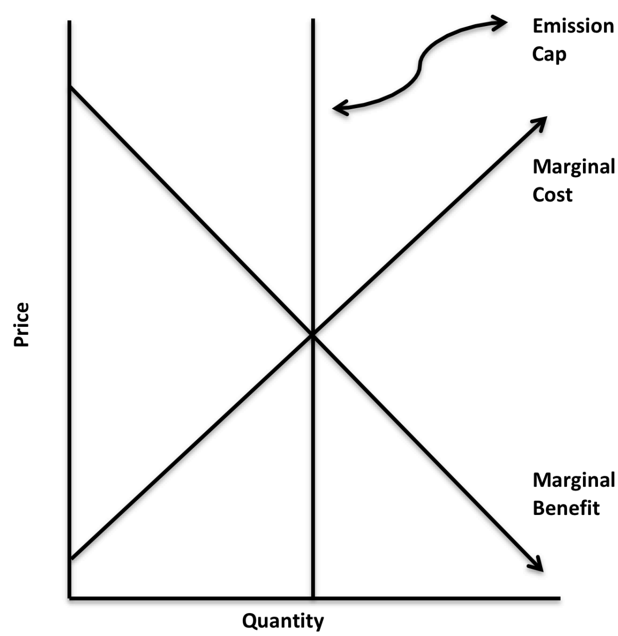

Figure 1: Strategic emission cap under emission trading program (abatement on X-axis). An outcome equivalent to an emission-trading program would occur if an emission tax were set equal to price at the intersection of the MC and MB curves.

Through either the process of inter-firm negotiation or bidding at auction, the final equilibrium permit price will equal the marginal cost of abating emissions. In an optimally designed program, the permit price will also equal the opportunity cost of damages caused by emissions (Muller and Mendelsohn, 2009). Because firms are able to select a response to the program based on unique compliance costs, economists find permit trading to be a cost-effective means of reducing emissions to an optimal level (Stavins, 2008; Muller and Mendelsohn, 2009). For this reason, policymakers in the RGGI member states opted to utilize emission trading as the foundation of the program.

In the formative years of the RGGI, the member states made the decision to auction permits instead of grandfathering, the method employed in the first phase of the European Union's Emission Trading Scheme. Proponents of the auction mechanism argued that states could counterbalance the impending electricity rate increases caused by emission trading by investing revenues from the permit auctions into energy efficiency programs (Huber, 2013). Since the activation of the exchange, several member states have been able to fill gaps in annual budgets with revenues from the sale of permits (Nearing, 2016). Auctions are held quarterly, with the RGGI Inc. office acting as the controlling agent of the auction platform. As described on the website, this office has no authority to regulate or enforce the agreement. Its sole purpose is to facilitate the implementation and maintenance of the exchange (RGGI).

In 2011, New Jersey Governor Chris Christie announced that he would be pulling his state out of the RGGI beginning in January of 2012. According to Christie, the state had been achieving prolific decreases in CO_2 emissions for reasons other than the exchange mechanism (Baxter, 2011). At the time of New Jersey's exit, permit prices were near the price floor of $1.83.[3] In June 2011, the time of Christie's decision, the total number of available permits was over 42 million. However, permit demand was low, and only 13 million were purchased. While New Jersey was the only state to leave the exchange, the remaining member states began to discuss further constricting the cap (State News Service, 2013). In 2013, the states amended the Memorandum of Understanding to restrict the 9-state emission limit to 91 million tons beginning in 2014. Beginning in 2014, the cap began to ratchet down by 2.5% annually. This diminishing of the cap will continue until 2020, at which point the cap will be locked at just over 78 million tons.

Roadmap for this Dissertation

In the ensuing three essays, I will examine several dimensions of the RGGI. The intent is to provide a unique and thorough analysis on the dynamic outcomes from the first emission-trading zone for carbon emissions in the United States. The first essay employs an event history model to examine the effects of key state-level variables on the decision to opt into the RGGI. The second essay examines the impact of the participation in the RGGI on state-level emissions between 2005 and 2013 using a panel fixed effects model. The third and final essay measures the impact of participation in the RGGI on emission abatement decisions made by power generating companies using a combination of panel fixed effects modeling, multilevel modeling, and panel-level Poisson regression.

[3] A floor price refers to a minimum threshold price for a permit. In the absence of a price floor, permit prices would have likely tended toward $0.

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ESSAY 1: STRENGTH IN NUMBERS AND THE DECISION TO JOIN AN EMISSION TRADING MARKET

INTRODUCTION

In August 2015, President Obama unveiled his administration's proposal for decreasing greenhouse gas emissions in the United States. The proposal, called the Clean Power Plan (CPP), presents rules by which states must align carbon dioxide emissions emissions from the electric power sector. Through the plan, the administration is seeking a 32% reduction in overall emissions by 2030 (FACT SHEET). While the reduction target is clearly defined, the means by which states achieve that target is self-determined. The CPP represents the first comprehensive federal policy designed to reduce carbon emissions in the United States.[4]

Prior to the CPP, the decision to reduce greenhouse gas emissions was deferred to the states. Without a federal mandate, states were not required on any level to adopt policies to reduce emissions. Curiously, a group of states did choose to work together to reduce emissions, an outcome that conflicts with the logic of game theory. The question at the core of this essay is why did these states decide to do so? The aim of this article is to identify the factors that explain these decisions.

Among the array of available policy options, one of the more popular is emission trading wherein power plants pay for the right to emit greenhouse gases. The first active

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[4] In 2011, the Environmental Protection Agency finalized the Cross State Air Pollution Rule that placed restrictions on coal and natural gas fired power plants in 28 upwind states. Several of the affected states challenged the rule, and in 2012, a federal appeals court ruled the EPA did not have sufficient authority to implement the rule. In 2014, the Supreme Court reversed this decision. While considered a success by advocates of environmental protection, the rule does not apply to the remaining 22 states. For more information, visit: http://www3.epa.gov/crossstaterule/.

interstate emission trading market for carbon emissions is the Regional Greenhouse Gas Initiative (RGGI). The RGGI, formed in 2005, is a compact of northeastern and mid-Atlantic states that originally targeted a 10% reduction from baseline emissions by 2020.

I employ both an event history analysis and longitudinal logit model to examine the effects of state-level conditions on the likelihood of the member states to join the RGGI market in the next period. I collect quarterly data on economic conditions, population, electricity generation, government ideology, and weather-related fatalities. The results suggest that government ideology and experience with climate events contribute positively to the likelihood that a state will opt in. I also find support for a non-monotonic relationship between rising per capita gross state product and the decision to join. In the coming sections, I cover the need for climate policy, a review of the policy adoption literature, the data and methods used in this essay, and results and concluding remarks, as well as the implications for future policy.

The Need for Climate Change Policy

In the developed world, quick and easy access to electric power is assumed. We expect to flip a switch and immediately have access to not only the daily comforts like climate controlled housing and lighting, but also the ability to communicate instantaneously with people around the world. All of these activities and functions share one common factor: electricity. Energy consumption is a vital and inextricable component of a vibrant and growing economy. Electricity is the most efficient and clean source of energy (Raugei and Leccisi, 2016). Given the importance of electricity to society, any regulations imposed on the sector will be felt in many other markets and sectors. Electricity production exists in a very unique type of market, one that has traditionally warranted extensive governmental intervention. The question we must ask is what regulations of the sector do we need?

Basic microeconomic theory finds that when conditions are optimal, private markets are the most efficient mechanism through which a nation can use its scarce resources to meet the aggregate needs of society. In these specific cases, economists recommend against regulating market activities. However, when one or more of these optimal conditions is challenged, these once efficient private markets may no longer respond to the proper signals, leading to either the overproduction or underproduction of market output. When private markets are no longer efficient, market failure is said to exist. When markets fail, economists suggest a role for government intervention.

Electricity production for residential, commercial, and industrial use occurs in a market that suffers from multiple suboptimal conditions that lead to market failures. These include negative externalities and natural monopoly. This paper focuses only on the former. From an environmental perspective, electricity production generates pollutants that contaminate regional air quality. Most of the contaminants of air quality (i.e. sulfur dioxide (SO_2), nitrogen oxide (NO_X), particulate matter, and mercury) result from using coal as a source fuel (Energy Information Agency). Electricity production may also emit carbon dioxide (CO_2) gas, which the vast majority of climate scientists believe to be a significant factor contributing to a global greenhouse effect (Oreskes, 2004). These carbon emissions stem from the use of coal, natural gas, and petroleum as source fuels.[5]

[5] Measuring the economic costs of the damages caused by the production of electricity is a complicated topic, and one that is not within the purview of this paper. The complexity of this subject stems from the imprecision of the methods used for generating a "market value" of damages. These methods include

While the impact of electricity production on air quality is more of a regional problem, increasing atmospheric concentrations of CO_2 are tied to global climate change, and therefore present a problem that traverses local, state, and national borders. CO_2 concentrations exist in the atmosphere for thousands of years. Methane has a stronger impact on the greenhouse effect than CO_2, but does not remain in the atmosphere nearly as long. For this reason, scientists recommend addressing carbon emissions more so than any other greenhouse gas (US EPA, 2015).

Earth's atmosphere is a true common good in that greenhouse gas emissions affect the global population, not just those people who benefit from the regional production of electricity that causes the emissions. Electricity markets, if left unregulated, will invariably fail to address the problem of greenhouse emissions because there is a lack of incentive to do so. According to Hardin, common goods will always suffer from overuse because no party can be prevented from using them, and none wish to incur the costs of preserving those resources (1968). The tragedy of the commons at its core is a problem of ill-defined and enforced property rights.

From a societal perspective, the power sector produces too much electricity because there is no incentive for power plants to reduce the negative atmospheric impacts. Without some form of governmental intervention, this overuse will likely continue due to the free-rider effect. Because none can be excluded from using the atmosphere, none can be prevented from enjoying the benefits that come when one party decides to reduce emissions in order to lessen the climate impact. This perverse incentive ensures a Nash equilibrium where each party, assuming no other party will act to reduce

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contingent valuation, hedonic pricing, travel cost measurement, and the use of measurable market impacts like crop damages.

emissions, maximizes benefits by continuing to emit greenhouse gases (Milinski et al. 2008). The aim of this article is to examine the factors that lead a particular state to overcome the inertia of the free-rider incentive by joining a collective market for CO_2 emissions.

Cap and Trade Markets for CO2 Emissions

Markets for carbon emissions are based in large part on the Coase Theorem, which argues that violations of common pool resources are best addressed by using markets so long as property rights are both assigned and enforced (Coase, 1960). As commonly implemented in existing markets preserving common resources, property rights are assigned to government, and the users of the common resource must pay for the right to continue their offending activity. While the mechanisms at work within a carbon market are logical and not in dispute, the problem of the free rider still seems to exist. That is, we know that cap and trade markets have the potential to work when properly applied (Stavins, 2008). The problem resides in finding the willingness to adopt this type of policy.

Under cap and trade policies, the governing body sets a limit on how much of a regulated greenhouse gas (CO_2 in the case of the RGGI) the affected party may emit in a given time period. Once the cap is set, it is then divided into units, typically tons of gas. These units are commonly referred to as permits or allowances, which means they give the holder the right to emit one ton of CO_2 per permit in a given time period. If the holder is found to have emitted more CO_2 than its allotted amount, it will be forced to pay a fine. In the case of the RGGI, these fines are levied by the states, not by the RGGI administrative body. Should the permit holder ultimately decide to emit fewer tons of gas than expected, it could then sell any excess permits to those firms that may not be able to economically reduce the amount of CO_2 they emit. Through the market, so long as the cap is set to the socially optimal level of emissions, the price the emitter is willing to pay for the right to emit should be equal to the marginal damage to the commons caused by production. The long run outcome under a carbon market should be a situation where firms with high costs of reducing emissions use the majority of total permits, for they will find it more cost effective to pay for permits rather than fines.

Cap and trade policies have been applied in a number of settings, the first notable incarnation being the Acid Rain Program established under the Clean Air Act of 1990 by the United States. Since that time, climate change has become much more of a hot button issue. In response to increasing consternation over emissions, the European Union opened the first cap and trade market for carbon emissions, referred to as the European Union Emission Trading Scheme (EUETS). The RGGI is distinguished from the EUETS and the Acid Rain Program in that it relies on a compact of state partners, whereas the former two were enacted at the federal level, and therefore require the participation of all states or countries. Essentially, the RGGI is voluntary and the other two are not.

The decision to join a program designed to detect and impose a price for CO_2 emissions has specific economic implications for the state (Newcomer et al., 2008). In the short run, CO_2 prices will increase marginal production costs, and therefore change the profit-maximizing rate of electricity production. This increase in production cost will lead to higher electricity rates, as consumers will pay for most of the increased costs assuming the typical relatively inelastic demand response (Spees and Lave, 2008). Utilities may be able to avert some of this price increase by dispatching units (i.e. using units for electricity generation as opposed to leaving them idle) with lower carbon reliance. These decisions will be made depending on the CO_2 price in tandem with the fuel price and start up costs (i.e. costs incurred ramping the plant up to levels capable of generating electricity for the grid) associated with the generating unit.

In the long run, utilities have many more options for handling the cost of carbon. These options are based in large part on market ready power generation technology. As carbon becomes more expensive, utilities will substitute renewable energy and natural gas technologies for the traditional coal fired units. Building a new fleet of generating units based on nascent technology poses some financial risks. Namely, the timing of when a utility decides to invest in new units has large cost implications. More established technologies tend to have lower cost curves due to continued innovation and refinement. Newer technologies, however, are not yet on par in a cost sense with the baseload technology already in operation. These newer technologies include not only wind turbines and solar panels, but also combined cycle gas plants and advanced coal where the intent is to maximize energy while minimizing emissions (US Energy Information Administration, 2015).

With electricity being such an integral factor of production in all developed economies, cap and trade markets for CO_2 emissions have enormous short run implications. Given these implications, it is interesting that some states have chosen to opt into the RGGI market. The question this situation poses is what features are unique to those RGGI member states that explain their willingness to join?

LITERATURE REVIEW

As mentioned in the introduction, electricity markets reliant on traditional coal fired power plants for production tend to cause market failure due to the negative externalities of poor air quality and impacts on global climate. However, it is important to consider that governmental action is a result of decisions made by individual policymakers, and that these decisions are made with conflicting incentives. Becker and Lindsey, in their study on state and local government contributions to charitable organizations, find support for their contention that governments do indeed exhibit the tendency to free ride (1994). In an article more related to the topic of this paper, Konisky and Woods find that states tend to enact fewer environmental enforcement actions in areas bordering foreign nations, effectively exporting unwanted pollution across borders (2010).

The free-rider effect exists whenever common goods exist, and states, through the actions of self-interested policymakers, are prone to the same behaviors as individuals as evidenced by the literature. In the case of climate change, lawmakers may perceive a reelection threat should they enact laws that impose costs on both ratepayers and power producers. At the same time, each state can benefit from the actions of others to reduce emissions regardless of their own participation. Should another state or nation decide to mitigate greenhouse gas emissions, any improvements in atmospheric gas concentrations would be shared by the world. Given these interacting incentives, the expected optimal short run decision for the policymaker is to avoid regulating greenhouse gas emissions. The result of the governmental free-rider literature should not be surprising given that governmental programs themselves often contain elements of public good characteristics

(Tullock, 1971). In the case of policies addressing climate change, the non-excludable nature of the outcomes is especially notable.

The literature on elected officials behavior is also relevant to this discussion. While public officials are said to be agents of the median voter, these voters face uncertain benefits from voting while incurring very certain costs (Downs, 1957). At the same time, the median voter theory is found to be more reliable when clear majorities exist (Holcombe, 1989). Therefore, when facing a voting public without clear consensus, lawmakers will be more likely to make policy decisions in response to requests by special interest groups (Lowi, 1972; Grossman and Helpman, 1996). According to Grossman and Helpman, elected officials will be more likely to implement special interest policies if they do not conflict with their traditional policy platforms (1996). That is, an official whose campaign focused heavily on a specific issue will likely continue to focus on that issue once elected. However, issues that lay at the fringes of their campaign tend to see less attention. This dynamic creates a situation where the government may not implement a solution to a public good market failure as long as that issue is not a prominent feature of the policymaker's ideology.

While the suboptimal outcome of inaction has been common among the US states, initiatives such as the Regional Greenhouse Gas Initiative demonstrate that the incentive for governmental free riding is not insurmountable. The question is, what factors explain this behavior?

Policy Adoption and the Diffusion of Policy Innovation

When interested in how and why governments adopt specific policies, essentially choosing to make punctuated (large) instead of incremental changes to policy, scholars of public policy commonly apply the diffusion of innovation model. When using the term "policy innovation," these scholars are referring to policies that are new to the adopting body, but not necessarily unprecedented. Never before seen policies typically begin with a single government, referred to as the policy leader or inventor. When other governments adopt identical or similar policies, that policy is said to have diffused among governments (Berry and Berry, 1990).

Researchers have applied this model to an array of policies including state lottery systems, school choice programs and death penalties (Berry and Berry, 1990; Mooney and Lee, 1995; Mintrom, 1997). It has also been used to examine the diffusion of policies at different levels of government, from local to national to international (Weiner and Koontz, 2010).

The diffusion of innovation framework is an amalgamation of two distinct models used to explain the likelihood of a government to innovate (i.e. adopt a new policy). The first model examines the factors leading to a regional diffusion of a policy. First among these factors is the learning process that states go through before deciding to innovate. Previous researchers of the regional diffusion model argue that the causal mechanism through which policies diffuse regionally is that of social learning, where states are able to witness the experience a fellow state has with the policy, and then decide to adopt based on its relative success or failure (Walker, 1969; Berry and Berry, 1990; Mooney, 2001). Researchers have found that this process of social learning occurs more fluidly and quickly when governments are geographically linked. Further research expounds upon the regional model by suggesting policymakers in neighboring states often share a great deal of information through shared media outlets and conferences (Mintrom and

Vergari, 1998; Boehmke and Witmer, 2004). A third component of this model posits that neighboring states are more likely to have systematically similar populations both demographically and economically, and are more likely to share similar problems (Boehmke and Witmer, 2004). When examining the regional diffusion of any individual policy, it is difficult to separate the relative impacts on the likelihood of adoption contributed by these three components. However, the overarching model provides a framework for explaining this diffusion. This makes any policy outcomes experienced by lead or early adopting states interesting for those neighboring states (Mooney, 2001).

Next, economic competition is thought to be a major driver of policy innovation (or lack of innovation) (Boehmke and Witmer, 2004). States compete with one another by enacting policies designed to attract business and human capital away from rival states (Tiebout, 1956). In this regard, states may also compete for business by offering subsidies to potential industry and structuring corporate law to be more favorable to business (Eadington, 1999; Bebchuk et al., 2002). Conversely, states may "race to the bottom" by providing few resources to the needy and poor (Peterson and Rom, 1990).

Policy adoption scholars also examine the level of government at which the policy of interest originates. Policy diffusion can occur in any of three ways: horizontal diffusion, where policies diffuse among like actors (e.g. state to state); top down diffusion, where policies diffuse from higher levels of government (e.g. federal to state); and bottom-up diffusion, where higher level governments adopt policies first enacted by lower level governments (e.g. local to state) (Shipan and Volden, 2006).

The route in which policies diffuse is important to consider because it will impact any analysis constructed to detect certain mechanisms at work. For example, policies implemented on a national level and forced down to the states will weaken or remove the regional diffusion effect (Daley and Garand, 2005; Lutz, 1986). When considering cap and trade for carbon emissions, there is no extant federal policy. As of this writing, the Obama Administration issued orders to reduce national CO_2 emissions to 32% of 2005 emissions by the year 2030, although the survival of these administrative rules may be tenuous due to pushback similar to that which faced the EPA's Clean Air Interstate Rule of 2005 (Texas Commission on Environmental Quality, 2016). A similar policy implemented by the federal government is the Acid Rain Program (ARP) for sulfur dioxide emissions, which was established under the Clean Air Act of 1990. The ARP utilized cap and trade policy to reduce SO_2 emissions, making it the most similar federal policy to the RGGI. This market was considered a success in that it lowered SO_2 emissions by over 60% from 1980 emissions (Chestnut and Mills, 2005). Given the lack of federal regulations on CO_2 emissions, the study of state-level policy on the subject at this point assumes horizontal policy diffusion.

A second model included in the policy innovation framework is referred to as the internal determinants model (Berry and Berry, 1990). It holds that each state possesses unique internal characteristics that affect the likelihood of the state to adopt the policy of interest. These characteristics include but are not limited to economic conditions within the state, the composition of the state's economy (i.e. more or less dependent on industry), political attitudes, political control over relevant institutions, and key geographical features, among others (Walker, 1969; Gray, 1973; Berry and Berry, 1990).

When selecting among the issues to include on the legislative agenda, policymakers must consider both the size and tractability of the problem, as well as the resources needed to properly address it (Hwang and Gray, 1991). The economic variables provide a measure of the financial capacity of the state to pay for the policy, while the political variables measure the willingness of the policymakers to pay for the policy. The latter are especially important when the policy is a distributive policy because the outcome will have very clear winners and losers (Meckling, 2011). Cap and trade policy has very clear losers, while the benefits of the policy are spread globally.

The study of policy innovation and diffusion has evolved over the years to include both models in single analyses (Berry and Berry, 1990; Mintrom, 1997; Mintrom and Vergari, 1998; True and Mintrom, 2001). Of specific relevance to this article, the comprehensive model has also been used to examine policies dealing with climate change at the state-level (Matisoff, 2008; Wiener and Koontz, 2010; Carley, 2011). However, to my knowledge none have utilized these models to explain why states would be willing to join a carbon cap and trade market.

With this background in mind, I use this paper to examine the factors that explain the state-level decision to enter into an interstate cap and trade market for CO_2 emissions. At this point, the only functioning market is the RGGI, although the Western Climate Initiative is currently working to create a market for emissions among its members California, British Columbia, Ontario, Quebec, and Manitoba (Western Climate Initiative, Inc, 2014). The next section will cover the data and methods I use to analyze the decision to opt into the RGGI.

DATA AND HYPOTHESES

I employ both the regional diffusion and internal determinants models to examine the conditions suspected to affect the decision of a state to join a regional cap and trade compact for carbon emissions. Descriptive statistics for the explanatory variables are located in Table 1.

Beginning with the internal determinants model, I gather state-level data on variables that affect the likelihood of a state to participate in an intergovernmental market for CO_2 emissions. Previous research on policy innovation suggests that economic resources are critical toward enabling a state to adopt a new policy (Walker, 1969; Matisoff, 2008; Ringquist and Garand, 1999). I hypothesize that a state will be more likely to participate in a cap and trade market if they have the financial resources to do so. I operationalize this factor by accounting for state per capita gross state product. Quarterly data on gross state product (GSP) are made available by the Bureau of Economic Analysis (BEA). While aggregate GSP provides a total measure of all economic activity within the state, it doesn't fully capture a state's ability to pay for a policy. For instance, if a state has a high GSP relative to other states but also has a much higher population, it will likely have fewer dollars to devote to a new program. Therefore, I use per capita GSP to capture the economic ability of the state to pay for any costs of the program as per capita measures of economic output are commonly used as a proxy for standard of living. I standardize the variable around the average for each state during the period covered in the analysis, giving the variable a mean of 0. As per capita GSP increases, tax revenues will also increase, thereby providing more resources for the state. I calculate the per capita GSP variable by dividing quarterly GSP by the state's population. The population data are only available on an annual basis, so fluctuations within the year are not fully captured in the model. The population data are available from the US Census Bureau.

While ability to pay for the policy is important, willingness to pay is equally as important. Another implication of economic health is that the magnitude of willingness to address carbon emissions may not be a linear function of per capita GSP. In fact, there may be a non-monotonic relationship between improving standards of living and environmental degradation (York et al., 2003). That is, while there may be a causal relationship between per capita GSP and the likelihood to adopt, the relationship may not be linear. Willingness to limit carbon emissions may actually decrease as standards of living increase in areas with extremely low standards of living (i.e. areas with low per capita GSP). However, in areas with already high standards of living, willingness to limit carbon emissions may increase as per capita GSP continues to increase (Grossman and Krueger, 1994).[6] In order to correctly operationalize the effect of per capita GSP on carbon emissions, previous research suggests the inclusion of a quadratic term. This is because economic growth is found to positively contribute to emissions up to a certain point, after which increases in growth may actually lead to diminished emissions (Dietz and Rosa, 1997). Therefore, in areas with comparatively high standards of living, the likelihood of joining a carbon market will increase as economic growth continues.

H_1: The likelihood of participation in a carbon market decreases as per capita GSP increases in states with low standards of living. In states with

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[6] This conceptualization is based on the Environmental Kuznets Curve (EKC), which suggests environmental impacts increase up to a certain point of per capita gross domestic product, after which degradations lessen with increasing affluence. Stern provides a rebuttal to the arguments of the EKC, including: problems of stationarity in longitudinal data; problems of omitted variables; and the fact that CO_2 emissions have long atmospheric lives, and thus are not subject to short-run variations in GDP (2003). While I do not use this paper to counter those arguments, I rely on the theoretical contention that willingness to improve environmental conditions does increase exponentially with incomes (Pezzey, 1989; Selden and Song, 1994; Baldwin, 1995; Dinda, 2004).

already high standards of living, increasing per capita GSP will increase the likelihood of participation.

The next critical economic factor influencing a state's likelihood to join a carbon market is its economic reliance on CO_2 emissions (Zahran, Grover, Brody, & Vedlitz, 2008; Matisoff, 2008). States are home to a wide array of private markets, all of which contribute in some way to the state economy. Some states rely more heavily on market activities that generate high levels of CO_2 relative to other markets. These high emitting markets include industry, transportation, and agriculture (The Guardian, 2011). The implications of carbon pricing for these industries, and therefore to economic production within the state, are significant. Industry must then account for CO_2 as a factor of production. Placing a price on carbon will shift the cost curve up, a move that will affect production decisions. These industrial producers will then make long-run choices on where to locate based in part on the locational cost of production (Blair and Premus, 1987). If a state relies more heavily upon carbon intensive industry, it has more to lose by joining a carbon market. Similarly, while individual businesses tend to have limited sway on policy changes, when many firms have a common interest, business coalitions can form that do have significant political power (Meckling, 2011). For this reason, it is important to control for the economic carbon intensity of the state economy. A state's economic carbon intensity is calculated by taking the ratio of its total CO_2 emissions to its gross state product. Essentially, a state whose economy is more dependent on production that emits high levels of CO_2 may be less likely to participate in a regional cap and trade market. This leads to my second hypothesis that the likelihood of participation in a carbon market is partially a function of the carbon intensity of the state's economy. Data on CO_2 emissions come from the EPA's Air Markets Program database.

> *H_2: States with lower levels of economic carbon intensity will be more likely to join a regional carbon market than states with high economic carbon intensity.*

Previous policy scholars acknowledge the important role of political ideology on the adoption and diffusion of a given policy (Walker, 1969; Gray, 1973; Mooney, 2001; Berry and Berry, 1990). Essentially, there is evidence suggesting that the political attitudes of citizens and elected officials help explain collective willingness to pay for specific types of policies (Nice, 1982; Matisoff, 2008).

In their work examining punctuated changes to the policy monopoly, Baumgartner and Jones write that leading promoters or advocates of a specific policy, referred to as policy entrepreneurs, will shop for venues that will be more open and amenable to considering their policy image (1993). A policy image refers to how policy entrepreneurs sell the importance and tractability of a problem. Successfully crafted and communicated policy images increase the odds that the issue will be added to a political agenda. These images are typically a mixture of both positive, fact-based analyses and normative judgments (True et al., 2007). Climate change is a prime example of an issue for which advocates have spent time and effort developing a salable policy image. This image is one of melting sea ice, warming temperatures, and severe storms (Leiserowitz, 2006). Policy entrepreneurs then shop this image to different policy venues with the intention of warranting consideration on an agenda.

The venue in which a policy issue is considered is a critical step along the path toward successful adoption and implementation of a policy. Venues may be more accommodating of policy images that fall in line with certain ideological beliefs. Overwhelmingly, results from national surveys demonstrate a clear link between people who self-identify as politically liberal and support for environmental policy (Dunlap et al., 2010; Jones, 2010; Gromet et al., 2013; Leonhardt, 2014). Similarly, researchers have found a positive correlation between policymakers with liberal political ideologies and support for environmental legislation (Kamieniecki, 1995; Dunlap and Allen, 1976). Given this link, I will operationalize state-level ideology as a function of the ideology of its policymakers.

Operationalizing a variable to represent policymaker ideology is a field of study all to its own (Taggard and Winn, 1993; Weber and Shaffer, 1972; Klingman and Lammers, 1984). This research led to a variable that operationalizes the ephemeral concept of political ideology based on a number of different components designed to capture political views over time for each state (Berry et al., 1998). This variable is available from Richard C. Fording's website and is based on the methodologies described in Berry et al. (1998).[7] These state government ideologies were tracked from 1960 to 2013. In the article by Berry et al., the authors attempt to place each state's elected representatives (i.e. legislative and executive branches) on a continuum ranging from extreme liberal to extreme conservative (1998). The authors use observations on interest group ratings for legislative members from both major parties as well as for the governor.

[7] In 2013, Enns and Koch put forward an alternative measure of ideology through longitudinal surveys and certain quantitative techniques. This alternative operationalization of ideology may eventually substitute for or replace the measure by Berry et al.. To this point, Enns and Koch have seen limited citations. For the purposes of this paper, I rely on the Berry metric.

Each component of the variable is weighted based on assumptions made by the authors about the relative power afforded to the respective branches as well as the power of the majority and minority powers within the legislature. The power of the majority party in either legislative chamber is a linear function of the majority advantage. That is, the minimum amount of legislative power wielded by the party with the smallest possible majority is 60%. The majority party achieves maximum power when they obtain at least 60% of total seats. The maximum power afforded to the minority party according to this model is 40%. Each party receives 50% if the seats are split. According to the measure of the variable, states with more liberal government leaders receive a higher score. The range of values goes from 0 if the state is perfectly conservative to 100 if perfectly liberal. Any score above 50 indicates a liberal lean, and any below 50 indicates a conservative lean.

Based on the link between liberal ideology and support for environmental policies found in previous research, I develop my third hypothesis. This hypothesis contends that states with liberal elected leaders will be more likely to join a carbon market. Using the measure of government ideology discussed above, the specific hypothesis suggests that as a state's government ideology score increases, the state will become more likely to join a carbon market.

H_3: States with more ideologically liberal elected government officials will be more likely to join a carbon market.

Scholars of public policy will be quick to point out that government officials are but one of the parties at the table when considering policy innovation. To more accurately explain the likelihood of a state adopting a carbon market policy, one must account for the aggregate support and opposition facing a policy. As established by Lowi, policy type is an important factor with regard to the development of coalitions in the policy arena (1964). Carbon markets fall into the category of distributive policy (Meckling, 2011). Under distributive policy, there are very clear and identifiable parties shouldering burdens from the policy. That is, policy costs are not spread evenly amongst the stakeholders. Therefore, building an agreeable coalition will be more difficult.

With climate change policy, the benefits are non-excludable and accrue on a global scale. Therefore, it is more interesting to consider the audiences that will be financially affected by this regulatory policy. Given that this policy explicitly targets the energy industry, we must assume that policymakers will have an easier job of joining their state with a carbon market if the native power industry is less affected (Matisoff, 2008). I must note that the power industry is not monolithic. While the majority of power in the United States comes from fossil fuel sources (coal, natural gas, and oil), more than a few states get most or all of their power from nuclear and renewable sources. In states with less power reliance on carbon heavy sources, carbon markets will not generate excessive costs. It is therefore logical that these states will see less pushback by industrial interests as well as consumers.

I am able to measure the amount of state electrical power generated by carbon-heavy sources by using data on Btu consumption by source fuel at the state level. These data are available from the Energy Information Agency. Within the data set, I am able to distinguish between Btus generated from carbon sources versus non-carbon sources (e.g. nuclear power and renewable sources). I build the variable by aggregating Btu production from oil, coal, and natural gas sources. My fourth hypothesis posits that higher energy consumption from carbon-heavy sources will have a negative effect on the likelihood of a state to join a carbon market.

H_4: States with lower reliance on carbon-heavy sources of energy will be more likely to join a carbon market.

Next, I consider the impact of personal experience on support outcomes. At this point, it is not possible to find consistent longitudinal observations of perceptions about climate change at the state-level. Survey researchers are beginning to adopt this measure in popular surveys, but so far there are no consistent annual measures for each state. To get around this issue, I had to look for another way to observe risk perceptions about climate change. An extant stream of literature contends that witnessing the negative impacts attributed to climate change may lead to an increased acceptance of the existence of climate change (Egan and Mullin, 2012; Howe et al., 2013; Li et al., 2011; Zaval et al., 2014). Specifically, researchers have found a positive relationship between the number of regional deaths attributed to climate-related natural disasters such as severe storms, heat, flooding, and droughts, and public risk perceptions about climate change (Brody et al., 2008; Spence et al., 2011; Egan and Mullin, 2012). Based on this relationship, I hypothesize that deaths attributed to climate-related weather events will increase the likelihood of a state joining a cap and trade market. More specifically, I expect there will be a year lag between the timing of the deaths and the adoption of policy. Data on the number of deaths attributed to climate-related events are available from the University of South Carolina's Spatial Hazard Events and Losses Database for the United States. This database contains observations for all states going back to 1960.

H_5: States with higher risk perceptions of climate change will be more likely to join a regional cap and trade compact.

Finally, I include the regional diffusion model. According to the logic of this model, a state is more likely to adopt a specific policy if they are geographically near other adopting states. I operationalize the regional variable by measuring the distance between the capital city of an individual state and the capital city of the lead state, which is Albany, New York. I hypothesize that the likelihood of adoption is inversely related to distance from Albany.

H_6: The likelihood of joining a carbon market decreases as the distance between the state and the lead state increases.

METHODS

This paper is a variation on the traditional diffusion of innovation model. My goal is to provide an empirical examination of the factors that lead a state to join a regulatory compact like a cap and trade market. Traditional diffusion models examine policy innovation by states over a period of years. These policies are typically quite similar, but not identical. In the case of a carbon market, the policy is identical and adoption is likely to occur within an extremely short period for all participants. Therefore, we will not see the traditional 'S'-curve common to the temporal diffusion of a policy across a region. The 'S' curve model is used to describe a trend where adoption of a policy occurs slowly at first, but soon grows exponentially as many states adopt. Finally, the curve flattens again as fewer states are left capable of adopting (Berry and Berry, 1990).

Recent articles that test the diffusion of innovation framework employ event history models (Berry and Berry, 1990; Mintrom, 1997; Mintrom and Vergari, 1998;

True and Mintrom, 2001). The event history model, also referred to as survival analysis, employs as its dependent variable the hazard rate of an event occurring. The hazard rate is a parameter that is not directly observable, but can be calculated using observations within the data set. The hazard rate, $h(t)_{it}$, is equal to the number of events that occur in a period over the number of non-events. It can also be written as $h(t) = f(t)/(1 - F(t))$, where f(t) is the probability distribution function for person i experiencing the event over one minus the cumulative probability distribution function of person i experiencing the event. In this form, the model is non-parametric. Most researchers wish to observe the effect of key explanatory variables on the likelihood of experiencing and event. For this type of estimation, one needs a parametric or semi-parametric model (Allison, 1984).

For this paper, I will be employing a Cox Proportional Hazard semi-parametric model (Cox, 1972). The Cox model assumes proportional hazards throughout the sample, which means that hazard rate for any one state does not vary with time. The outcome variable is referred to as a hazard ratio, which compares the hazard rate of one case to that of another. The Cox model begins with a baseline hazard rate of an event occurring, and it is assumed to be equal for all cases within the sample. This baseline hazard rate, $h_0(t)$, is the hazard function for an individual with values of zero for all explanatory variables. Next, one incorporates the explanatory variables into the model. These variables enter the model exponentially: $h_i(t) = h_0(t)e^{\beta_1 X_1 + \cdots + \beta_k X_k}$. Taking the natural log of both sides, the explanatory variables contribute to the baseline hazard in an additive fashion. Each beta coefficient represents the change in the hazard ratio for the individual in response to a 1-unit change in the independent variable (Allison, 1984).

In the world of political science, researchers often employ the event history model to examine policy diffusion and innovation because it enables one to measure changes in the likelihood of adopting a specific policy over time. The outcome variable for this model is the conditional hazard ratio of a state joining the RGGI. The model will include the variables covered in the data section:

$$h(t|(X_i) = h_0(t)\exp\,(\beta_1 X_{1it} + \beta_2 X_{1it}^2 + \beta_3 X_{2it} + \beta_4 X_{3it} + \beta_5 X_{4it} + \beta_6 X_{5it} + \beta_7 X_{6it})$$

where X_1 represents per capita gross state product at the state quarter; X_2 represents economic carbon intensity at the state quarter; X_3 represents government ideology scores at the state year; X_4 represents Btu consumption from coal, oil, and natural gas at the state quarter; X_5 represents the year-lagged number of deaths attributed to climate-related events at the state quarter; and X_6 represents the distance from the capital city of state i to Albany, New York.

Membership into the RGGI market occurred in two separate waves. The first occurred in the fourth quarter of 2005 when Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, and Vermont signed the Memorandum of Understanding (MOU). The second occurred in 2007, and was a little more spread out than the primary wave. In the first quarter, both Rhode Island and Massachusetts officially signed the MOU. Finally, Maryland signed on in the third quarter of that year. The data set continues until the fourth quarter of 2011, which is the point at which New Jersey opted out of the market. Since that time, participation in the RGGI has remained stable.

In most event history models, the event of interest occurs in a somewhat random and staggered way. For example, in a study of the mortality rate of heart surgery patients, one expects the long-run probability of death to be 1, while the deaths of individual patients are assumed to be independent from each other. Additionally, event history analysis will benefit when ties in event occurrence are limited (Cox, 1972). However, ties are typically unavoidable, especially in cases where the data are collected in a discrete time unit as opposed to continuous (Jenkins, 2005). In my model, where the data are considered to be discrete because observations are lumped into quarters, there are many instances where events occur simultaneously. Whenever ties are prevalent, modelers assert that the Efron approximation is more effective than the Breslow approximation (Allison, 2010).[8]

I also employ a longitudinal logit model. The logit model offers a means of analyzing event history data in a purely discrete manner, as opposed to the mixed method of the Cox proportional hazard model. When running a logit model using panel data, one must make a decision about the type of effects to control for. The two primary choices are fixed effects and random effects. I control for random effects because the lack of variation in the dependent variable severely limits the number of observations.

RESULTS

Results for the event history analysis and logistic regression are located in Table 2.[9] The first variable I examine is the effect of per capita gross state product on a state's decision to join the RGGI. My hypothesis suggests a non-monotonic relationship between increasing per capita GSP and the likelihood to opt into the RGGI. A positive finding would show low likelihood when per capita GSP is very low, but increases exponentially

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8 For more information on the methods for handling ties in a discrete time dataset, please visit: http://soep.ue.poznan.pl/jdownloads/Wszystkie%20numery/Rok%202014/06_borucka.pdf.

9 The author also specified the model to weight the environmental variables (thermal energy and carbon intensity) to a rank-ordering of gross state product. These results are shown in Table 3.

as per capita GSP increases. To avoid collinearity, I center these observations around the sample mean.

The results from both models find directional support for this hypothesis. For the event history model, the result for the linear term shows that for an increase of $1000 in per capita GSP, the likelihood of joining the RGGI in the next instant decreases by 16 percentage points from the baseline hazard ratio. This result is not statistically significant with a 90 percent level of confidence ($p = 0.165$). The logistic regression finds that likelihood of participation decreases by 36 percentage points as per capita GSP increases by $1000. This result is significant with a 95 percent level of confidence ($p = 0.018$).

Next, both models show that the quadratic term leads to increased likelihood of participation when paired with economic growth. In the event history model, the likelihood of participation increases by 1 percentage point over the baseline hazard as per capita GSP increases by $1000. This result is not significant ($p = 0.121$). In the logistic regression model, likelihood of participation increases by 4 percentage points over the baseline hazard ratio as per capita GSP increases by $1000. This result is significant with a 95 percent level of confidence ($p = 0.025$). The directional effects of both per capita GSP regressors are similar in both models, which lends support for the first hypothesis. However, the results of the Cox model are not statistically significant, so I cannot confidently reject the null hypothesis.

The second hypothesis maintains that states that are more economically reliant on carbon-intensive industries will be less likely to join a carbon market. With this relationship in mind, I expected to see a negative relationship between a state's carbon intensity (tons of CO_2 emissions per million dollars of GSP) and the likelihood of it joining the RGGI. According to the Cox model, the likelihood of joining increases by about 3 percentage points over the baseline hazard ratio as the state's emissions per thousand dollars of GSP increased by 1 ton. This result is not statistically significant with a 90 percent level of confidence ($p = 0.546$). According to the logistic regression model, this variable has no measurable effect on the odds of joining the RGGI (beta = 1.003). Again, the coefficient for economic carbon intensity is not significant ($p = 0.968$). Given these results, I cannot find support to reject the second null hypothesis.

The next potentially causal factor explaining RGGI membership is state government ideology. I hypothesize that the likelihood of membership is higher in states with more liberal state government ideology scores, which follows along with findings from previous research on policy diffusion. The results from my analyses show unison of the directional effect, but differ in magnitude. According to the Cox model, the likelihood of joining the RGGI in the next period increases by 2% percentage points relative to the baseline hazard ratio as state government ideology increases by one point. This result is statistically significant with a 90 percent level of confidence ($p = 0.071$). The logistic regression model reports an increase in the odds of membership of 25 percentage points. This result is significant with a 90 percent level of confidence ($p = 0.054$). Given the common directional effect found in both models, and the relative statistical significance of both, I find support for my second hypothesis.

The third hypothesis suggests that states with more carbon intensive energy production will be less likely to join a carbon market. The coefficient from the Cox model holds that as the ratio energy produced from carbon-intensive sources to gross state product increases by 1, a state's likelihood of joining a carbon market decreases by

0.003 percentage points relative to the baseline hazard ratio. This result is significant with a 95 percent level of confidence at the ($p = 0.012$). The logistic regression estimates indicate that the odds of being in the RGGI decreases by 0.006 percentage points as the ratio increases. The odds ratio is significant with a 95 percent level of confidence ($p = 0.021$). Given the similar direction, magnitude, and statistical significance for both models, I find support for my third hypothesis. However, the effect of this relationship in both models appears to be quite small.

For my fourth hypothesis, I expect that climate-related negative experiences within a state will have an effect on the willingness to support climate policy. According to the literature, an increase in deaths attributed to climate-related weather events will lead to increased support for climate policy. I control for this trend in my model by measuring the number of weather-related deaths in the previous year. My weather-death variable uses a one-year lag under the assumption that policy responsiveness to these deaths will be delayed as policymakers assimilate the information. The Cox regression reports that the likelihood of participation in the RGGI in the next period increases by 3.5 percentage points over the baseline hazard with each weather-related death. This result is not significant with a 90 percent level of confidence ($p = 0.495$). The logistic regression reports an increase in the odds of joining the RGGI of over 17 percentage points as deaths increase. This result is statistically significant with a 99 percent level of confidence ($p = 0.006$). While the directional effect is similar in both models, the lack of statistical significance in the event history model detracts from the robustness of the test, causing me to fail to reject the null hypothesis.

My final hypothesis contends that regional influence plays a role in the adoption of carbon market policy. According to this theory, the likelihood of policy diffusion increases when adopters are nearer in a geographical sense. I operationalize distance in the model by measuring the distance between Albany, NY and each state's capital city. I use Albany as the locus of distance because New York is credited with being the progenitor of the RGGI. The results from the Cox model demonstrate that the likelihood of participation in the RGGI in the next period decreases by 1.4 percentage points under the baseline hazard as distance increases by one mile. This result is significant with a 90 percent level of confidence ($p = 0.068$). The logistic regression model supports this finding as it suggests that as distance increases by a mile, the odds of joining a carbon market decreases by 5.3 percentage points relative. This result is significant with a 99 percent level of confidence ($p = .000$). Both models find similar directional effects, and both are statistically significant. Therefore, I found suitable support to reject the null hypothesis and accept the alternate hypothesis that distance has a negative effect on the likelihood of joining the RGGI.

CONCLUSION

While the tangible effects of mankind's impact on the global climate are uncertain, the growing chorus of voices from climate scientists suggests that our behavior will inevitably lead to serious and perhaps irreversible consequences in the future, consequences that could affect the viability of mankind itself and for nearly all other ecosystems. In response to these voices, governments around the world are increasingly adopting policies designed to impede or slow the onset of climate change. One of the most popular climate policies is cap and trade for carbon emissions.

Carbon markets provide case studies for research on the elements explaining the adoption of environmental policy. The purpose of this paper is to isolate and analyze the effect of these unique elements with the hope of explaining how future climate-related policies will diffuse. Many previous studies on the diffusion of policy innovation examine the effects of political, economic and regional influences on the likelihood of policy adoption. While this paper covers those grounds, it also control for the impact of regional experiences with the impacts of climate change events. This allows for a unique take on the motivation for policy adoption.

There were several limitations of the study due to the quality of the data. The most significant limitation of the data is related to the timing of adoption. States entering into the RGGI did so in two large waves. It was for this reason that I included logistic regression analysis. In the future, as more states opt into (or out of) these markets (assuming no federally mandated market), there will be more variation in the timing of the event (entry into the carbon market). Fortunately, I was able to generate estimates using both models.

The first result from this paper relates to the effect of economic resources on the adoption of carbon market policy. Historically, researchers have found a positive correlation between financial resources and the likelihood of adopting a specific policy. The findings of this paper run counter to the conventional wisdom in this area. I find that higher per capita gross state product has a complicated effect on the likelihood of a state to enter into a carbon market. While the results of the event history analysis were not statistically significant, both models show a similar effect of per capita gross state product on adoption of the RGGI. In states with low standards of living, economic growth may decrease the likelihood of a state to enter. In contrast, already economically advantaged states will be more likely to enter into a carbon market as living standards continue to increase.

Next, there may be some support for the link between real-world experience with impacts from climate-related events and the decision to join a carbon market. While neither model found statistically significant evidence of this link, both models showed similar positive directional relationships between weather-related deaths and the decision to enter the carbon market.

A third result from this paper is the finding of support for the link between politically liberal ideology and the adoption of environmental programs. At this point in time, the divergence of candidate platforms leading up to the 2016 presidential election clearly demonstrates this effect. While the Democratic candidates have pushed environmental problems nearly to the top of their respective agendas, the Republican candidates give the topic little treatment (Leatherby, 2015). It will be interesting to see if the link between ideology and environmental policy support continues as the domestic population experiences increased negative consequences of a changing climate.

Finally, I found strong support for the regional diffusion model. This finding was not surprising as the RGGI is a regional program by design. This finding needs further dissection because the nature of this regional relationship is different than the one assumed by policy researchers. Traditional regional diffusion theory contends that policy diffuses regionally because states are able to learn from the experiences of their neighbors, neighbors with whom they typically share some common traits. In the case of the RGGI, there was not sufficient time to examine the social learning aspect of the model because multiple members joined at the same time. Therefore, there can be no social learning in this context. The result of this analysis does perhaps suggest a new line of thinking regarding the economic competition component of the diffusion model. By states joining together in a compact that will serve to increase the costs of production and electricity rates, they are assuring themselves that economic leakage will be kept at a minimum relative to unilaterally adopting such a policy. In this way, the formation of the RGGI somewhat mirrors the logic of cartels in oligopolistic markets. Governments may be more willing to incur costs that would typically put them at a competitive disadvantage if they believe their neighbors will incur the same or similar costs. The title of this paper indicates that a state may feel more confident to join a carbon market if they know other states will join as well.

That is not to say that social learning won't be a factor in the future as additional states make decisions on climate policy. At this point, the results show that carbon emissions have diminished and revenues from trading provide an additional stream of government revenue. Other states may learn from these experiences and decide to either opt into the RGGI in the future, or begin a new carbon market.

These results create a reason to continue with the study of climate policy adoption. At this point, adoption of climate policy, both in the United States and internationally, is at a very early stage. As more governments adopt these policies, and more data become available, the role of policy researchers will grow. Of particular interest to future researchers will be the cartel-model of policy diffusion. I hope to examine this possibility by interviewing policymakers, bureaucratic officials, and stakeholders in the RGGI states. A qualitative perspective analysis will allow for an explicit test of this model.

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APPENDIX 1: ESSAY 1 TABLES

Table 1: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Per Capita GSP	1,344	-1.17E-07	8.165833	-15.4935	28.67312
Per Capita GSP Sq	1,344	66.63122	100.5839	0.000112	822.1479
Carbon Intensity	1,344	68.39446	75.92969	0.106703	449.717
Ideology	1,344	51.23054	25.55745	2.580879	92.45091
Thermal Energy	1,344	11268.06	42000.62	0	316870.5
Lagged Weather Fatalities	1,344	2.453318	19.69729	0	687
Distance	1,344	1022.688	709.7945	0	2492

In Table 1, Per Capita GSP is mean-centered; Carbon Intensity is CO2 (million metric tons)/GSP (millions of dollars); Thermal Energy is carbon BTU (in BTUs)/GSP (millions of dollars).

Table 2: Effect of state-level variables on likelihood of state joining the Regional Greenhouse Gas Initiative. Model 1 is estimated using Cox proportional hazards regression. Models 2 and 3 are estimated using panel logistic regression. Coefficients reported as hazard ratios for Model 1, and odds ratios for models 2 and 3. Robust standard errors reported in parentheses.

Variable	**Model 1**	**Model 2**	**Model 3**
Per Capita GSP	0.843	0.862	0.639**
	(0.104)	(0.116)	(0.121)
Per Capita GSP Sq	1.01	1.012*	1.041**
	(0.001)	(0.007)	(0.019)
Carbon Intensity	1.028	0.931	1.003
	(0.051)	(0.081)	(0.067)
Ideology	1.019*	1.086**	1.260*
	(0.011)	(0.044)	(0.151)
Thermal Energy	0.997**	0.992**	0.994**
	(0.001)	(0.004)	(0.003)
Lagged Weather Fatalities	1.035	1.141**	1.173***
	(0.052)	(0.065)	(0.069)
Distance	0.986*	0.989*	0.947***
	(0.008)	(0.06)	(0.014)
Constant		0.222	0.000023*
		(0.685)	(0.000)
Chi Sq	50.152***	49.94***	148150.15***
N	1120	1344	1344
Hazard Ratio	Yes	No	No
Odds Ratio	No	Yes	Yes
Year FE	-	No	Yes

* p<.1, ** p<.05, *** p<.01

Table 3: Estimation using rank-ordering of gross state product in the denominators of Thermal Energy and Carbon Instensity.

Variable	Model 1	Model 2	Model 3
Per Capita GSP	0.865	0.901	0.642**
	(0.091)	(0.109)	(0.133)
Per Capita GSP Sq	1.01	1.01	1.041**
	(0.005)	(0.007)	(0.019)
Carbon Intensity	0.999	0.999	1.000
	(0.000)	(0.000)	(0.000)
Ideology	1.007	1.085**	1.251*
	(0.016)	(0.043)	(0.145)
Thermal Energy	0.782*	0.513**	0.649
	(0.111)	(0.138)	(0.239)
Lagged Weather Fatalities	1.047	1.098***	1.135**
	(0.051)	(0.037)	(0.866)
Distance	0.989**	0.989*	0.949***
	(0.005)	(0.005)	(0.016)
Constant		0.271	0.000023
		(0.763)	(0.000)
Chi Sq	47.12***	36.85***	2211.83***
N	1120	1344	1344
Hazard Ratio	Yes	No	No
Odds Ratio	No	Yes	Yes
Year FE	-	No	Yes

* p<.1, ** p<.05, *** p<.01

ESSAY 2: EFFECTIVENESS OF THE REGIONAL GREENHOUSE GAS INITIATIVE: RESULTS FROM A VOLUNTARY EMISSION TRADING MARKET

INTRODUCTION

Over the past decade, emission trading has become an increasingly popular policy mechanism for mitigating greenhouse gas emissions from high impact sectors like electric power production (Ellerman, 2003; Stavins, 2008). Generally, emission trading programs enjoy the support of both policymakers and key interest groups, both of whom recognize the benefit of certainty in reduction levels and a reduced cost of achieving those levels relative to command and control policies (Keohane, 2009).

In 2009, the Regional Greenhouse Gas Initiative (RGGI), an emission trading market for CO_2 emissions, activated its exchange after over five years of planning and development. This paper uses quarterly state-level CO_2 emissions data to examine the results of the RGGI from its inception through 2013, while controlling for confounding factors inherent to quasi-experimental analysis. I examine these data using the theoretical lens of environmental identity-based utility maximization. This model posits that the magnitude of emissions reduction the member state achieves will vary based on unique identity formulations. Results show that simple participation in a voluntary emission trading market does not alone produce significant reductions in emissions relative to states that elect not to participate. Instead, significant reductions within the market are linked to the interaction between market participation and liberal ideological attitudes. In the coming sections, I first discuss climate policy broadly, and then focus specifically on emission trading policy. From there, I examine the literature on the effectiveness of emission trading, with the section culminating in the presentation of the environmental-identity model. Next, I explain the sources of data and methods I use, before ultimately presenting the empirical results. Finally, I make some concluding remarks and present some ideas for future research.

Climate Change Policy

As the focus on global climate research over the last several decades has intensified, the overwhelming majority of peer-reviewed findings show evidence that anthropogenic (man-made) sources of greenhouse gas emissions are leading to a global shift in climate.[10] Of the array of activities that contribute to climate change, electrical generation from fossil fuel sources is the largest source of greenhouse gas emissions in the United States (see Figure 2). While the findings from climate research increasingly navigate their way into public discourse, policymakers around the developed world are turning to economic scholars for assistance in developing strategies that will help ease the onset of climate change at the lowest cost to society.[11] Traditional regulatory approaches for reducing environmental externalities often involve command and control mechanisms under which firms are left with few options through which to adapt behavior. Command and control solutions include mandated adoption of specific technologies, limitations on source fuels, and specific ambient conditions (i.e. limits to acceptable levels of certain pollutants).

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[10] The Intergovernmental Panel on Climate Change (IPCC) is regarded as the hub for research on climate change. The most recent assessment report was published in 2013: http://www.ipcc.ch/report/ar5/.

[11] In December of 2015, representatives from countries around the world met in Paris to arrive at global agreement on cooperative emission reductions. An agreement was reached among the participants, although the formal reduction strategies and commitments will not be required until 2020. The outcome in Paris marks the first successful agreement after failed attempts in Kyoto and Copenhagen.

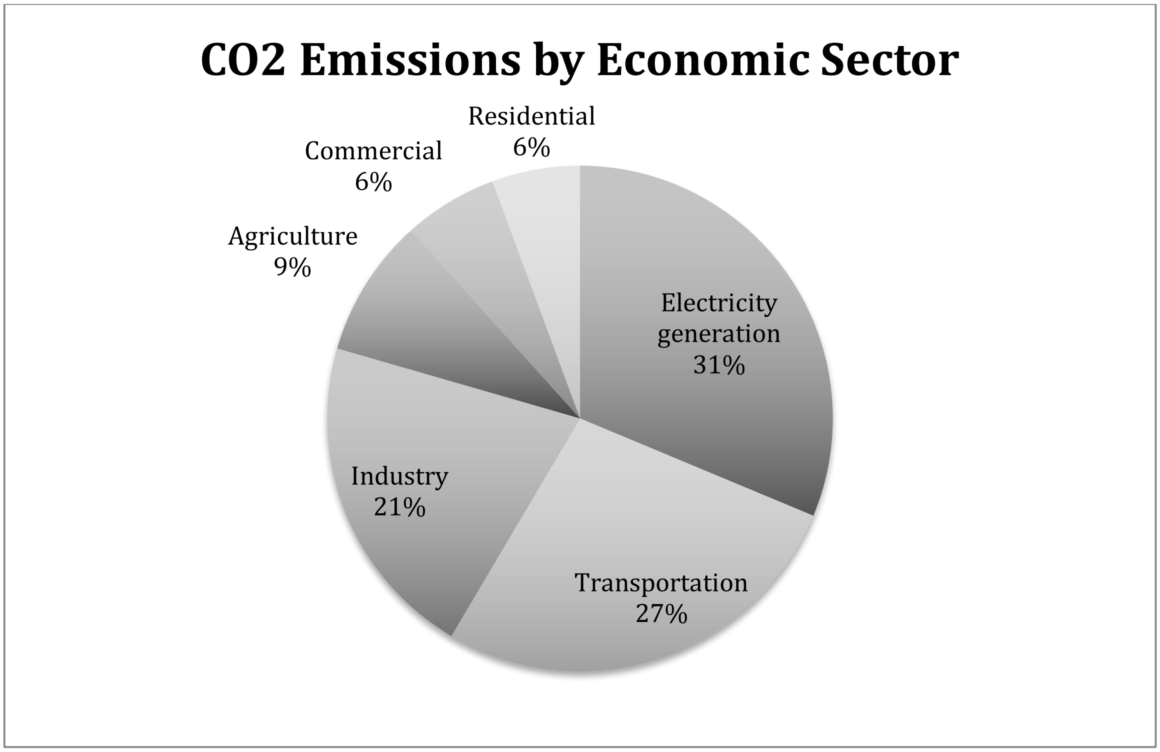

Figure 2: Source, Environmental Protection Agency.

Economists do not favor such policies because firms are treated as homogeneous units with identical marginal abatement cost curves, which runs counter to the more realistic case where firms have varying abatement costs. Marginal abatement cost refers to the cost incurred by the plant to reduce emissions by one unit, with units typically measured in tons of gas.[12] The short-run cost for a firm is a function of the price of the source fuel needed to run the turbines, the heat content of the fuel, the heat rate efficiency of the plant, and any labor costs incurred for plant operation (Kaderjak, 2007). The cost of abating emissions includes any costs related to additions to physical capital, fuel costs, labor costs, and maintenance costs associated with achieving reductions in emissions. Given the permutations of generation and abatement options for power producers, policies requiring parallel reductions across all firms impose very high costs on firms with high marginal abatement costs, while firms with low marginal abatement costs achieve the new mandates with relative ease. If the goal of the policy is to achieve an aggregate level of reduction at lowest total cost, command and control policies are inferior to market-based policies.

Market-based policies are designed to take advantage of individual maximizing behaviors by placing minimal requirements on who actually does the abating. In cases where a negative externality such as greenhouse gas emission is present, market actors can be separated into two groups: those negatively affected by the externality and those creating the externality. In the case of climate change, the affected group is society and the offending group is composed of those emitting greenhouse gases. Both groups have their own objectives, and seek to maximize benefits relative to that objective. The affected group is experiencing a cost from the externality, and would prefer either the cessation of emissions or remuneration for damages caused by the emissions. The

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[12] Marginal abatement cost (MAC): $MAC_i = \frac{\partial TC(A)_i}{\partial A_i}$, where TC is the total cost of abatement and A is the abatement of emissions. $TC(A) = rK + wL + tM + pF$, where K is capital, L is labor, F is fuel and M is maintenance. The coefficients r, w, t, and p are the multiplicative contributions of each respective factor.

offending group is receiving profits from selling the power, of which greenhouse gas emissions are a byproduct, and would prefer to continue producing so long as it incurs no cost.

One form of a market-based strategy designed to achieve an efficient level of negative externality is a quota system. Systems based on quotas allow the affected and offending parties to make private deals based on their own maximizing behavior, the end result of which is the optimal level of the externality. The logic of a quota-based system stems from the Coase Theorem, which asserts that negative externalities can be internalized within the market by establishing and enforcing property rights over the affected area (1960). In this system, the individual to whom property rights are conferred is able to negotiate with the other party and in so doing, find the optimal level of reduction. Theoretically, the outcome itself will not differ regardless of which party receives the property rights. Should rights be conferred to the offending party (i.e. the polluter), the affected party (i.e. local residents and businesses) can pay the offender to reduce or eliminate the offending output. If the rights are given to the affected party, they can receive rents from the polluter in exchange for use of the property. Participants find the optimal solution when the value of producing the last unit of the offending output, or the payment made to encourage the cessation of the last unit of production, exactly equals the cost of the damage caused by that unit. It is on this model that emission trading policies are established.

Emission Trading Markets for Carbon Dioxide

Emission trading policies are designed to set limits on the volume of greenhouse gases emitted in a given period. Typically, the regulating body sets a limit, and issues permits for the right to emit gases to the sectors covered by the policy. The polluter can then either exchange the permit for the right to emit a ton of gas or hold the permit for use in a future period. As mentioned in the previous section, the electric power sector is responsible for a large share of emissions, and is therefore the sector most affected by these policies.[13] Currently, there are only two prominent examples of emission trading schemes: the European Union Emission Trading Scheme (EU ETS) in 2005 and the Regional Greenhouse Gas Initiative (RGGI), established in 2009. The latter is seeking to expand its membership, even considering members with whom they do not share a border (Kessler, 2016).

At the time of this writing, both of these markets have been in operation for at least 5 years. It is informative to review how effective these markets have been during this time, and given that both markets have maintained thorough data on aggregate emissions, this type of macro view is possible. Figure 3 and Figure 4 below provides the total annual emissions of both the EU 28, all of which participate in the EU ETS. The aggregate data show that in the first three years of market operations, emissions remained roughly stable before seeing a modest drop in 2009. In 2010, emissions rebounded somewhat, while years 2011 and 2012 saw lower emissions similar to the nadir in 2009.

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[13] During the implementation of the RGGI, stories emerged of disaffected parties not part of the power sector. One notable story marks the struggles of Mittal Steel and the New Page Corporation paper plant, both operating in Maryland, to compete in their respective markets after paying for emissions. Both companies generate their own power for operations, and are thus covered under the RGGI. (April 3, 2006 Monday). Impact of MD General Assembly's pollution bill reaches beyond utility power plants. The Daily Record (Baltimore, MD), Retrieved from www.lexisnexis.com/hottopics/lnacademic.

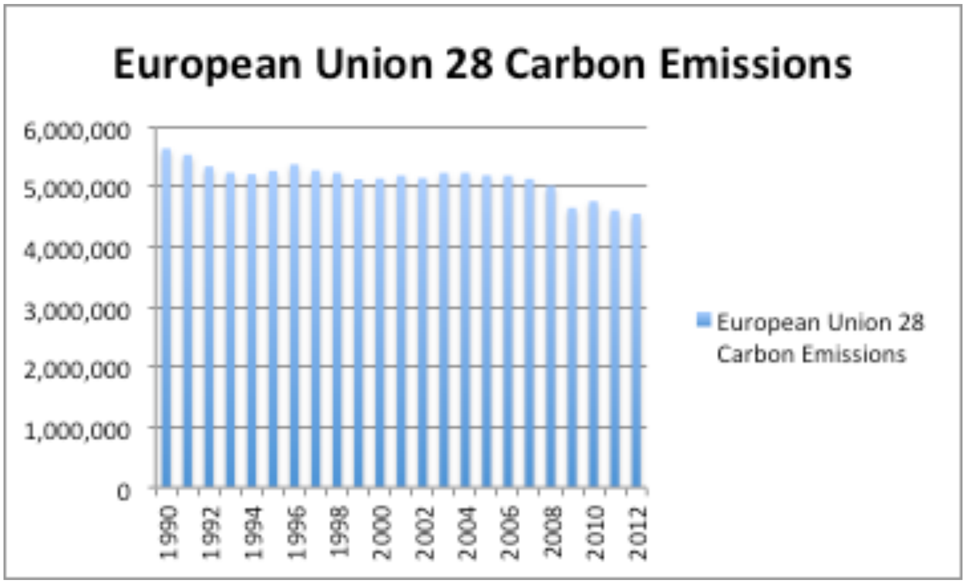

Figure 3: Carbon dioxide emissions (in thousand tons) for EU 28 members. Data provided by European Environment Agency (EEA).

Annual emissions from the RGGI states are presented below in Figure 3. As the table shows, there were two punctuated drops in emissions over the course of the 22-year period. The first drop, although relatively minor, occurred in 2005. The drop beginning in 2009 is more remarkable. It begins a trend where, with the exception of a small increase in 2010, emissions decrease with each subsequent year. One commonality between the trendlines for both the European Union countries and RGGI member states is a notable diminishing of emissions precisely in 2009, which coincides with the global economic downturn. Given this dynamic, it is difficult to state with confidence that the respective emissions markets were responsible for those reductions without controlling for these types of exogenous factors. Therefore, it is useful to examine how these markets function and what factors may help explain these outcomes.

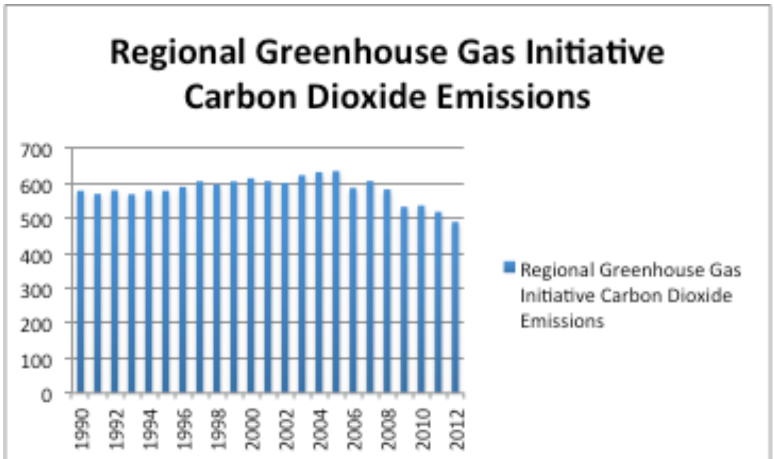

Figure 4: Carbon dioxide emissions (in million tons) from RGGI states. Data provided by Environmental Protection Agency.

REVIEW OF LITERATURE

The logic of emission trading presumes that by establishing a limit to emissions, commoditizing those emissions into allowances (permits), and allowing firms to trade those allowances, the overall level of emissions will reach the target at lower cost than a command and control policy (Hahn and Stavins, 2010). From an economic perspective, such an outcome is considered efficient because the long-run price of the emissions permit will equal the marginal abatement cost of each firm, thus injecting the previously excluded cost of the externality into the private market (Weitzman, 1974).

While the theory behind emission trading is well covered, there is a relatively underdeveloped strand of literature that suggests anticipated gains from emissions trading may not take place (Hovi and Holtsmark, 2006; Neuhoff, 2011; Nordhaus, 2007;

Wittneben, 2009). According to this literature, there is much more nuance involved in setting the cap by a government, the ultimate effect of which depends in large part on conditions within that government.

This literature begins with a theoretical examination by Bohm (1992) on the distributional implications of an emissions market that includes both developed and developing countries. In this article, the globally optimal level of abatement is achieved by shifting a majority of the abatement to the developing countries due to their lower marginal opportunity costs of abatement. Essentially, less developed countries sacrifice less value by reducing emissions than do developed countries. Bohm does not assert that emission markets will not achieve large reductions, but does hint to this possibility. The contention is that while developing countries would welcome abatement due to low opportunity costs, this position would change when perceived benefits of reducing emissions began to diminish (i.e. opportunity costs of abatement increase). As standards of living within a country change, there may also be a concomitant change in willingness to abate emissions.

Helm (2001) picks up on this subtle notion and extends it further by introducing the concept of endogenous emission caps. This simply means that countries (or any autonomous area) set emission caps in a non-cooperative way based on unique perceptions of costs and benefits. Until this point, researchers assumed exogenous emission caps, and wrote based on the assumption that market participants maximized their benefits under the constraint of that cap (Keohane and Olmstead, 2007). Helm's paper was written after the results of the Kyoto Protocol emission targets showed that Russia and Ukraine each received targets much higher than their expectations. Helm provides a model for optimizing the production of emissions without participation in an emissions market:

$$\boldsymbol{\pi}_i'(\boldsymbol{e}_i^*) = \boldsymbol{v}_i'(\boldsymbol{e}_i^*)$$

where $\boldsymbol{\pi}_i'$ are the marginal benefits of emissions from government *i* and $\boldsymbol{v}_i'$ are the marginal damages caused by emissions in government *i*. With the introduction of an emission market, the number of emission allowances is referred to as $\boldsymbol{\omega}^{\boldsymbol{N}}$. Helm finds the optimal emissions solution for the market relative to the allowance allocation for a government:

$$\sum_{i=1}^{I} \boldsymbol{\pi}_i'\left(\boldsymbol{e}_i^*(\boldsymbol{\omega}^{\boldsymbol{N}})\right) = \sum_{i=1}^{I} \boldsymbol{v}_i'(\boldsymbol{\omega}^{\boldsymbol{N}})$$

where the individual marginal benefits of emissions as a function of the market cap, found on the left-hand side of the equation, are equal to the marginal damages of emissions as a function of the market cap, found on the right-hand side. The ultimate proposition of this paper is found when Helm compares the incentives of countries with low marginal damages to those with high damages. Countries facing high marginal damages (i.e. the right side of the equation is larger) prefer a lower allocation of permits and an increased desire to reduce emissions. The opposite is true for low damage countries.

The Helm model opened up the possibility that emission trading markets may actually lead to an increase in global emissions should the number of countries perceiving low damages outnumber those perceiving high damages (2001). In their update of the Helm model, Eyckmans and Kverndokk (2009) create a specification to account for the role of a government's identity function in this outcome. Identity, they contend, contributes additively to the Helm model for countries that harbor significant ethical or moral concerns about mankind's effect on the global climate.

The concept of the identity function in Eyckmans and Kverndokk's article is based on the model of Akerloff and Kranton, who include the psychological and sociological concepts of identity in economic models (2000). In their specification, Akerloff and Kranton create an identity function:

$$\boldsymbol{I_j = I_j(c_j, \epsilon_j, P_j)}$$

where the identity of person j is a function of several factors. Within this function, c_j is the social category to which individual j is assigned. This assignment can be either exogenous or endogenous to the individual. An example of an exogenous assignment to a social category is gender at birth. An example of endogenous assignment is political ideology (where on the liberal/conservative spectrum one finds herself). $\boldsymbol{\epsilon}_j$ are the characteristics of person j that are consistent with her assigned social category. That is, to what degree does her characteristics align with those of her social category. Using political ideology as an example of social category, a person who has extremely liberal views will find a much stronger correlation between those views and the ideals of the liberal social category. Finally, P_j are the prescriptions attached to the social category. Prescriptions are the behaviors expected out of a person assigned to a specific social category. For an individual who self-assigns to a liberal ideological social category, a prescription would be support for environmental protection and social programs among others. As $\boldsymbol{\epsilon}_j$ becomes more aligned with c_j, person j will adjust her behavior to more closely align with the prescriptions of that social category. The authors include identity in the larger social utility function for the individual:

$$U_j = U_j(a_j, a_{\ldots j}, I_j)$$

where a_j are the actions taken by person j and $a_{\ldots j}$ are the actions taken by others. In this regard, people receive utility from both their own actions as well as the actions taken by others.

Eyckmans and Kverndokk (2009) include this identity component within the larger benefit function for governments participating in emissions trading markets. The logic for including identity within the benefit optimization formula presented by Helm rests on the assumption that there is a moral or ethical component involved in selecting optimal emission caps. While the Akerloff and Kranton model is based on the individual, Eyckmans and Kverndokk argue that policymakers act as moral interpreters of the population they serve, and as such are held to the same identity formulations as the individual. In this context, policymakers representing populations with high levels of environmental concern want to be seen as doing their best to protect the environment. This statement needs some qualification, however. Voter sentiment about environmental protection in general, and climate change specifically, is not identical in all areas. Certain groups feel a 'moral concern' about greenhouse gas emissions and their effect on the global climate (Eyckmans and Kverndokk, 2009).

The concept of moral concern can be placed within a group of social identity norms to which people may subscribe that are based on the broad social categories people align themselves with. Building on the concept of self-assigned social category mentioned above, a simple example of a social norm grouping is the political party to which one chooses to align. Individuals use this ideological alignment to instruct their policy preferences, inform their voting behavior, and influence their opinion of elected officials (Goren, 2005). In the United States, there are two prominent parties that house the majority of politically conscious individuals. Each respective party has its own core ideals for policy, and each individual member builds some component of her identity by supporting policy prescriptions that further these ideals (Akerlof and Kranton, 2000; Goren, 2005). Specifically, moral concern about harming the global climate is partially an expression of one's conceptualization of identity. For those who align with social groups that possess higher moral concerns about environmental degradation, there will be more support for a policy that seeks to limit those damages. Even though these policies can be costly, the individual psychically benefits more through the policy's implementation than suffers from the costs (Akerlof and Kranton, 2000).

According to the utility function described by Akerlof and Kranton, seemingly irrational economic decisions can be explained by examining the components of one's social identity function (2000). Theorists attribute the development of publicly-minded identities such as those who seek to promote environmental issues to a notion of impure altruism, whereby the individual gains utility from the "warm glow" of contributing to a socially beneficial cause as well as any public approbation or recognition (Becker, 1974; Andreoni, 1990). According to this model, environmental identity is strongly affected by social influence (Clayton and Opotow, 2003). That is, stronger environmental identities develop when surrounded by other people who possess environmental concerns. Individuals and groups with strong environmental identities will have a relatively high willingness to pay for environmental policy.

Research suggests that an individual's likelihood of supporting policies addressing climate change is a function of certain key characteristics, most of which tend to be unique to the individual (Zahran et al., 2006). However, political ideology tends to be a strong predictor of support for or opposition to climate change policy (O'Connor et al., 2002; Gromet et al., 2013; Dunlap et al., 2010). The link between ideology and perceptions about climate change is currently receiving a great deal of attention. In a recent article by the Pew Research Center, views on the seriousness of the climate change problem, as well as the view that greenhouse gas emissions should be limited, differed sharply by stated partisanship (Stokes et al., 2015). The results from this survey indicate similar divergences in opinion based on ideology in a number of other countries as well. Other studies show similar findings as well, with all showing vast differences between liberals and conservatives on issues of a changing climate (Jones, 2010; Elke and Stern, 2011; Liu et al., 2014).

In states with larger groupings of people concerned about environmental protection, policymakers will likely face increasing aggregate demand from voters and special interest groups for policies protecting various aspects of the environment. In the absence of direct voting on referenda, voters in these areas will seek to elect leaders with similar views. According to the Down's theory on democratic policymaking, political parties, through the agent of the elected policymaker, will formulate public policy based on the signals sent by the voting public (Downs, 1957). Policymakers representing voting publics with a higher level of collective moral concern about climate change will face electoral pressure to limit greenhouse gas emissions. In this case, the policymaker gleans an advantage by pursuing policies that at a minimum make some effort to address climate change. In the same vein, policymakers as individuals have views on the proper use of government intervention in specific areas. It is important to note that policymaker views tend to follow a pattern similar to that of voters in that support for environmental policies is correlated with liberal political ideology (Dunlap and Allen, 1976; Kamieniecki, 1995). Given the preponderance of evidence supporting a linkage between ideology and opinion on climate change on a collective level, valid proxies for state government ideology should adequately operationalize the environmental identity component of the Akerlof/Kranton model at the state-level.

On the other hand, policymakers do not want to put their own private sector at a competitive disadvantage by imposing costs on firms within their own borders that firms in other states do not face. This latter concern is consistent with public choice theory where policymakers are considered to be rational actors who develop and enact policies with the intent of getting reelected (Buchanan, 1984; Michaelowa, 1998; Tompkins and Adger, 2003). Lobbyists representing the business sector have spent a great deal of time and resources in keeping electricity prices low, and therefore favor limiting the regulations on the power sector (Gardner, 2010).

When faced with these countervailing forces, policymakers may decide to satisfice by selecting a policy that will appeal to both sides. According to Grossman and Helpman, policymakers will act in a manner that maximizes the aggregate welfare among both the voting public and special interest groups (1996). Within this argument, the degree to which the policy reflects one side over the other is a function of the relative size of the constituent base and the strength of ties between that base and demand for a specific policy (a sentiment echoed by Akerloff and Kranton). As discussed above, environmental protection is highly correlated with politically liberal ideology. Therefore, applying the argument of Grossman and Helpman, we can expect states with higher concentrations of politically liberal voters to enact policies designed to protect the environment.

With regard to capping carbon emissions, policymakers will attempt to maximize the collective welfare from all voting and special interest groups. In states with an even balance of liberal and conservative ideologies, policymakers may enact policy that enjoins their state with an emission trading market, thereby satisfying liberal voters, but will allay concerns about the economic impacts of participation by setting the cap so that it has minimal impact on emissions. By allowing participation in an emission trading market, policymakers are seen as protecting the environment because they are visibly doing something to address climate change. However, the emission limit will likely be set to a level that will not affect status quo emissions significantly, thus avoiding overly burdensome costs on the business sector, the electricity sector, and rate payers. Additionally, policymakers may set a high limit if they feel it to be morally wrong to sell emissions, although this concept is difficult to measure. Indeed, discerning the true motivations of policymakers may not be possible. Yet, it is possible to observe evidence of policymaker motivation by examining the results from the emission trading markets themselves.

HYPOTHESIS

The goal of this paper is to measure the effectiveness of the RGGI on state-level GHG emissions relative to non-participating states. I will be examining the question of whether conditions within a state that chooses to participate in a voluntary emission-trading scheme will render the compact no more effective than a policy of inaction. Using the theoretical constructs presented earlier, I expect that simple participation in the RGGI will not be sufficient to reduce emissions relative to the counterfactual situation. Instead, the impact of the market on emissions is affected by the interaction between participation in the market and state government ideology.

H_1: RGGI member states with more liberal state governments will see reductions in emissions relative to non-member states, while less politically liberal member states will see no impact on emissions.

DATA

I examine the impact of the RGGI market on emissions by gathering data on state CO_2 emissions, while controlling for the other factors that impact these emissions at the state level. The dependent variable is tons of CO_2 emitted quarterly by each state in the comparison and treatment groups between 2005 and 2013. For comparison, I use states with deregulated electricity markets because all members of the RGGI except for Vermont also have deregulated markets. For this reason, I exclude Vermont from this analysis.[14] Using a quarterly time increment is optimal because the RGGI auctions its permits quarterly, and the permit price is based on quarterly supply and demand. By using panel data from the period of 2005 to 2013, I control for state and time fixed effects that may bias the coefficient on the treatment. Data on CO_2 emissions are available through the EPA's Air Markets Program database.

The Air Markets Program database contains facility-level emission observations on a number of different air pollutants and greenhouse gases going back to 1990, although the CO_2 data are only consistently reported beginning in 1997. The

[14] Vermont is an extreme outlier in terms of emissions. During the years of this study, emissions in Vermont were extremely low relative to the rest of the country. Please see Table 4 in the appendix for more information about average annual emissions by state.

Environmental Protection Agency (EPA) began tracking these emissions under authorities granted through the Clean Air Act of 1990.[15] Although the intent of the program was to reduce the amount of sulfur dioxide emissions generated by the power sector, regulators chose to include carbon emissions in the tracking program. The database only includes large emission facilities, which are classified as those facilities that emit more than 25,000 metric tons of greenhouse gases per year (EPA, 2016).

The scope of the RGGI covers those power plants that have a nameplate capacity of 25 megawatts (MWs) and larger. It reasonable to question whether all of the RGGI regulated facilities will be captured in the Air Markets database. To answer this question, I calculated the expected CO_2 emissions from a power plant with a capacity of 25 MWs. The EPA provides conversion rates based on different fuels that enable the user to estimate how much greenhouse gas is emitted by a plant based on its capacity. For a traditional coal plant, about 2 tons of CO_2 is emitted per MWh, whereas a natural gas-fueled power plant emits about 1.22 tons per MWh. Therefore, a coal plant with a 25 MW capacity will become eligible for regulation under the RGGI after about 500 hours. For a natural gas plant, this figure is about 819 hours. Therefore, it is reasonable to believe that nearly all of the power plants covered under the RGGI are required to report to their emissions to the EPA, and are included in the dataset.

To estimate the effect of participation in the RGGI on emissions, I control for factors at the state level that affect both the willingness and ability to abate emissions. As mentioned earlier, energy use for electricity generation is the leading cause of greenhouse

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[15] The Clean Air Act (CAA) of 1990 expanded authorities under the 1970 provisions of the CAA to include regulations of sulfur dioxide emissions, a program known as the Acid Rain Program. For more information on the CAA, please visit: http://www2.epa.gov/clean-air-act-overview/1990-clean-air-act-amendment-summary.

gas emission in the US. Because of this fact, the RGGI focuses only on emissions from that sector. Therefore, I control for those factors related to electricity production and consumption at the state level. These include economic health, population changes, weather variation, and fuel prices (Kamerschen and Porter, 2005; Mansanett-Bataller et al., 2007).

The first set of control variables reflects the demand for energy based on changing demographic and socioeconomic conditions within human populations. In the 1970s, Paul Ehrlich among others proposed the I=PAT equation for predicting anthropogenic environmental damage, where I (environmental damage) is the product of P (population), A (affluence), and T (technology) (Ehrlich and Holdren, 1971). While the broad categories of PAT fully identify environmental damage (in the way that 1+1 always equals 2), these categories themselves are composed of more specific factors like income distribution and political control, among others (O'Neil and Chen, 2002).[16] The overarching IPAT model has been accused of failing to accurately predict the outcomes of rising populations and global standards of living (Simon, 1980; Meyer and Turner, 1992; Harrison, 1994; Paul, 1989).[17]

Still, the model provides a useful starting point for selecting variables to explain emissions. Within the literature, the most common factor researchers control for is the standard of living (i.e. affluence) for the population. Economic growth is correlated with increased energy consumption, which in turn leads to higher emissions depending on the

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[16] The IPAT equation is an identity equation, in that regardless of what value the independent variables take, the dependent variable will always be 1. The equation provides a useful starting point to selecting individual independent variables.

[17] According to the IPAT equation, population affects environmental impacts multiplicatively. Therefore, if the equation holds, as population grows, so too does environmental damage. This contention has not stood up to empirical scrutiny, as described by the environmental Kuznet's curve.

source fuel used to produce electricity.[18] Most of the environmental and scientific literature suggests that as societal affluence grows, energy demand follows (Meadows et al., 1972). However, this assumption has since been refined, most notably by Dietz and Rosa in their paper on the effect of human population, influence and technology on environmental impacts (1997). They suggest that rising standards of living do contribute to negative environmental impacts (e.g. emissions, pollution), but only up to a point. Instead, the negative effects caused by improving affluence on the environment reach a peak around $10,000 per person, after which impacts begin to decline. This interaction forms the basis of an environmental Kuznets Curve (Grossman and Krueger, 1991).[19]

In order to capture state-level affluence trends on a quarterly basis, I use the Bureau of Economic Analysis' (BEA) new quarterly measure of gross state product. I calculate per capita gross state product by taking the ratio of the quarterly BEA measure and annual state population using data provided by the Census Bureau. These population data are based on intercensal measurements, which make assumptions about the change in population between census measurements to generate year specific estimations. I also use a quadratic measure of per capita gross state product to capture the non-monotonic effect of rising affluence on emissions.

The next IPAT factor that I control for is population change. Simply put, as the population within a state increases, the aggregate load profile will increase as there are

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[18] Historically in the United States, economic growth has been strongly correlated with increased electricity consumption because much of it was in industrial sectors with heavy electrical needs. As the economy shifts from industrial production to services, the correlation between economic growth and electrical consumption has weakened but remains a factor: http://www.eia.gov/todayinenergy/detail.cfm?id=10491

[19] Stern (2004) argues that evidence of the environmental Kuznet's curve (EKC) is a product of poor econometric modeling. He contends that the previous literature supporting the presence of the EKC does not properly account for non-stationary fluctuations in damage indicators. I include a model specification with first differences for the affluence variable in the appendix.

more people consuming electricity (Hahn et al., 2009). As mentioned earlier, these population data come from the US Cenus Bureau.

Finally, the IPAT model, and more specifically the Kaya Identity, includes technology as a determinant of environmental impact (Kaya, 1990). Captured within this category are all of the means at the disposal of mankind to turn affluence into environmental damage. While technology as a category is quite broad, many authors use energy intensity as a more precise measure (Cole and Neumayer, 2004). Energy intensity is measured as the ratio of energy used by society to gross domestic product. I am specifically concerned with the carbon energy intensity of the state, so I construct a variable from the ratio of British thermal units (Btus) generated by power production using coal, natural gas, and petroleum sources to gross state product. Data on energy consumption in Btus by fuel source are available from the Energy Information Agency (EIA). These data are measured annually by state.

Next, I control for the effects of regional temperature variation on emissions. Specifically, daily temperatures have an impact on household and business energy consumption patterns (Hart and de Dear, 2004). To this point, the IPAT literature has largely ignored the impact of regional temperature variations on energy demand, instead conceding the effect to the error term (Cole and Neumayer, 2004). Data on temperature patterns are readily available from the National Oceanic and Atmospheric Administration (NOAA) website.[20] These data are divided into two categories: heating degree-days and cooling degree-days. Degree-days are calculated by taking a baseline temperature, 65°F in this scenario, and subtracting it from the average temperature for the day in question.

[20] Degree day records contain observations back to 1960.

Cooling degree-days occur when the baseline is above the average daily temperature, and heating degree-days occur when it is below. I employ the cooling degree-day measure in the model. Cooling degree-days are critical in explaining increased usage of electricity due to the electrical requirements of cooling units (Hart and de Dear, 2004).

Another notable omission of the IPAT model is the effect of fuel prices on energy demand. Mansanett-Bataller et al. demonstrate that energy prices have a large effect on carbon permit prices in the EU, and so too on electricity prices (2004). Higher energy prices push up the cost curve for plants using commodities that are subject to international supply and demand pressures, such as coal, petroleum and natural gas. On the demand side of the power market, recent studies demonstrate that power consumption tends to be relatively price inelastic, which means higher energy prices are transferred to consumers nearly in full (Kirschen et al., 2000; Lijesen, 2007). While demand for electricity may be relatively inelastic, rising electricity prices will still have an attenuating effect on emissions through reduced demand quantities. Given this factor, the final economic control variable I use is the market price for city gate natural gas, which is available for each state from the EIA. Over the last 15 to 20 years, oil and gas exploration and drilling companies have dramatically increased the application of hydraulic fracturing, which enables access to supplies of natural gas and oil that were previously inaccessible. This increasing supply of natural gas has had a sharp negative effect on price, as the city gate price of natural gas has dropped from a high of $12.48 per thousand cubic feet in 2008 to $4.19 in 2012.[21] Due in part to this drop in price, power plants have

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[21] The city gate price of natural gas refers to the price gas utility companies pay to the transmission companies. I use this price because the price of natural gas used for electricity production is not available for all states.

begun substituting natural gas for coal as a source fuel.[22] Carbon emissions from natural gas fueled power plants are roughly half as much as coal-fired plants.[23] Therefore, as natural gas becomes a larger part of the energy mix, CO_2 emissions around the country will also decline. It is important to separate the relative impacts on CO_2 emissions due to participation in the RGGI from related to lower natural gas prices as much as possible. I use a mean-centered quadratic term for natural gas price to account for the non-linear relationship between emissions and price in the data. Data on quarterly state-level city gate natural gas prices are available from the EIA.

Next I control for the impact of identity on support for limiting CO_2 emissions. According to Eyckmans and Kverndokk, a state's moral concerns about emissions will have an effect on actual emissions (2009). Those harboring significant moral concerns about the anthropogenic factors affecting climate will prefer higher levels of abatement. As mentioned above, previous surveys find a strong link between political liberalism and environmental concern (Jones, 2010; Elke and Stern, 2011; Liu et al., 2014; Stokes, 2015). Therefore, I operationalize environmental identity by taking a measure of a state's political ideology. To capture this environmental identity component of the model, I incorporate a state government ideology variable constructed by Berry et al.'s measure (Berry et al., 1998). This measure ranks state government ideology on a 0 – 100 scale, with a score of 100 being completely liberal. This score is calculated for each state on an annual basis.

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[22] Electric generation from natural gas has greatly expanded over the 15 years, with the share of coal slipping 21% during that time. http://www.naturalgasintel.com/articles/104167-eias-latest-data-shows-continued-shift-to-natural-gas-from-coal-for-power-generation.

[23] The carbon content information of different fuels is available from the EIA: http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11.

The Eyckmans and Kverndokk model continues a bit further in its contentions, in that it suggests differing outcomes within the emissions market depending on the identity function of the participants. They argue that some participants will be less likely to see a reduction in emissions because they anticipate more potential costs caused by the program itself (i.e. economic and political costs) than benefits received by reducing emissions. For these participants, we expect to see them in the market, but should not expect a lower emissions level. I control for this element of the model by creating an interaction between participation in the RGGI and state government ideology.

METHODS

I collect data quarterly for each state with the exceptions being population, carbon energy consumption and state government ideology, which are measured annually. I analyze the model using panel state and time fixed effects ordinary least squares estimation. I choose to control for fixed effects based on the results of the Hausman test, which compares the coefficients from the fixed effects model with those of the random effects model. Therefore, all regression results presented below are controlling for fixed effects.

The specification of the model is as follows:

$$E_{it} = \beta_1 X_{it} + \beta_2 (X_{it} * G_{it}) + \beta_3 W_{it} + v_i + \gamma_t + \varepsilon_{it}$$

Where E_{it} are z-standardized carbon emissions by state i in time t; X_{it} is a vector containing a dichotomous RGGI treatment indicator; the $(X_{it} * G_{it})$ vector contains the interaction between participation in the RGGI and state government ideology for state i in time t; W_{it} is a vector of control variables including per capita gross state product and its square, cooling degree-days, natural gas prices, economic energy intensity, and state government ideology for state i in time t; v_i is the intercept for entity fixed effects; γ_t is the intercept for the time fixed effects; and ε_{it} is the error term. I standardize the dependent variable around the state-level Z-score in order to present the relative magnitude of change in emissions within each state (UCLA, 2016).[24]

The model I described above assumes that the explanatory variables contribute to emissions additively. However, the IPAT model of Ehrlich and Holdren contends that population, affluence and technology have a multiplicative impact on environmental damage. To test the IPAT model, York et al. constructed the STIRPAT (Stochastic Impacts by Regression on Population, Affluence and Technology) model: $I_t = aP_i^a A_i^b T_i^c$, where the exponents represent the elasticity for each of variable (2003). To address the IPAT literature, I also estimate these models using a log-linear transformation. I present these results in Table 11.

One final note before proceeding into the results section is that there is cause for concern over the issue of carbon leakage. Carbon leakage occurs when electricity generated from carbon-intensive sources outside of the area covered under the policy supplants power generated by covered producers. Leakage is especially prevalent along the outlying borders of the emission-trading zone. Scholars of cap and trade markets often point to emission leakage as an unintended and problematic side effect of emission markets (Burtraw et al., 2006; Huber, 2013). The issue of carbon leakage is not within the scope of this article, but it is a topic that merits further consideration in future research.

RESULTS

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[24] A straight forward panel regression analysis of total quarterly emissions by state can be found in Table 13 the appendix.

The results for the panel OLS regression of the RGGI treatment and ideology/treatment interaction on z-standardized CO_2 emissions are presented below in Table 5. Standard errors are clustered at the state level. The coefficient on the interaction between participation in the RGGI and state government ideology, suggests that as ideology score increases by one unit (i.e. the state becomes marginally more liberal) for states participating in the RGGI, quarterly emissions decrease on average by over 5,600 standard deviations relative to the comparison group. This result is significant at the 95% confidence level ($p = .034$). I compare this to the non-interaction RGGI term, which sets the intercept for RGGI states with a state government ideology score of 0. This coefficient reports that RGGI states are emitting CO_2 at over 390,500 standard deviations above non-RGGI states. This result is significant at the 95% confidence level ($p = .030$).

Through the lens of environmental identity theory, these results are sufficient to reject the null hypothesis. However, it is useful to examine them in the context of the groups of states they describe. Figure 5 demonstrates the impact of state government ideology on emissions for the treatment group only. For the treatment group, there is a clear negative relationship between state government ideology and CO_2 emissions. Figure 6 demonstrates the relationship between emissions and ideology for the non-RGGI states. For this group, there is no clear relationship between the two variables, although there appears to be a slightly positive slope to the fitted values. Given the limited scale of the RGGI’s emission abatement targets, this finding supports the hypothesis that more liberal states within the exchange can expect greater reductions.

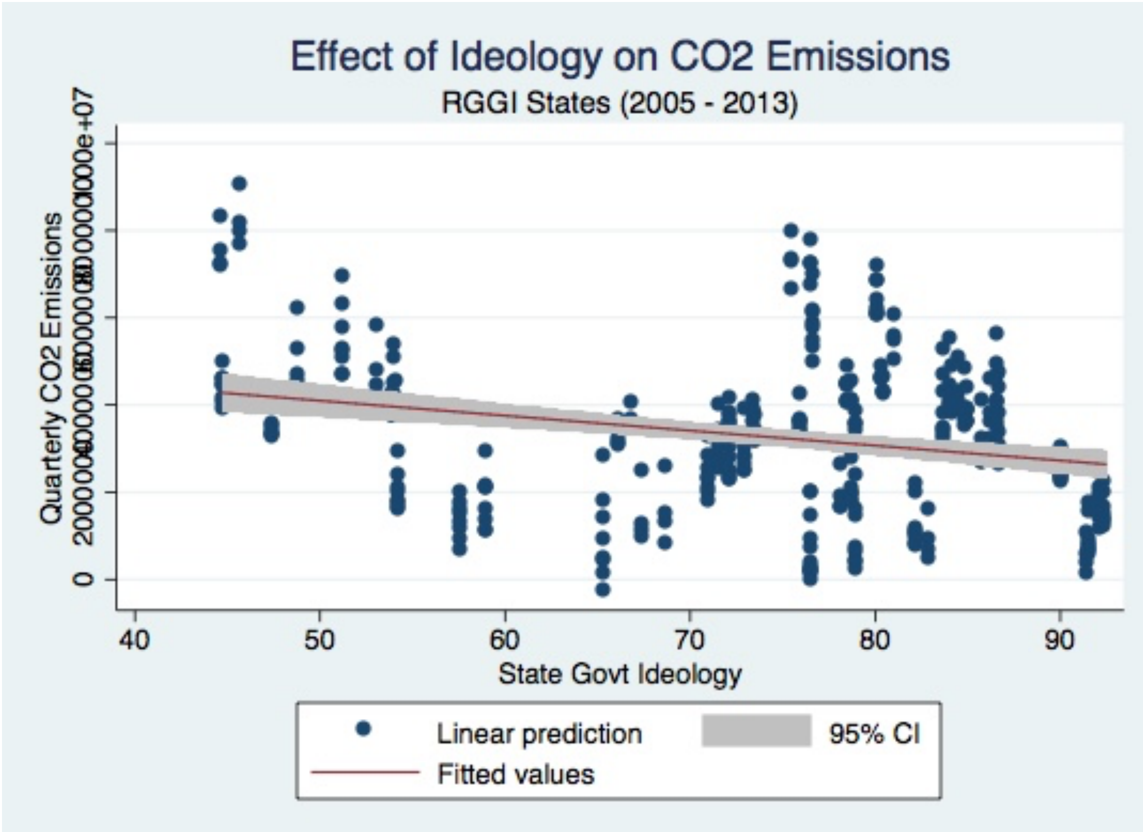

Figure 5: Effect of ideology on CO2 emissions for RGGI states only.

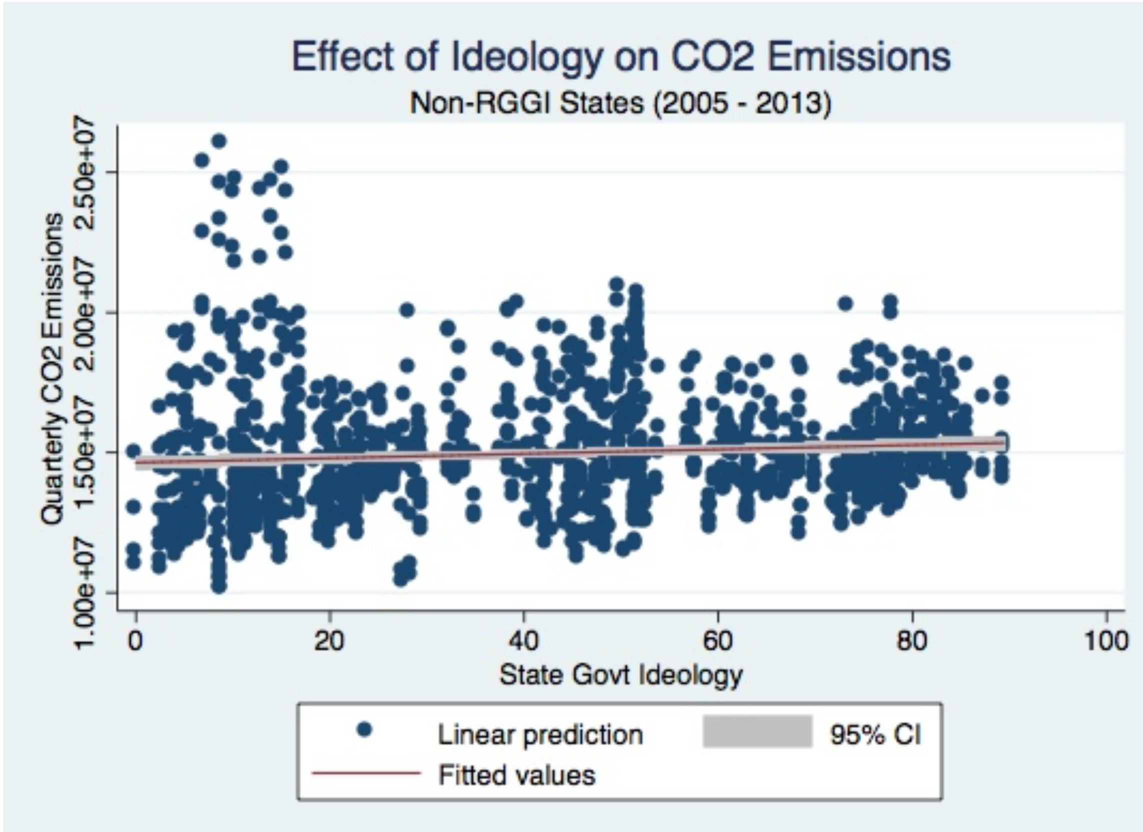

Figure 6: Effect of ideology on CO_2 emissions for the non-RGGI states.

Moving on to the control variables, the first variable of interest with respect to the IPAT model is affluence. As described earlier, I operationalize a population's affluence by measuring per capita gross state product (PCGSP). The results from the analysis show the relationship between PCGSP and CO_2 emissions to be sharply positive. The coefficient indicates that as PCGSP increases by $1,000, emissions increase by about 105 standard deviations. This result is significant at the 95% confidence level ($p = .011$). The next term is the quadratic of PCGSP. I include this term in response to the literature on anthropogenic environmental damage that contends that improving affluence leads to increased emissions up to a certain point, after which emissions should decline. The coefficient for this term suggests that at high levels of PCGSP, emissions decline at a rate of roughly 0.0009 standard deviations as PCGSP increases by $1,000. This result is significant with a 95% level of confidence (p = .015).

The final variable in the IPAT equation is technology. According to economic theory, waste products such as pollution are symptoms of inherent inefficiencies in the production process, inefficiencies that will diminish with continual technological innovation. The energy sector has made notable gains in the effort to improve the technical efficiency of power plants. One primary example of such innovation is the combined cycle power plant, which uses waste heat from the burning of coal or natural gas to power a second turbine. In this way, producers are able to generate more power from the same quantity of fuel. For the purposes of this paper, I operationalize technology by taking the ratio of thermal energy for power generation to gross state product, a ratio also referred to as energy intensity. As power plants become more efficient, the ratio of thermal energy to gross state product will decline over time, ceteris paribus. As this ratio diminishes, so too will the rate of CO_2 emissions diminish. The results of the regression find a positive relationship between energy intensity and emissions. As the energy intensity ratio increases by 1, quarterly state emissions increase on average by 0.003 standard deviations, holding all other factors constant. The coefficient is significant with a 90% level of confidence (p = .097).

Next, I include several variables not mentioned in the IPAT literature. First among these is the effect of weather conditions on emissions. Specifically, cooling degree-days generate increased energy demands as households and businesses must rely on air conditioning. As the number of cooling degree-days increases, the amount of electricity required to meet demand is likely to increase. As demand increases, so too does the deployment of carbon-intensive generators. The results of the analysis confirm this expectation. As cooling degree-days increase by one, CO_2 emissions increase on average by about 525 standard deviations. This result is significant with a 99% level of confidence ($p = .000$).

Finally, I control for the impact of fuel prices on emissions. Specifically, I control for natural gas price, as it represents the most likely substitute for coal. The coefficient for natural gas price shows that as price increases by $1, emissions increase by just over 5700 standard deviations on average. This result is significant at the 90% confidence level ($p = .097$).

CONCLUSION

As confidence in the existence of anthropogenic climate change increases, societies are implementing policies designed to mitigate the emission of greenhouse gases. One of the most popular policies in recent years is cap and trade. The logic in emission trading suggests that by setting a cap on the total amount of allowed emissions and leaving the decision on which power plants continue to emit up to the private sector, society will achieve the optimal level of emission at lowest cost. However, this logic is based on the assumption of an exogenous emission cap. In reality, policymakers endogenously choose emission caps. According to recent literature, this endogenous choice is a function of conditions within the state or country. States that perceive high benefits may choose lower emission caps with the intent of reducing emissions significantly. States that perceive lower benefits of reduction are likely to choose a higher cap in order to prevent large reductions. The difference between high emission and low emission states is largely due to differing identity functions.

I test this assertion by operationalizing the identity function of the state using the measure of state government ideology. According to the literature on environmental identity, people who identify as politically liberal are more likely to support policies that address negative environmental externalities like greenhouse gas emissions. The results of the analysis provide support for this theory. Using the RGGI as the model, I find evidence that participating states with more liberal government ideology are on average more likely to reduce carbon emissions relative to other states within the Initiative, ceteris paribus. Aside from the more liberal states within the initiative, the results show that since the onset of the program, emissions among less ideologically liberal member states are higher on average than those for non-members. This result suggests that the benefits of voluntary emission trading schemes may not occur. Instead, there must be strong political support within the government to spur significant reductions in emissions. Governments measured as more liberal on the ideological spectrum that opt into an emission trading program are much more likely to see significant emission reductions.

Irrespective of the discussion above, ideology's influence on emissions through the mechanism of emission trading is likely more complicated than this model assumes. While the model does find evidence that abatement accomplishments in the RGGI are correlated with liberal state government ideology, the coefficients for these terms are likely picking up a number of other factors. First, more liberal states that opt into emission trading programs may be more likely to implement other policies designed to reduce emissions. I control for the impacts of renewable portfolio standards, but there are other policies such as incentives for energy efficiency, installation of solar panels, as well as other policies at the state and local levels at work at the same time as the RGGI. Next, utilities operating in liberal states are likely anticipating more stringent climate change policy in the future, and are making efforts to decouple emissions from power generation at every turn. This statement is likely the most supportive of the thesis of this essay in that liberal states are systematically different in certain areas from other states with regard to greenhouse gas emissions. While the emission budgets these liberal states agree to may be similar to those of the rest of the states within the exchange, these structural differences within the state lead to a hastened achievement of emission reductions. Finally, the citizens within a state play an important role in electricity markets, and so to in the emission of greenhouse gases. Consumer demand for energy has an enormous impact on emissions, as carbon-intensive generating units are used to generate power. In states with high proportions of citizens concerned about emissions, many more households are likely to install solar panels, thus reducing their demands on the grid, as well as reducing the need to use carbon-intensive generation. Again, this dynamic is one that is consistent with the thesis of the paper, but is one that cannot be isolated within the model.

POLICY IMPLICATIONS

The RGGI represents a state-level innovation designed to address negative externalities that transgress state borders. As such, media outlets and officials have described the RGGI as the model for any future federal program. In 2015, President Obama publicly announced the Clean Power Plan (CPP), an executive order directing the EPA to impose limits on greenhouse gas emissions from states.

It should be noted that the implications from this paper are not generalizable to a United States where a federally-run emission trading market exists, and the cap is set at the federal level. However, the EPA does not have the authority under the Clean Air Act (CAA) to establish and run an emission-trading program. Instead, states are required to develop State Implementation Plans (SIPs) that describe how they will achieve air pollution standards under the CAA (US EPA, 2007).

Under the CPP, the EPA will set an emission target that each state must meet by a certain year. States, through the SIP process, are free to implement any policy to achieve these targets once the EPA approves their plan. In this regulatory environment, states would be free to create new emission-trading programs or join existing programs such as the RGGI. Should states select a trading program, they would not be required to achieve 100% of their target solely through that one program. Instead, should they so choose, it is feasible that states construct their SIPs with multiple policy instruments. Therefore, the trading program may not be the sole means by which a state reduces its CO_2 emissions. Given the results of this paper, it is likely that the results from any trading program arising from the CPP mandate would follow a similar path. That is, the program will be more likely to succeed in states with more liberal state governments.

In the absence of federal regulatory authority over CO_2 emissions, the decision to regulate will continue to rest with the states. Should the CPP ultimately fail to become law, the RGGI may seek to expand its membership, perhaps welcoming back New Jersey, as well as opening membership to several Canadian provinces. In this scenario, the results from this paper will have the most power. States with a political but not ideological reason to enter into the agreement will be less likely to see significant reductions in emissions. Should states like Pennsylvania, Ohio, and Michigan perceive a benefit to joining, but do not face significant ideological pressure to achieve significant reductions, the expansion will prove less beneficial than an expansion including more politically-liberal states.

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APPENDIX 2: ESSAY 2 TABLES

Table 4: Average annual emissions by state between 2005 and 2013.

State	CO2 Emissions	State	CO2 Emissions
Vermont	107,999	Kansas	9,884,945
Idaho	180,462	Iowa	10,370,073
Rhode Island	768,253	South Carolina	10,422,722
Maine	880,240	New York	10,666,555
South Dakota	895,703	Colorado	11,191,724
Delaware	1,313,620	Wisconsin	12,243,956
New Hampshire	1,671,285	Wyoming	12,460,413
Connecticut	1,960,162	Louisiana	12,599,566
Oregon	2,322,717	Tennessee	12,798,996
Washington	2,983,533	Oklahoma	12,855,634
New Jersey	3,939,990	Arizona	15,327,877
Nevada	4,478,853	North Carolina	17,610,762
Massachusetts	4,905,608	Michigan	18,201,696
Montana	4,951,838	West Virginia	20,266,927
Nebraska	6,571,276	Missouri	20,307,355
Maryland	6,734,426	Georgia	21,094,594
Mississippi	6,974,359	Alabama	21,160,628
Virginia	8,271,857	Kentucky	24,621,872
New Mexico	8,331,412	Illinois	26,175,955
North Dakota	8,593,187	Pennsylvania	29,610,883
Arkansas	8,705,938	Indiana	30,723,780
Minnesota	8,949,712	Ohio	31,149,562
Utah	9,610,572	Florida	31,906,472
California	9,804,320	Texas	64,474,095

Table 5: Effects of participation in RGGI and interaction between participation in RGGI and ideology on quarterly state-level CO_2 emissions. Comparison group includes remaining 38 contiguous US states. Standard errors presented in parentheses. Models 1 and 3 control for time effects.

Variable	Model 1	Model 2	Model 3
RGGI Participation	392751.8**	473737.5***	10822.7
	(175564.1)	(175005.7)	(85162.4)
Ideology*RGGI	-5564.7**	-7987.0***	
	(2545.1)	(2375.7)	
Ideology	752.8	2915.2**	
	(1257.7)	(1200.1)	
RPS	-410314.7	-778381.9***	
	(318280.3)	(273039.3)	
Per Cap GSP	105.0**	112.4**	
	(39.50)	(42.63)	
Per Cap GSP Square	-0.000868**	-0.000974**	
	(0.000344)	(0.000384)	
Cooling Degree Days	525.6***	523.8***	
	(97.06)	(95.80)	
Energy Intensity	0.00311*	0.00140	
	(0.00184)	(0.00164)	
Natural Gas Price	-5761.7*	16256.9***	
	(3399.8)	(4718.6)	
Constant	-3050838.7***	-3263987.1***	118250.8***
	(1086057.3)	(1169295.3)	(31916.1)
Observations	1728	1728	1728
Year FE	Yes	No	Yes
R-squared	0.365	0.324	0.089

Standard errors in parentheses
* p<.1 ** p<.05 *** p<.01

Table 6: Treatment group descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Emission Z-Score	360	0.00145	249325.2	-858308	1817655
RPS	360	0.236444	0.135263	0	0.5
Per Cap GSP	360	53627.73	9139.483	37392.73	70314.15
Cooling Degree Days	360	165.9861	249.4374	0	1015
Ideology	360	73.41682	13.39126	44.72255	92.45091
Natural Gas Price	360	7.134481	2.189078	2.5	13.84
Energy Intenstiy	360	3.965448	3.982722	0.012768	15.56271

Table 7: Descriptive statistics for comparison group used in estimation for Table 2.

Variable	Obs	Mean	Std. Dev.	Min	Max
Emission Z-Score	1,368	-0.0111835	380958.3	-1640817	2477828
RPS	1,368	0.1008626	0.1175278	0	0.5
Per Cap GSP	1,368	44281.73	7009.983	30715.75	74882.38
Cooling Degree Days	1,368	314.9678	422.1029	0	1948
Ideology	1,368	42.37217	26.09633	0	89.40877
Natural Gas Price	1,368	7.203414	2.323886	2.466667	18.71333
Energy Intenstiy	1,368	37.27105	47.03813	0.687773	302.2664

Table 8: Effects of participation in RGGI and interaction between participation in RGGI and ideology on quarterly state-level CO_2 emissions. Comparison group includes states with deregulated electricity markets. Standard errors presented in parentheses.

Variable	Model 1	Model 2	Model 3
RGGI Participation	339245.4	372350.1	-16401.3
	(222422.7)	(211753.5)	(116859.5)
Ideology*RGGI	-4626.8	-6991.1**	
	(2745.6)	(2531.6)	
Ideology	-213.9	2365.7	
	(2057.9)	(1969.1)	
RPS	-133913.3	-538113.8	
	(531282.1)	(579725.0)	
Per Cap GSP	106.8	87.01	
	(87.28)	(78.00)	
Per Cap GSP Square	-0.00113	-0.00101	
	(0.000748)	(0.000748)	
Cooling Degree Days	862.8**	860.4**	
	(296.4)	(291.4)	
Energy Intensity	3554.3	1249.2	
	(2137.7)	(1142.3)	
Natural Gas Price	7123.5	20856.5*	
	(10215.8)	(9920.6)	
Constant	-2583694.9	-2086830.3	157372.0**
	(2549235.1)	(2145633.5)	(60984.3)
Observations	540	540	540
Year FE	Yes	No	Yes
R-squared	0.486	0.456	0.089

Standard errors in parentheses

* p<.1   ** p<.05   *** p<.01

Table 9: Effects of participation in RGGI and interaction between participation in RGGI and ideology on quarterly state-level CO_2 emissions. Comparison group includes states matched based on average ideology score over the span of the study. Standard errors presented in parentheses. Models 1 and 3 control for time effects.

Variable	Model 1	Model 2	Model 3
RGGI Participation	250864.9	280613.3	-70003.6
	(237018.4)	(222289.6)	(96034.3)
Ideology*RGGI	-4565.7	-5866.1*	
	(3335.2)	(2802.5)	
Ideology	-776.0	909.3	
	(2118.3)	(1940.1)	
RPS	-644630.0	-665249.7	
	(493693.8)	(411890.0)	
Per Cap GSP	174.4**	119.8*	
	(69.55)	(67.44)	
Per Cap GSP Square	-0.00160**	-0.00117	
	(0.000677)	(0.000687)	
Cooling Degree Days	487.7***	486.5***	
	(100.1)	(98.30)	
Energy Intensity	9005.6	4562.2	
	(8866.7)	(8315.8)	
Natural Gas Price	-9853.0	4676.2	
	(5946.7)	(6676.7)	
Constant	-4523325.1**	-3059962.2*	100844.9
	(1754721.5)	(1646328.5)	(59795.0)
Observations	684	684	684
Year FE	Yes	No	Yes
R-squared	0.261	0.216	0.072

Standard errors in parentheses
* p<.1 ** p<.05 *** p<.01"

Table 10: Descriptive statistics for comparison group.

Variable	Obs	Mean	Std. Dev.	Min	Max
Emission Z-Score	324	0.011367	393544.2	-1462810	1228316
RPS	324	0.19537	0.149515	0	0.5
Per Cap GSP	324	46113.72	6843.328	33452.5	56565.2
Cooling Degree Days	324	217.0525	315.606	0	1386
Ideology	324	71.06113	16.73606	6.652	89.40877
Natural Gas Price	324	7.28177	2.450251	2.5	16.24333
Energy Intenstiy	324	42.26422	30.81255	7.879664	124.3305

Table 11: IPAT model. Coefficients reported as elasticities. Standard deviations reported in parentheses. Models 1 and 3 control for time effects.

Variable	Model 1	Model 2	Model 3
RGGI Participation	0.0534	0.0949	-0.0646
	(0.236)	(0.294)	(0.0729)
RGGI*Ideology	-0.00155	-0.00268	
	(0.00290)	(0.00350)	
RPS	-0.270*	-0.418***	
	(0.155)	(0.129)	
Ideology	-0.00908	0.0356**	
	(0.0215)	(0.0170)	
Per Cap GSP	4.445	7.354	
	(9.472)	(9.651)	
Per Cap GSP Square	-0.191	-0.330	
	(0.440)	(0.450)	
Cooling Degree Days	0.0498***	0.0497***	
	(0.00870)	(0.00871)	
Energy Intensity	0.0395	-0.0176	
	(0.0756)	(0.0681)	
Natural Gas Price	-0.0149	0.0708**	
	(0.0321)	(0.0316)	
Constant	-9.919	-25.36	15.85***
	(51.10)	(51.86)	(0.0216)
Observations	1337	1337	1728
Year FE	Yes	No	Yes
R-squared	0.176	0.148	0.061

Standard errors in parentheses
* p<.1 ** p<.05 *** p<.01

Table 12: State descriptive statistics.

	Statistics	CO2 Emissions	Per Cap GSP	Cooling Degree Days	Ideology	Population	Energy Intensity
Mississippi	Mean	6,974,359	0.032	554.22	42.19	2,952,382	4.46
	Standard Deviation	1,310,508	0.001	527.70	8.05	31,484	0.31
Missouri	Mean	20,307,355	0.043	334.39	36.46	5,942,271	0.73
	Standard Deviation	1,464,325	0.000	381.77	15.41	83,718	0.08
Montana	Mean	4,951,838	0.037	55.50	58.43	980,743	31.02
	Standard Deviation	1,045,776	0.001	91.06	6.84	23,670	2.78
Nebraska	Mean	6,571,276	0.049	261.08	21.15	1,813,572	3.44
	Standard Deviation	795,144	0.002	312.83	2.81	36,111	0.66
Nevada	Mean	4,478,853	0.048	539.86	39.85	2,651,093	0.39
	Standard Deviation	1,113,282	0.004	583.48	4.54	109,677	0.10
New Hampshire	Mean	1,671,285	0.047	80.19	62.27	1,314,577	2.28
	Standard Deviation	469,200	0.001	118.55	15.09	7,172	0.18
New Jersey	Mean	3,939,990	0.057	231.69	70.49	8,762,740	0.75
	Standard Deviation	937,324	0.001	292.90	16.35	88,895	0.04
New Mexico	Mean	8,331,412	0.040	254.08	68.06	2,027,075	30.01
	Standard Deviation	773,623	0.001	290.22	19.44	54,023	2.35
New York	Mean	10,666,555	0.061	166.11	70.84	19,335,254	0.74
	Standard Deviation	2,517,260	0.001	222.71	14.01	197,445	0.04
North Carolina	Mean	17,610,762	0.045	375.92	61.88	9,367,451	1.36
	Standard Deviation	2,489,639	0.001	412.49	23.14	371,386	0.05
North Dakota	Mean	8,593,187	0.052	117.97	28.05	672,758	34.81
	Standard Deviation	701,124	0.009	156.84	3.11	25,014	9.73
Ohio	Mean	31,149,562	0.044	208.14	36.37	11,523,148	2.02
	Standard Deviation	4,005,070	0.001	246.60	22.13	34,335	0.18
Oklahoma	Mean	12,855,634	0.040	507.75	34.87	3,708,303	17.75
	Standard Deviation	1,888,385	0.001	554.61	17.90	99,142	1.07
Oregon	Mean	2,322,717	0.049	52.92	78.28	3,790,985	2.35
	Standard Deviation	943,422	0.003	89.31	4.79	101,857	0.17
Pennsylvania	Mean	29,610,883	0.046	186.53	48.54	12,643,771	5.88
	Standard Deviation	2,580,012	0.001	232.80	16.17	111,390	1.75
Rhode Island	Mean	768,253	0.047	150.56	74.40	1,055,757	0.06
	Standard Deviation	209,429	0.001	212.28	3.04	5,813	0.02
South Carolina	Mean	10,422,722	0.036	491.97	8.03	4,555,456	3.94
	Standard Deviation	1,722,426	0.001	498.57	4.60	162,675	0.11
South Dakota	Mean	895,703	0.046	186.83	22.51	808,361	4.89
	Standard Deviation	198,207	0.002	242.63	0.64	22,377	1.18
Tennessee	Mean	12,798,996	0.041	369.08	42.76	6,279,435	1.96
	Standard Deviation	2,937,771	0.001	403.01	23.26	162,058	0.12
Texas	Mean	64,474,095	0.049	723.64	11.40	24,719,507	9.67
	Standard Deviation	8,339,810	0.002	616.61	3.01	1,194,944	0.81
Utah	Mean	9,610,572	0.044	132.69	11.90	2,701,375	9.37
	Standard Deviation	948,248	0.001	183.68	4.97	145,229	0.48
Vermont	Mean	107,999	0.042	64.25	78.79	624,584	2.97
	Standard Deviation	24,463	0.001	94.67	8.12	1,731	0.25
Virginia	Mean	8,271,857	0.052	294.81	44.71	7,926,507	2.75
	Standard Deviation	1,568,794	0.001	345.23	17.27	225,853	0.26
Washington	Mean	2,983,533	0.053	42.19	80.97	6,638,863	2.83
	Standard Deviation	1,481,634	0.001	68.43	3.61	233,233	0.23
West Virginia	Mean	20,266,927	0.035	206.81	79.57	1,843,428	61.55
	Standard Deviation	2,566,883	0.001	247.22	3.21	12,785	4.98
Wisconsin	Mean	12,243,956	0.045	140.72	44.97	5,656,663	1.17
	Standard Deviation	1,273,393	0.001	178.35	29.91	64,800	0.10
Wyoming	Mean	12,460,413	0.065	76.58	35.82	552,048	279.61
	Standard Deviation	1,259,778	0.004	114.86	22.01	22,962	23.02

Table 13: Regression results using aggregate quarterly emissions by state as the dependent variable.

Variable	Model 1	Model 2	Model 3
RGGI Participation	2,108,418*** (773,128)	2,747,496*** (935,814)	479,713 (388,382)
Ideology*RGGI	-25,264** (10,985)	41,124*** (12,131)	
Ideology	6,604 (719)	18,016*** (3,176)	
RPS	-4,131,341* (2,116,244)	-5,876,916*** (889,822)	
Per Cap GSP	504** (216)	520*** (138)	
Per Cap GSP Square	-0.004** (0.002)	-0.004*** (.001)	
Cooling Degree Days	3,501*** (719)	3,515*** (125)	
Energy Intensity	19,914 (12,962)	11,991* (6,452)	
Natural Gas Price	21,212 (28,069)	140,456*** (21,145)	
Contstant	-2,674,708 (5,985,959)	-4,165,259 (3,525,469)	
Observations	1728	1728	1728
Year FE	Yes	No	Yes
R-Square	0.407	0.374	0.093

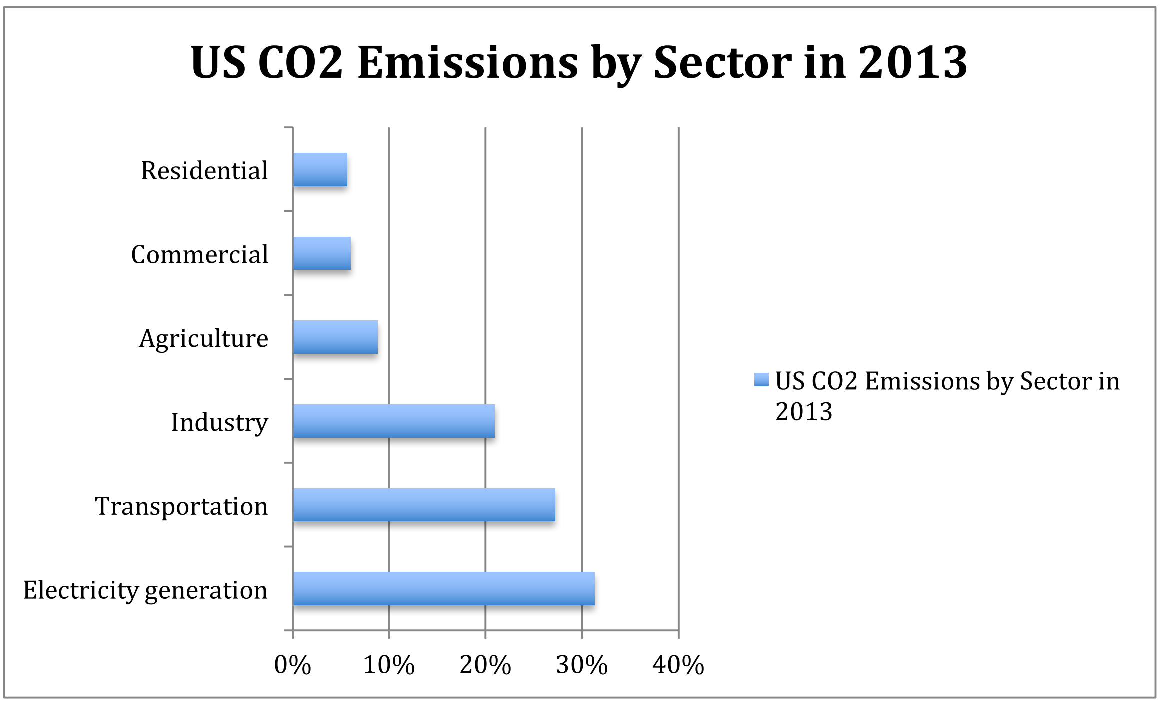
ESSAY 3: RATCHET EFFECTS AND THE IMPACT OF EMISSION TRADING ON EXISTING POWER GENERATION INFRASTRUCTURE

INTRODUCTION

As policymakers and regulators place more focus on anthropogenic climate change, policy researchers have kept pace with the development of literature explaining the effects of these policies on outcomes. In recent years, researchers and policymakers alike have emphasized emission trading as an effective and politically viable means of reducing greenhouse gas emissions. This paper furthers the literature on strategic behaviors related to emission trading programs by conducting an empirical analysis of data from the Regional Greenhouse Gas Initiative (RGGI), an emission-trading market for carbon dioxide emissions. Within this essay, I focus on the decisions made by existing coal-fired electric generating companies (gencos) in the effort to adapt to the constraints of the program. I specifically examine three adaptation strategies by which these gencos can achieve emission abatement. I find evidence that the RGGI may be hampering longer-term investment decisions in capital designed to mitigate emissions. In the coming sections, I first describe the conditions leading to the call for climate policy, and then describe certain behaviors that may limit the effectiveness of quota-based policies. I also spend time describing the power sector, and the impact of deregulation of the wholesale market on outcomes from the RGGI. Finally, I conclude with a discussion of the impacts of the Regional Greenhouse Gas Initiative on future emissions and the implications of these impacts for a national program.

Emissions and the Power Sector

The interest in addressing greenhouse gas emissions has led to a heightened focus on the power generation sector due its relatively high level of carbon emissions (see Figure 7). The overwhelming majority of these emissions come from power plants that use coal, natural gas and fuel oil to generate electricity. The power sector is a vital component of all developed countries, and therefore presents large potential opportunity costs for policymakers considering regulatory policies (Leung and Meisen, 2005).[25] To highlight these costs, the asset valuation of the power generation sector was determined to be nearly $840 billion in 2014.[26]



[25] A major concern about global greenhouse gas emissions has to do with the acknowledgement that large international populations are moving more towards development and away from traditional agriculturally-based economies. These transitions are linked to the spread of access to electric power systems (Chow et al., 2003).

[26] Figure provided by Edison Electric Institute.

Figure 7: Greenhouse gas emissions by sector. Data used to create graph were retrieved from the EPA.

Determining feasible and cost effective regulatory limits to emissions is complicated by the non-uniformity of emission abatement costs in the sector. Fuel prices, age of capital, generator efficiency, and size of the plant (i.e. nameplate capacity) all affect emission abatement costs.[27] For this reason, command and control policies that force all individual power plants to reduce emissions equally have the potential to increase total costs relative to incentive-based policy (Stavins, 1995).[28] The optimal cost-effective solution occurs where low abatement cost power plants undertake the majority of reductions (Keohane and Olmstead, 2007). For this reason, quantity based emission-trading policies for carbon emissions are a means by which society can reduce its emissions at the lowest possible cost (Stavins, 2008).

Policies designed to target emissions from the power sector focus either on moving generation toward renewable sources like solar and wind, or incentivizing fossil fuel generators to become more efficient and use fuels with lower carbon content. As described above, the opportunity costs of abandoning the current infrastructure in favor of new, lower emission generation capacity make such a policy cost a non-starter.

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[27] Per the Energy Information Agency's report titled "Analysis of Heat Rate Improvement Potential at Coal-Fired Power Plants."

[28] Stavins (1995) provides circumstances under which incentive-based policy may not see cost decreases relative to command and control. Transaction costs from 1) search and information, where gencos reveal abatement cost information; 2) bargaining, where gencos reach agreements on purchasing and selling permits; and 3) enforcement, where regulators ensure compliance; all increase the total costs of an emission trading program.

Instead, regulators seek to improve the emissions coming from current gencos instead of abandoning them outright.

Regulatory Policy and the Ratchet Effect

Government-enforced carbon emission ceilings are an example of regulatory policy.[29] Typically, policymakers design these limits to address some form of market failure. In that vein, ceilings are used to prevent the overproduction of goods with negative spillover effects. When left unregulated, the power sector will overproduce air and water pollution resulting from combusting carbon-intensive fuels. Power producers operate to maximize profits subject to regulatory constraints, a fact that may impact their willingness to comply with regulatory pollution targets.

In the absence of perfect information about firm-level production costs, regulators face a challenge in how to set production targets. Tarui and Polasky (2005) find that when uncertainty about damages from pollution is low, consistent rules are the best solution because firms are not able to manipulate behaviors. When uncertainty about damages is high, as is often the case, adjusting policy after learning of firm compliance costs is best (2005). Gencos, when faced with potentially costly regulations on CO_2 emissions, have an incentive to retain information on the costs of abatement in order to prevent a more stringent future target. Regulatory policies that adjust production targets over time tend to exacerbate the need for firms to hide their costs (Freixas et al., 1985; Sappington, 1991). The literature labels policies that adjust quantity-based targets over time as ratcheting policies (Weitzman, 1980; Laffont and Tirole, 1988; Bottasso and

[29] Regulatory policy can sometimes be structured to either limit or ensure a minimum level of production of some output or service. Examples include construction of low-income housing in the United States during the 1960s and 1970s (Turner et al., 2003) and milk quotas in the UK.

Conti, 2009).[30] Energy sector emission trading programs commonly contain ratcheting elements whereby regulators ratchet emission ceilings down over time.

A major component of the adaptation strategy for gencos facing limits on emissions is the adoption of new technologies. As described by Dearden, Ickes and Samuelson (1990), the costs to the agent (the individual genco in this case) of adopting technological innovations derive from the cost of purchasing and installing the new components, as well as the expected costs of complying with a lower emission ceiling in the future. Adopting key technological innovations enables the genco to achieve pollution targets at a lower cost, thus signaling that more stringent future targets are feasible. From this perspective, the perceived benefits of investing in new technology may be insufficient to overcome the costs related to future target constrictions.

Firms that anticipate higher future costs resulting from increasingly stringent emission targets will face an incentive to attenuate future emission abatement in any way possible. This behavior is referred to as the ratchet effect (Weitzman, 1980). In the context of an emission-trading program, gencos receive payment for abated emissions, but also incur a cost from abating emissions (ε). Both the benefits (b) and the costs (C) come in the form of the price of an emission permit (p). The benefits of emissions (q) in the current period are reduced by present value of the future target constriction (λ):

$$C(\varepsilon_t; p) = \frac{b(q_t; p)}{1 + \frac{\lambda}{r}}$$

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[30] Other examples of research on the ratchet effect include Murphy's (2000) study of the effects of sales performance incentives on managers' decisions to control earnings; Choi and Thum's (2001) study of the decision to procure a business permit; Macartney's (2014) study of the reaction of schools to achievement incentives; and Chulkov's (2014) study of the effect of production quotas in the USSR on the adoption of technological innovations.

where r is the discount rate (Weitzman, 1980). As the future emissions target becomes more onerous, the benefits of further abatement in the current period diminish, leading to the perverse incentives of the ratchet effect.

Emission trading markets place gencos in a dynamic environment, where profits in the current period must account for future costs generated by diminishing emission ceilings (Hepburn, 2006). The literature finds that the structure of climate policy has a large effect on the behavior of regulated firms. In their work on comparing tax-based emission regulation to quantity-based regulation, Moledina et al. (2001) find that firms react to quantity-based targets by under-abating, while firms react to tax-based regulations by over-abating.

I use this paper to empirically identify the presence or absence of the ratchet effect in the compliance decisions of gencos in the RGGI. In the next section, I focus on critical elements intrinsic to the power industry that may contribute to or detract from the incentive for gencos to strategically manipulate emissions.

The Power Industry, Emissions Trading, and the Ratchet Effect

As discussed in the previous section, the ratchet effect from a theoretical perspective may lead profit-maximizing gencos to under-abate emissions. Critical to the empirical component of this article is the fact that gencos in most areas of the United States do not operate like traditional profit-maximizing firms. In this section, I discuss the unique aspects of the power sector that will contribute to or detract from the incentive of gencos in the RGGI to strategically manipulate emissions in a manner consistent with the ratchet effect.

Historically, the power sector operated in a heavily regulated environment (Christensen, 1998). Utilities would typically vertically integrate, meaning that each utility would own the full range of infrastructure required to deliver electricity to end users. Included within this infrastructure are electric power generation, transmission lines, distribution lines, and sales. As the size and scope of the electricity industry grew, vertical integration made economic sense because all three stages in the supply chain possessed natural monopoly characteristics.[31] Vertical integration by utilities removed competition in regional power markets, leading to the regulation of prices by regulators, thus avoiding price increases predicted by monopoly economic models.

Until the 1980s, electric utilities were subject to rate of return regulation designed to control prices and ensure sufficient levels of production. Under rate of return regulation, power producers and distributors do not set prices according to profit-maximizing principles (Jamison, 2005). Instead, regulators assign prices to allow for a normal profit, but one that is lower than an unregulated monopoly would merit (Christenson and Greene, 1976). The price for electricity that customers ultimately pay is based on the average cost of production over a specified period of time (Borenstein, 2009). Under traditional rate of return regulation, the regulatory authority, in most cases the Public Utility Commission (PUC), is responsible for setting the rate that utilities can charge for electricity. Should the costs of generation and delivery change, the utility must

[31] Power generation benefitted to a certain extent from economies of scale, whereby increasing the capacity of coal-fired plants lowered the average cost of production. This drop in average costs only occurred to a certain point, after which increasing investments in capacity did not provide increasing returns to scale (Christenson and Greene, 1976). As for transmission and distribution, both are mostly considered to be natural monopolies due to the costly and aesthetically displeasing nature of erecting competing power lines (Joskow, 1997).

request a rate change from the PUC (Philipson and Willis, 1999). Rate of return regulation virtually removes the risk of economic losses for power producers. Instead, producers may be able to maximize total profits by investing in costly capital upgrades, thus increasing the rate they receive from production (Averch and Johnson, 1962). This fact is important in the context of regulatory policies designed to place a ceiling on emissions because these policies will invariably drive up costs.

Over the course of nearly a century, power generation became much more efficient. As a result, the cost of electricity production dropped from nearly $4.50 per kWh in 1902 to less than 5 cents currently.[32] The majority of these efficiency gains came from scaling up the size of the generator (Philipson and Willis, 1999). Eventually, through the combined forces of smaller, more efficient generation technology and the realization that economies of scale for power generation do not persist indefinitely, a movement began to open portions of the electric power industry to competition (Rothwell and Gomez, 2003). This meant disassembling the vertically integrated utilities and allowing power generators to operate separately from the rest of the power supply chain. In the deregulated environment, competitive gencos are able to act more like traditional profit maximizers, selling their product in wholesale markets. Under competition, efficient and low cost gencos are able to sell their product at a higher profit than they otherwise would have received under regulation. Coincidentally, higher cost gencos are subject to losses. The fact that gencos in deregulated power markets face higher risks of economic losses suggests a diminished incentive to invest in expensive emission

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[32] Prices at the turn of the century until around 1930 can be found here: http://instituteforenergyresearch.org/history-electricity/ . For prices in the last half of the 20th century and the first part of the 21st century, please visit: http://www.eia.gov/totalenergy/data/monthly/pdf/sec9_11.pdf.

mitigation capital. For this reason, it is unreasonable to compare deregulated gencos to those still under traditional regulation when studying climate policy adaptation behavior.

This last remark is critical with respect to the development of the research design for this article. With the exception of Vermont, all of the member states of the RGGI have deregulated electricity wholesale markets. Gencos within these member states will face different profit scenarios than regulated gencos, and may respond in a fundamentally different way to emission limits. Should ratchet effects be present in power markets participating in emission trading programs, they are most likely to exist in deregulated power markets.

EMISSION TRADING AND THE RATCHET EFFECT

The cost of electricity generation has a notable impact on the economic viability of a genco in a deregulated setting because they can no longer rely on guaranteed normal profits. Therefore, any attempt to implement a restriction on emissions in a deregulated market will have serious implications for a subset of producers. This is because emission-trading programs are designed to locate and assign a price on carbon emissions, thus unavoidably increasing the average cost curve for generators that use fossil fuel sources. From a theoretical perspective, emission trading will lead producers with relatively low abatement costs to undertake the largest emissions reductions, while those with higher abatement costs pay for the right to continue emitting (Keohane and Olmstead, 2007). In practice, it is unclear how these abatement decisions will actually be made. Therefore, it is important to consider the effect an emission-trading market might have on decisions made by gencos.

Under emission trading, regulators provide the right to emit CO_2 by allocating permits. The form of allocation can be based either on historic emissions (i.e. grandfathering) or through auction. In the latter, firms bid on the quantity of permits they think they will need during a specified period of time based on a permit price. In either scenario, the policy allows participants to either use the permit in the current period, or bank it for use in a later period. This affords power plants the option to make emission abatement decisions based on the dynamic value of the permit. This decision has consequences for the future, however. Using the logic of the ratchet effect, the genco takes into account the impact this abatement decision will have on future emission limits. If the sector abates more than anticipated by regulators, that is, not all permits make it back to the exchange, regulators may adjust future targets downward accordingly.

The intent of setting the emission limit from a societal perspective is to achieve reductions in aggregate emissions in a cost-effective way. If the benefit of reducing the last ton of CO_2 is at least as great as the cost of doing so, then regulators will want to set a target to achieve that last ton of abatement. In emission-trading markets, regulators determine future emission targets using historic emission quantities as a baseline, ratcheting the target downward when deemed feasible (Stavins, 2008). When facing compliance with emission regulation constructed using ratcheting principles, gencos have the ability and incentive to present their abatement costs as higher than the least cost solution in order to prevent a more stringent future cap. In this way, the ratcheting effect can have a deleterious effect on the ability of the policy to achieve its target (Weitzman, 1980; Joskow, 2007).

If the ratcheting effect occurs, I expect to observe similar performances from gencos facing emissions limits and those with no limits. In a study on the effects of power market deregulation on outcomes in a pollution permit market, Fowlie (2005) found evidence that gencos in deregulated power markets were less likely than their regulated counterparts to adopt pollution mitigation technology, a result that is relevant to this paper. At the same time, provided that carbon prices contribute positively to the marginal costs of generation, deregulated gencos competing on cost will seek to limit the carbon costs if possible. However, if these same gencos opt to reduce their costs by abating emissions, regulators will be able to continue ratcheting down emission targets. Within a deregulated market subject to carbon constraints, gencos must balance the desire to avoid emission costs by abating with the intuition that by abating they are sending a signal to the regulator that lower future targets may be feasible (Moledina et al., 2003).

To this point, researchers have not given an empirical treatment to measure the impact of the ratchet effect on genco decisions to invest in abatement measures in an emission-trading market.[33] There is a contention that in a market where permits are auctioned rather than grandfathered, the perverse incentives inherent to ratcheting regulations will either be small or non-existent (Demailly and Quirion, 2006; Hepburn et al., 2006; Neuhoff et al. 2006). According to this line of literature, the free allocation of permits has a limited effect on the average cost curve for the power producer, so day-to-day operations remain relatively untouched as the external costs are not infused into the price of electricity. The marginal costs of production will only increase if the genco pays for the right to emit. Similarly, if regulators freely allocate permits based on historical

[33] The literature does look at plant investment strategies when facing regulatory uncertainty (Blyth et al., 2007; Sekar et al., 2007).

emissions, then these plants will want to maintain as high a permit budget as possible, thus avoiding the need to make costly abatement investments (Neuhoff et al., 2006). Contrasting this perspective, Woerdman et al. (2007) suggest that by requiring power plants to purchase permits through an auction, the costs of abatement are passed on to the consumer. These costs are easily passed on because consumer demand for electricity has been shown to be price inelastic, meaning that increases in prices have limited effects on demand (Lijesen, 2007; Borenstein, 2008).[34] From this view, the net effect of auctioning permits will be the same as under grandfathering. This leads to the underlying research question for this article: will the ratcheting component of emission-trading schemes have an effect on the emission abatement decisions made by generating companies?

Standard Operating Costs

According to theory, the optimal level of abatement a genco will choose occurs where the marginal cost of abatement just equals the price of the permit (Montgomery, 1972). Before understanding what the costs of abatement facing a producer might be, it is useful to examine the array of operating costs that generation companies incur. Any adoption of abatement technology will add to these existing operating costs. For the purposes of this paper, only gencos using coal fuels at the time their state entered into an emission-trading scheme will be considered.[35]

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[34] Borenstein (2008) notes that historic measures of price elasticity of electricity demand have suffered from failures to account for the fact that consumers may not be perfect optimizers when it comes to adjusting behavior to account for changing electricity prices. Instead, consumers operate using bounded rationality, whereby price response develops over time. Regardless, his results show highly inelastic demand response.

[35] Coal has the highest carbon content of any of the major fuel sources used for the generation of electricity (see http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11). As such, coal-fired power plants will be impacted the most by cap and trade policies.

When making an investment decision in power generation, that is, expanding the size of the plant or replacing existing pieces of equipment, the standard cost parameters include capital (fixed costs) and operation/maintenance (variable costs). Capital includes the boiler, turbine, generator, transformer, and transmission lines (Mazer, 2007). Operations and maintenance (O&M) includes fuel costs, labor, and general upkeep. For standard coal-fired power plants, capital costs are roughly $2,700 per kilowatt of installed capacity, while variable O&M is about $4.50 per MWh (US EIA, 2016). Gencos seeking to expand production may decide to construct new plants or upgrade existing plants.

Abatement Options and Costs

In 2014, the Environmental Protection Agency's (EPA) Office of Air and Radiation released a guideline on options for reducing carbon emissions for existing power plants. The EPA, with authorities granted under the amendments made in 1990 to the Clean Air Act, is responsible for measuring and tracking emissions of various greenhouse gases and other pollutants from the power sector. I use these guidelines to formulate the dependent variables for this paper as they represent the most comprehensive and detailed list of abatement options available.

First among the emission abatement options is the improvement of the generator's heat rate. Heat rate refers to the amount of thermal energy (Btus) per unit of electricity generated (kWh). As the generator becomes more efficient, the heat rate ratio becomes smaller. Heat-rate efficiency is defined as maximizing the amount of work done while minimizing the inputs. In this context, as power producers improve heat rate efficiency they reduce the amount of fuel needed to maintain production. Reductions in fuel requirements leads to lower emissions, ceteris paribus.

According to the Energy Information Agency (EIA), heat rate ranges from a low of about 8,200 Btu/kWh for natural gas to nearly 11,000 Btu/kWh for petroleum, with coal (10,400) and nuclear (10,400) falling in the middle (US EIA, 2011). Historically, coal served as the primary fuel source in the United States due to large natural reserves, making it both abundant and cheap.[36] As described above, coal-fired power generators tend to be less heat-rate efficient than natural gas-fired generators. As it stands, coal contains nearly twice as much carbon as natural gas. Therefore, relying primarily on coal for electricity supply is not optimal from an emissions standpoint. In recent years, natural gas is increasingly serving as a substitute for coal as a fuel source for power generation (see Figure 8 below) (US EIA, 2016). Nationally, the overwhelming majority of all new plant builds use natural gas.[37] Coincidentally, the development of heat-rate efficient combined cycle gas turbines (CCGT) technologies led to the erosion of traditional economies of scale for electric power generation (Colpier and Cornland, 2002).[38] That is, larger plants are no longer the most cost-effective producers of electricity. These trends have had significant impacts on potential regulatory structure needed to manage the electric power sector.

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[36] Historically, coal represented well over 50% of total electricity generation, followed distantly by nuclear and natural gas: http://www.eia.gov/pressroom/presentations/sieminski_06052013.pdf.
[37] Data on new capacity additions are available from the EIA. In 2013, natural gas additions accounted for nearly 50% of all new installed capacity. Solar/photovoltaic accounted for the next highest at nearly 22% http://www.eia.gov/electricity/annual/.
[38] CCGTs enable gas-fired power plants to become much more heat-rate efficient because they capture the waste heat that was lost in older gas-fired plants and use it to spin a second turbine. Much more of the heat generated from combustion is used to generate power than in any other type of generator. https://powergen.gepower.com/resources/knowledge-base/combined-cycle-power-plant-how-it-works.html.

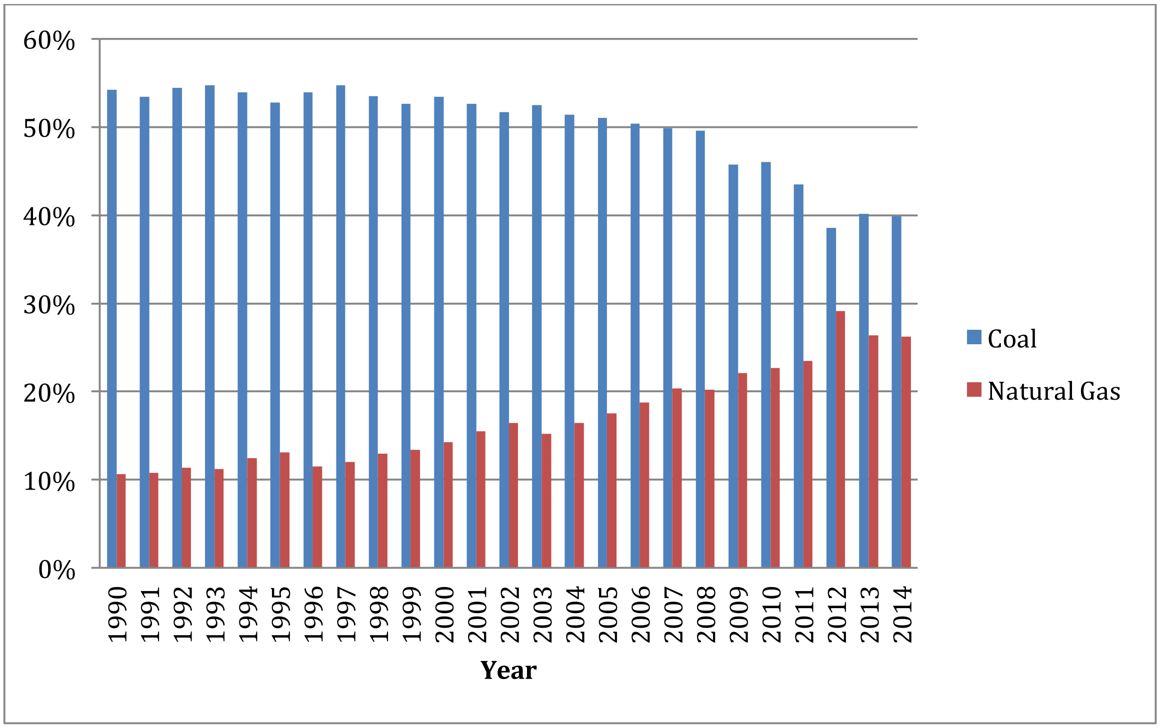

Figure 8: Coal and natural gas usage as percentage of total net electricity generation between 1990 – 2014. Data provided by EIA.

For regulators concerned about emissions coming from the power sector, improvements in generator efficiency is a positive trend. Of all the components of the generation system, boilers have the largest impact on heat rate. Within the boiler, fuel is combusted and the resulting thermal energy is used to either turn water to steam or superheat air within the chamber. The components of the boiler include a fuel feeder, combustor, sootblower, and air heaters. Gencos have a choice of three boiler options: subcritical, supercritical, or ultra-supercritical. Subcritical boilers have relatively low heat rate efficiency, while ultra-supercritical boilers are the most efficient. Fixed costs rise while marginal costs decline with the efficiency of the boiler, so trends in fuel costs and carbon prices will have an impact on which type the genco chooses. Some additional factors affecting heat rate efficiency include the size of the genco (higher generation capacity is correlated with higher heat rate efficiency), the type of turbine used, the flue gas system, emission control technologies, and the nature of the genco's deployment as a supplier of electricity to the grid (baseload gencos are more efficient than peaker units).[39]

The second option for abating emissions involves the choice of source fuel. Natural gas has roughly half the carbon content of coal. By switching from coal or petroleum to natural gas, genco CO_2 emissions will drop significantly without compromising electricity production targets. This switch is subject to greater cost uncertainties due to limitations on storing large quantities of natural gas. Historically, a switch from one fuel to another within a single unit required an investment in new technology, and was therefore only an option when a genco made the decision to build a new unit (Courtemanche and Penterson, 2012). However, modifications to boiler technologies over the last several decades now enable gencos to switch between fuel sources without constructing a new unit, although this can be a potentially lengthy process (Soderholm, 2001). Fuel switching can also occur among separate existing units within the genco. Frequently, gencos own several generating units, each of which may be powered by different fuels. Should the genco decide to switch from coal to natural gas, it could shift production from its coal units to the natural gas units.

The third option is to close the generating unit. Typically, the majority of the burden of achieving compliance with emissions regulations falls on older coal-fired generating units. These units were built during a period when CO_2 emissions were not a

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[39] The Energy Information Administration (EIA) produced a report examining the influence a various factors on power plant heat rate. I use these factors as control variables for this paper: https://www.eia.gov/analysis/studies/powerplants/heatrate/pdf/heatrate.pdf.

primary concern, and as a result tend to rely on carbon-heavy coal. Similarly, many of these older plants use older, less efficient boiler technologies. In some cases, the cost of shuttering a plant may be lower than retrofitting the plant with modern technology and switching fuel sources.

A fourth option technically exists, and that is to invest in carbon capture and storage (CCS). Capture can occur at different stages in the combustion process. However, carbon capture from power plants most frequently refers to the post-combustion phase. This post-combustion carbon capture process is commonly referred to as scrubbing. This is where the CO_2 gas generated by the combustion of coal is prevented from leaving the flue and going into the atmosphere. Once the CO_2 is sequestered, it can then be transported, often via pipeline, to geologic storage areas. More recently, this gas is being used in oil production as a means to get oil out of the ground. Carbon capture and storage technology is fully developed and readily available for use in large-scale power plants. However, retrofitting existing plants with scrubbers and transport pipelines is very costly. In fact, retrofitting these plants is not economically viable within the realistic range of carbon costs. Therefore, CCS is not an option for existing plants at this point.

Regional Greenhouse Gas Initiative and the Ratchet Effect

The RGGI provides a setting in which to test the theory of the ratchet effect in emission trading. It is the first market for CO_2 emissions in the United States, and as such serves as a testing ground for other states and the country as a whole. As the RGGI is the first of its kind in the US, regulators have limited information on the costs of abating CO_2 by firms within the compact.

In 2009, the RGGI commenced operations with an aggregate CO_2 limit of about 188 million tons. This limit was set based on a 4% projected increase in the average emissions for the participating states between 2002 and 2004. According to the ratchet effect theory, firms should have maintained emissions at the upper bounds of this limit to demonstrate that a more restrictive limit was not feasible. However, this was not the outcome. In fact, over the first 5 years of the RGGI's operation, emissions have decreased from year to year to the point where regulators have assigned a new and much lower limit beginning in 2014.

According to the ratchet effect, this should not be the case. However, the inception of the RGGI occurred around the same period when new natural gas production techniques dramatically increased the domestic supply, thus lowering prices. Additionally, 2009 marked the onset of the Great Recession, during which power demands retracted. While demand rebounded in 2010, it continued a downward trend in the next two years. Thus, a component of the analysis in this study will be to distinguish between abatement measures taken in response to participation in the RGGI and those resulting from the combined effects of dropping natural gas prices and diminishing demand.

DATA

In this essay, I empirically analyze the abatement decisions firms within the RGGI made when faced with limits to CO_2 emissions. Given the research question underlying this study, the unit of analysis will be the individual genco in a given year. In this section, I describe the indicators for abatement decisions made by gencos. I also describe the empirical models used to identify the impact that cap and trade regulation has on genco decisions.

The data on these gencos come from multiple sources, all of which are made available by the EIA. Of interest are observations on fuel source, generation (i.e. number of megawatt hours per year), thermal input (number of annual Btus), electrical generation capacity (i.e. nameplate capacity), years of operation, closing year, and fuel prices. Annual observations on fuel source, generation and thermal input come from the EIA's form 906/920/923 from 2005 - 2013. The EIA uses these forms to collect monthly data from a random sample of 1,900 electricity generators on a wide array of measures. The agency also collects annual data on the same variables from the remaining nearly 4,050 generators. Accounting for non-response, each annual report contains observations on 85% of all gencos at a minimum, with a maximum response rate of 90%. Periodically, gencos will fail to submit the survey in time to be included among the observations, leading to missing data. Out of concern for bias due to these omissions, I conducted the analyses using multiple methods of imputation for the missing observations. First, I took an average of previous and future observations. Next, I imputed using previous observations. Finally, I imputed using the forward observations. I compared the empirical outcomes of these three iterations to the analysis of the data with missing observations and found no substantive difference. The findings reported in this essay reflect analysis using non-imputed data.

Observations on years of operation, nameplate capacity, and retirement year come from EIA form 860. Finally, observations on coal and natural gas prices come from the EIA's Electric Power Monthly report. Plant-level fuel costs are not available because the gencos studied in this paper all operate in deregulated markets. As such, they are not required to report fuel costs. Therefore, I use the annual composite measure of coal prices from the EIA for my fuel price variable.

COMPARISON GROUP

Given the aim of this paper, selection bias poses a threat to internal validity. As mentioned in the section on deregulated markets, gencos are expected to face significantly different incentives depending on the type of power market in which they operate. Under traditional rate of return regulation, gencos may see an opportunity to increase economic profits by investing in emission abatement capital. The same cannot be said of those operating in deregulated power markets. Any increase in fixed and/or variable costs for these firms will reduce economic profits. Therefore, it is difficult to make the case for comparing gencos that do not face similar competitive forces. For this reason, I present results in the main body of the paper using gencos operating in deregulated power market states as the comparison group. This group includes Oregon, Texas, Illinois, Michigan, Ohio, and Pennsylvania. All of the states participating in the RGGI have deregulated markets as well except Vermont. As Vermont's fleet is minute relative to the rest of the RGGI, I exclude it from the analysis. I present the generation trends for this comparison group in Table 14.

MODELS

As mentioned in the section on abatement costs and adaptation options, there are three options by which gencos may economically abate emissions: improve heat rate, switch to lower carbon content fuel, and cease plant operations. In this section, I present each of the models I use to estimate the impact of the RGGI on these emission abatement options. Additionally, I condense the three models in Table 15.

HEAT RATE

I first look for evidence of the genco's efforts to improve heat rate, which is the ratio of Btus used to kWhs generated. While there are a number of options to improve efficiency options available, the most impactful is the type of boiler (Campbell, 2013). By investing in more efficient boilers, gencos use less fuel to generate the same flow of electricity, resulting in lower emissions. If a plant decides to install a more efficient boiler, the heat rate measure from the plant would decrease from the previous period, an indication that the amount of fuel needed to produce a kWh has gone down. Within an emission-trading program, permit prices will have the greatest effect on coal-fired plants as these units emit roughly twice as much CO_2 per kWh as natural gas plants. Therefore, I only consider coal-fired power plants in my analysis of heat rate efficiency improvements.

I am not able to observe all of the factors that influence heat rate, as the data do not identify specific factors (e.g. types of boiler and turbine). I do control for the size of the genco (i.e. nameplate capacity), time of service (number of years of operation), and the mix of fuel used by the genco, all of which affect heat rate.[40] Within the mix of fuel variable, I separate coal into type (i.e. bituminous, subbituminous, and lignite) because each has a different Btu and carbon content. I also control for the mean price of coal for the state in which the genco operates. Controlling for these factors will separate the

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[40] As noted earlier, the EIA controls for these factors in its analysis of plants that would benefit by improving heat rate:
https://www.eia.gov/analysis/studies/powerplants/heatrate/pdf/heatrate.pdf.

primary endogenous plant characteristics that affect heat rate outside of regulatory constraints. In order to reduce the likelihood of omitted variable bias, I employ entity fixed effects, which allows me to control for those factors that vary across gencos but not over time.

Next, I consider the quality of the data I use for this study. Within the data set for the fleet of gencos, a subset of these plants act as outliers. First, the RGGI only affects those plants with a nameplate capacity greater than 25 MWs. To account for this, I remove all plants with a nameplate capacity lower than 25 MWs. Next, gencos only report net power generation, which is the difference between total generation (MWhs) and power generated for use within the genco. Power used by the genco will not transmit to the grid, and is not captured in the data. This data set captures all entities that generate electricity, and as such it also includes industrial companies that generate power for internal use, most of which never reaches the grid. In these scenarios, heat rate measures tend to be highly misleading. The EPA accounts for outliers caused by atypical generation scenarios in their study by removing plants with heat rates outside of the 6.5 – 15 Btu/MWh range, and I do the same (US EPA, 2014).

According to the theory of the ratchet effect, plants will delay making changes to their production schedule if they anticipate a more stringent future production quota (Weitzman, 1980). Therefore, if power plants do consider the impact of their current production on future emission caps, they will see an incentive to delay any large adaptations to their plant.

> *H_1: Heat rate will be higher for power generating companies operating within states that participate in the RGGI than their counterparts operating in non-cap and trade states.*

I test this hypothesis by using a panel fixed effects linear regression model. Table 16 and Table 17 provide descriptive statistics for the treatment and comparison groups. The fixed effects model provides a means to control those factors that affect the outcome variable, are not included in the model, and are correlated with the included explanatory variables (Stock and Watson, 2012). This model also controls those factors that vary across time but not across groups within the panel. The data in this study are unbalanced between the years 2005 and 2013. The lack of balance in the data is due to non-response and closure. In order to account for heteroskedasticity and autocorrelation concerns, standard errors are clustered to the genco. The fixed effects model for heat rate is:

$$Y_{it} = \beta X_{it} + \gamma W_{it} + \lambda_t + \varepsilon_{it}$$

where i = 1,…,n for each genco in the panel and t = 1,…,9 for each panel year. The dependent variable Y_{it} refers to the heat rate for the genco. The parameter ε represents the within-entity error term. The key explanatory variable of X_1 is an Nx1 vector containing the dichotomous indicator for participation in the RGGI. W represents a matrix of control variables including: cubic term for coal prices; total genco nameplate capacity; total genco operating time in years; and coal rank. The parameter λ captures time fixed effects.

It is important to note that each genco is composed of smaller generating units. For example, one genco can have five coal-fired generating units on its premises, each generating power for the grid. The data provided by the EIA forms do not provide sufficient means to identify each generating unit, so I aggregate data for all generating units up to the level of the genco. Each genco has a unique identifier that is shared among all EIA forms. This identifier is what allows me to observe each genco over the years of this study. For the nameplate capacity and years of operation variables, I take sums from the individual generating units in order to create observations for the genco. By doing this, I lose the ability to observe changes within a specific generating unit. Unfortunately this is unavoidable given the nature of the dataset.

FUEL SWITCHING

Next, a genco is able abate emissions while continuing to generate electricity by substituting low carbon content fuels for higher carbon content fuels. Notably, coal and petroleum sources generate high levels of CO_2 emissions relative to generators using natural gas as a fuel source. A power producer deciding to abate emissions by switching source fuels could switch from the higher carbon content fuels to natural gas.

As mentioned in the EMISSION TRADING AND THE RATCHET EFFECT section, short run marginal costs for gencos are primarily a function of fuel costs, and to a lesser extent labor and maintenance costs. In this context, fuel prices will affect the likelihood of a genco to switch fuels. In recent years, domestic supplies of natural gas have increased significantly, while prices remain low compared to coal and petroleum. Natural gas also has the benefit of being much more heat rate-efficient for electricity generation. The efficiency of gas combustion combined with a low carbon composition leads to much lower carbon emissions per kWh. For these reasons, should a genco operating in an RGGI state be inclined to reduce emissions, substituting natural gas for coal is an economically viable option.

According to the logic of the ratchet effect, power plants may decide to delay switching to cleaner fuels so as to prevent a more stringent future emissions cap.

> *H_2: The rate at which coal-fired power generating companies operating within states participating in the RGGI substitute other fuel sources for coal fuel will be lower than their counterparts operating in non-participating states.*

I test this hypothesis by estimating a panel fixed effects linear model and multilevel model. The models are constructed as follows:

$$Y_{it} = \beta X_{it} + \gamma W_{it} + \lambda_t + \varepsilon_{it}$$

where the dependent variable is the mean-centered percentage of total power generation produced from coal-fired units at the genco level (calculated by dividing the total amount of power generated by the genco into the power generated by coal-fired units); X is the indicator for participation in the RGGI; W is a matrix of control variables including the total nameplate capacity of all coal-fired units operating within the genco in a given year; is the operation life for all units operating within the genco within a given year; the cubic terms for the average annual price of coal; indicators for coal type used by the genco; λ_t is the time fixed effects intercept; and ε_{it} is the error term.

As with the model for heat rate, this model also suffers from unavailable generating unit identifiers. Table 18 and Table 19 present the descriptive statistics for both the treatment and comparison groups. Given that I cannot accurately identify individual generating units within the genco using these data, I aggregate all data to the level of the genco year. I sum the total net generation in megawatt hours (MWhs) from all of the coal-fired units and divide that by the total net generation from all combined generating units within the genco. This ratio gives me the percentage of total generation coming from coal-fired units at that power plant. This ratio will decrease if the genco switches from coal to other fuels. The data set for this model contains only gencos operating within the RGGI and those in the comparison group. I only look at gencos that had a sum greater than zero of coal-fired power generation in 2005, the year of the official formation of the RGGI. This allows the possibility that a genco switches completely away from coal at some point during the study period, but also omits those gencos that did not use coal for generation prior to the formation of the RGGI.

CLOSING GENERATING UNIT

The final strategy gencos can employ in response to regulations on carbon emissions is to close the generating unit. The closure decision occurs when the long run price of power is less than the average total cost of generation. The implementation of an emission trading market for carbon emissions has significant implications for the costs of gencos that use carbon-intensive source fuels for generation. With a price on carbon emissions, the marginal cost of fuel now includes both the fuel price and the price of emissions from each unit of fuel. As average total costs increase, the profitability of the genco diminishes. As profitability diminishes, the likelihood of closure increases.

According to the logic of the ratchet effect, gencos will work to keep the cap as large as possible. As such, gencos may anticipate a minimal effect of the cap and trade on the price of carbon emissions. The closure decision is a forward-looking decision in that gencos must anticipate future marginal costs and future electricity prices (Strbac and Kirschen, 2004). Therefore, if gencos anticipate an insignificant cost effect from the cap and trade market, they will not be any more likely to close a unit than any other owner.

In the third model, I analyze the effect of the RGGI on decisions to close existing generating units. One of the long-run goals of policies that place a price on carbon emissions is to purge older and less efficient coal and petroleum fueled power plants from the fleet of active generators. Annual data on the full fleet of active generating units are available through the EIA's Form 860. If a unit ceases operations during a given year, its operation status will change from "OP" to "RE." Units within a genco receiving an operating status change will receive a value of 1. I aggregate the number of closing units within a genco-year together to compute the dependent variable. Using the logic of the ratchet effect, plant owners operating in RGGI member states will not anticipate significant carbon prices, and will make shutdown decisions accordingly.

> *H_3: Power generating companies units operating within states participating in the RGGI will be more likely to close units than their counterparts in the non-participating states.*

I test this hypothesis by using a panel random effects negative binomial regression model where the dependent variable is the total number of generating units closed within a genco in a given year. The model is as follows:

$$Y_{it} = \beta X_{it} + \gamma W_{it} + \lambda_t + u_{it} + \varepsilon_{it}$$

where X is the indicator for participation in the RGGI; W is a matrix of genco-level controls including the cubic term for coal price; total years of operation for the units within the genco; total nameplate capacity for the genco; indicators for the type of coal used by the genco; λ is the year intercept; u is the between-entity error term; and ε is the within-entity error term. I use random effects because the fixed effects estimator removes the majority of observations due to lack of variance.

Descriptive statistics for the treatment and comparison groups can be found in Table 20 and Table 21. The data for this model do not suffer from the same generating unit identification problems as the previous two. This is because I am not looking at changes in production levels or fuels by a generating unit as I did in the first two, and therefore do not need to merge Forms 860 and 906/920/923. Instead, I am looking at unit closings. The data provided in Form 860 show when each generating unit within a genco closes, the year the unit began operations, its nameplate capacity, and its primary fuel source. I am still using the genco year as the unit of operation as I did in the other two, but in this model, the dependent variable is the sum of all closed units within the genco in that year, making it a count variable. As for nameplate capacity and years of operation, I create these by taking averages only for those units that close within the year. For robustness, I estimate the odds ratio of a genco closing at least one generating unit in a year using a panel logistic regression.

RESULTS

In this section, I present the results of the tests of the three separate hypothesis tests for the different strategies gencos can use to adapt to carbon pricing. The output tables for each model are located in the Appendix.

Effects on Heat-Rate Efficiency

According to the logic of the ratchet effect, gencos operating within an RGGI state will be less likely to improve heat rate for their generating units over time. Through this logic, should these RGGI gencos show marked improvements in carbon emission levels resulting from investments in heat rate efficiency modifications, they will expect to see a more restrictive limit on emissions in the future. Although it is not possible to observe the specific technology at work in each unit, it is possible to observe changes in heat rate over time at the genco level.

The analytical results of the effects of the RGGI on heat rate efficiency are presented in Table 22. According to these results, coal-fired gencos operating within the RGGI over the period covered by this study on average have higher heat rates relative to the comparison group, ceteris paribus. This result is significant at a 99% level of confidence (p = .001). The treatment effect reflects the changes to the plant infrastructure while controlling for preexisting infrastructure and fuel source. The time fixed effects control for stochastic variations in demand due to macroeconomic shocks, climate, and other fundamental demand determinants. The results from the multilevel regression are similar to those of the panel OLS regression. The coefficient is significant at a 99% level of confidence (p = .002).

Given the direction of the effect of participation in the RGGI and the significance of the finding in both models, I reject the null hypothesis that there will be no difference in the heat rates of gencos operating in the RGGI zone and those not affected by the regulation. Instead, I find evidence that emission-trading markets may create perverse incentives that delay or prevent investment in capital to improve heat rate within a coal-fired genco, leading to the observed increase in heat rates for RGGI gencos relative to non-RGGI gencos. This finding allows me to accept the alternative hypothesis that heat rates are higher for RGGI gencos.

When faced with the prospect of a constricting aggregate emission target, it appears that coal-fired gencos within the RGGI are responding by avoiding heat rate improving capital investments relative to gencos outside the exchange. This finding implies that technological improvements that would otherwise be adopted by the power sector in the absence of an emission-trading program will not be adopted in the short run.

In the long run, climate policies with pricing mechanisms such as emission taxes and permits will encourage a transition away from carbon-intensive fuels and low-efficiency generation. These transitions will occur as gencos retire older facilities and build new capacity. However, in the short-run, which is the period where gencos operate facilities built prior to the implementation of emission constraints, emission-trading markets appear to generate incentives for gencos to underinvest in heat rate-improvement technology. The ratchet effect accurately predicts this result. According to the model, the apparent net benefits to the genco of abating emissions in the current period by investing in new capital are insufficient to counterbalance the expected cost of the future emission target.

Effects on Fuel Switching

The effect of participation in the RGGI on the percentage of power generated by coal sources measured by the panel fixed effects and multilevel regression models is presented in Table 23. The fixed effects model finds a mild statistically significant difference between gencos within and outside the RGGI trading program ($p = .059$). According to the analysis, gencos in RGGI members states are reducing the percentage of electricity generated from coal sources by nearly 6 percentage points relative to gencos in the comparison states. The multilevel model presents statistically significant evidence in support of this result, with a coefficient of -0.049 ($p = .029$). Given the evidence from the two analytical models, I do not find statistical support to reject the null hypothesis.

According to the logic of the ratchet effect, gencos concerned about lower future carbon caps should be less likely to switch away from higher carbon fuels in the short run. Instead, they are expected to lag behind the counterfactual. I cannot find sufficient support to reject the null hypothesis. Therefore, I cannot say that the ratchet effect is preventing gencos from switching to lower carbon fuels in response to regulation under the RGGI.

While unexpected, this result may be explained in part by trends within the member states of the RGGI in the years prior to its inception. In the mid 1990s, the states that would eventually form the RGGI began to rapidly increase the proportion of natural gas-fueled power generation at the expense of nuclear and petroleum sources.[41] Therefore, these states were well suited for participation in the RGGI prior to its development and implementation. This preparation may have had an attenuating impact on the ratchet effect.

It should be noted that the purpose of this study is to examine the impacts of the RGGI on *existing* coal-fired gencos. What these models do not capture is the rate at which these states are building new natural gas generation capacity. Since the 1990s, the RGGI members states have seen much more prolific growth in this capacity relative to the comparison group states. I leave the analysis of the effect of the RGGI on new plant builds for future research.

Effects on Incidence of Generating Unit Closing

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[41] Please see **Table 25** in the appendix for the exact generation by fuel source trends by RGGI and comparison group states.

The final step gencos can take to comply with capped carbon emissions is to close the unit. According to economic theory, the decision to close a unit is made when the owner compares long run average total costs to the price of electricity and expects economic losses. Given that fuel and carbon prices contribute positively to variable costs, carbon-intensive power generators operating in emission-trading member states should be more likely to shutdown than those operating in states with no price on carbon, ceteris paribus.

The results of the panel random effects negative binomial regression and the panel logistic regression are presented in Table 24. After controlling for the price of coal, the capacity of the plant, and years of operation for the plant, the panel negative binomial model does not present statistically significant evidence of a relationship between participation in the RGGI and the number of retired generating units within the power plant ($p = .779$). The coefficient on the treatment, which reports the incidence-rate ratio, is negative, indicating that gencos in RGGI member states are closing fewer coal-fired generating units than gencos in the comparison group. The result from the panel logistic regression supports the direction of the panel regression treatment coefficient, a result that is also not statistically significant ($p = .815$). Given the lack of statistical significance of the panel poisson regression treatment coefficient, I cannot confidently reject the null hypothesis of no relationship between participation in the RGGI and incidence of coal-fired generation unit closing.

As noted earlier, the decision to retire a generating unit is one that depends on the long run economic viability of the generator. This study covers four years prior to and four years following the activation of the exchange mechanism of the RGGI. It is possible that the time frame covered by this study is insufficient to capture these decisions. At the same time, permit prices in these early stages of the RGGI have been low, often hovering around $2 per permit. It is possible that these variable costs do not increase the cost curve enough to generate economic losses for gencos. Future studies will be more likely to detect differences in the likelihood to close a generating unit between the firms within and outside the RGGI.

CONCLUSIONS

The RGGI is an emission-trading program that commenced in 2009 after several years of development. The intent of the RGGI is to reduce the annual rate of carbon emissions to a total of roughly 56 million tons by 2020, nearly a third of what total emissions in the region were at the outset of the program. The RGGI specifically regulates carbon emissions from the electric power sector due to that sector's significant annual contributions to aggregate emissions. The mechanics behind how these reductions are achieved within the electricity sector result from the adaptation decisions made by the individual electricity generating companies (gencos). Essentially, a price on carbon creates a new category of variable cost, which directly affects production decisions. According to the US Environmental Protection Agency, there are three strategies gencos can pursue to reduce emissions that can prove economically viable. These include retrofitting the plant to improve heat rate, switching to lower carbon content fuels, and closing units with high abatement costs.

While gencos are aware of their options, previous research finds that firms operate somewhat differently than the traditional profit maximizing model predicts when faced with policies that temporally adjust production targets, referred to as ratcheting policies. According to the literature, when current firm-level production makes future targets more difficult to achieve, firms will adjust production levels in order to make those future targets more manageable. This incentive to shape current production based on anticipated future targets is referred to as the ratchet effect. According to this model, the benefits of adopting new technologies and processes may not match the costs of more burdensome future targets. In this scenario, short-term bonuses are traded for more manageable regulatory targets. The RGGI exemplifies a ratcheting policy in that the emission limit is ratcheted down over time.

This paper examines the effects of participation in the RGGI on abatement options available to power generating companies (gencos), using the ratchet effect model as its theoretical underpinning. I hypothesize that gencos within the RGGI member states will be less likely than their counterparts to pursue any of these strategies. I test for symptoms of the ratchet effect using data made available from the US Energy Information Administration.

The empirical evidence suggests that ratcheting effects may be present in the decisions to address heat rate. I find statistically significant evidence that gencos within the RGGI have higher heat rates on average than their counterparts in non-RGGI states. This result suggests that gencos are not responding to their state's participation in the RGGI by retrofitting their generating units to improve heat rate. Instead, generating units in the RGGI are less efficient than those in the comparison group.

A third option to adapt to limits on emissions involves substituting lower carbon content fuel for more carbon intensive sources. Were gencos acting in a manner consistent with the ratchet effect, a switch away from coal fuels would be unlikely.

Empirical results do not support this hypothesis. I find evidence that gencos within RGGI member states are more likely than their counterparts to switch away from coal fuel sources.

Given these results, it is possible to state with some certainty that the ratchet effect is a factor in genco response to emission trading within the RGGI. This effect is not present in all decisions, however. Indeed, the experience of the RGGI suggests that gencos may be more likely to pursue certain emission reduction strategies while foregoing others. What this analysis does provide is a micro-level view of what these gencos are doing in response to regulation. As the RGGI continues its operations in subsequent years, it will be interesting to monitor how these entities continue to adjust their operations as emission targets ratchet further down. Perhaps the price of carbon will reach a critical mass, at which point there will be demonstrable differences between gencos under and not under regulation. At this point the differences are not substantial.

One of the major weaknesses inherent to this study is a lack of key data on the real decisions being made by firms. Over time, the data reported in the EIA Form 860 has grown to provide more detail on the operations of gencos. However, the data used for this study had several limitations. For this paper, I focused explicitly on gencos operating in deregulated wholesale generation markets. For these firms, fuel prices and fuel transportation costs are an important predictor of output. Data on fuel costs for competitive gencos are not available, as that is proprietary information and thus not reported by the EIA. Therefore, I proxy the real fuel cost to the firm using state-level average annual fuel prices. Next, current versions of EIA Form 860 allow gencos to report the deployment of carbon capture, boiler type (e.g. subcritical), and other capital investment that are relevant to this study. However, this information is not available for many of the earlier years of this study. Future research in the area will benefit from the expansion of EIA data, but this paper is limited by a lack of direct observation on the investments made by gencos.

POLICY IMPLICATIONS

The RGGI presents an important case study for the impacts of market-based climate change policy. The RGGI is looked upon as the model for what environmentalists hope will eventually be a national emission trading market. As the EPA's regulatory authority over pollutants deemed to be harmful to public health continues to grow, the probability of federal regulation of carbon emissions rises.[42] Therefore, the results from the RGGI are important when anticipating the potential outcomes from a national emission-trading program.

The first key finding from this paper is that gencos in the RGGI are seeing less improvement in heat rate than are those outside the RGGI. Essentially, firms appear not to be investing in retrofitting their existing plants with more fuel-efficient technology like ultra supercritical boilers. This does not mean that new builds are not deploying this technology. Instead, the fleet of existing coal-fired plants continues to operate much as it did in the years prior to the commencement of the RGGI exchange.

A second key finding is that RGGI firms appear to be no less likely to close coal-fired units than are firms outside the RGGI. Power plants, especially the high capacity

[42] Legal scholars see an opening for the EPA to garner much more regulatory authority over greenhouse gas emissions in the wake of the Paris Agreement signed at the 2015 United Nations Climate Change Conference. This opening stems from section 115 of the Clean Air Act, which states that the United States must reciprocate efforts made by other countries to limit pollutants that endanger the US population: https://www.law.cornell.edu/uscode/text/42/7415.

baseload plants, have very high up front capital costs. While economic theory argues that fixed costs are sunk costs, and therefore not a factor in current production decisions, amassing the financial capital needed to construct a new plant is difficult. Once the expectation of long-run economic profits disappears due to higher emission costs, owners will decide to close existing facilities. Until that time, these facilities will continue to operate.

Finally, the evidence demonstrates that gencos in the RGGI are moving away from coal as a source fuel at a higher rate than those firms outside the RGGI. The long-term implications of relying solely on a switch away from coal are important. While I do not have direct evidence that all movements away from coal are made towards natural gas, national data demonstrates that new plant builds are overwhelmingly utilizing natural gas as the primary source fuel (US EIA, 2014). While the combustion of natural gas releases about half of the CO_2 of coal combustion, emissions are still a factor. Once generation switches from coal to gas, ceteris paribus, there is no reason to assume that further emission reductions will be likely from that plant. Therefore, short-term gains from switching fuels will occur, but long-term gains may be a function of the price of natural gas. Should natural gas prices rise significantly relative to coal prices, there may be some transitioning back to coal. Were this to happen, aggregate emissions would rise, negating gains made in the initial years of the program.

Combining this result with the evidence on heat rate, the reductions in CO_2 emissions in the RGGI area may be temporary. At this point, there are no indications of a structural change to the existing fleet of coal-fired plants. There is no evidence that the RGGI has led to an investment in capital that will enable long-term reductions in emissions. The RGGI is an innovative policy that attempted to accomplish what was not possible at the federal level at the time. In that regard it serves as a model of what motivated states can do in lieu of a top-down solution. However, the voluntary nature of the RGGI likely led to a reduction in the punitive impact of the policy. That is, the policy did not go sufficiently far to reduce emissions. Over time these results will most likely change as the cap continues to ratchet further down, keeping this line of research open.

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APPENDIX 3: ESSAY 3 TABLES

Table 14: Generation percentage by fuel in RGGI states and deregulated electricity market comparison group states

Deregulated Electricity Market States Comparison Group									
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Coal	43%	43%	42%	42%	39%	39%	36%	31%	34%
Natural Gas	23%	24%	25%	24%	26%	26%	28%	33%	30%
Nuclear	24%	25%	25%	25%	26%	25%	25%	25%	25%
Petroleum	3%	1%	1%	1%	1%	0%	0%	0%	0%
Renewable	6%	7%	7%	8%	9%	8%	10%	10%	10%
RGGI States									
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Coal	22%	22%	22%	21%	17%	16%	12%	8%	9%
Natural Gas	26%	30%	31%	32%	33%	37%	40%	45%	40%
Nuclear	30%	31%	31%	32%	34%	33%	33%	33%	35%
Petroleum	11%	3%	4%	2%	1%	1%	1%	0%	1%
Renewable	11%	13%	11%	13%	14%	13%	14%	13%	15%

Table 15: Display of models tested in this essay.

Issue	Power Plant Heat Rate (Btu/MWh)	Heavy reliance on coal as a fuel source	Continuing operation of coal-fired power plants
Hypothesis	Power plants operating in RGGI member states are expected to avoid or delay adopting technologies that improve heat rate (i.e. reduce heat rate) in order to attenuate ratchets to future carbon cap.	Power plants operating in RGGI member states are expected to avoid or delay substituting lower carbon content fuels for coal in order to attenuate ratchets to future carbon cap.	Power plants operating in RGGI member states are expected to avoid or delay closing power plants that use coal as a fuel source.
Dependent Variable	Btu/MWh	$\frac{MWhs\ generated\ using\ coal}{Total\ MWhs}$	Number of generating units closed within a power plant.
Time Unit	Year	Year	Year
Data for Dependent Variable	Observations of Btus and MWhs for each plant come from EIA form 906/920/923.	Observations of fuel source and generation come from EIA form 906/920/923.	Observations of generating unit closing come from EIA form 860.
Sample Population	All power plants with heat rates between 6.5 and 15 operating in RGGI member states and states with deregulated power markets.	All power plants using a coal fuel source in 2005 in RGGI members states and states with deregulated power markets.	All power plants using a coal fuel source in 2005 in RGGI members states and states with deregulated power markets.

Table 16: Descriptive statistics for treatment group in heat rate model.

Variable	Obs	Mean	Std. Dev.	Min	Max
Heat Rate	277	10.93024	1.260778	6.590325	14.93367
Nameplate Capacity	277	427.0025	311.4574	18	1370
Years of Operation	277	91.94224	69.07891	6	366
Bituminous Percent	277	0.813583	0.316913	0	1
Lignite Percent	277	0	0	0	0
Subituminous Percent	277	0.128362	0.312688	0	0.999144

Table 17: Descriptive statistics for comparison group in heat rate model.

Variable	Obs	Mean	Std. Dev.	Min	Max
Heat Rate	1,066	11.05425	1.461618	6.623297	14.99819
Nameplate Capacity	1,066	823.7706	783.3557	2.5	3397
Years of Operation	1,066	101.6829	82.35156	0	386
Bituminous Percent	1,066	0.407119	0.447325	0	1
Lignite Percent	1,066	0.061426	0.224253	0	1
Subituminous Percent	1,066	0.393608	0.447221	0	1

Table 18: Descriptive statistics for treatment group in fuel switch model.

Variable	Obs	Mean	Std. Dev.	Min	Max
Percent Coal Generation	357	0.850157	0.26019	0	1
Nameplate Capacity	357	343.2347	316.6308	0	1370
Years of Operation	357	94.53221	90.59635	0	532
Bituminous Coal	357	0.904762	0.293956	0	1
Lignite Coal	357	0	0	0	0
Subbituminous Coal	357	0.165266	0.371942	0	1

Table 19: Descriptive statistics for comparison group in fuel switch model.

Variable	Obs	Mean	Std. Dev.	Min	Max
Percent Coal Generation	1,265	0.920468	0.209039	0	1
Nameplate Capacity	1,265	691.7396	760.6019	0	3279.6
Years of Operation	1,265	103.8656	81.92059	0	386
Bituminous Coal	1,265	0.607115	0.488585	0	1
Lignite Coal	1,265	0.06166	0.240632	0	1
Subbituminous Coal	1,265	0.423715	0.494342	0	1

Table 20: Descriptive statistics for treatment group in plant closing model.

Variable	Obs	Mean	Std. Dev.		Max
Retired Coal Generators Per Power Plant	351	0.06268	0.34896	0	4
Nameplate Capacity	351	383.266	324.083	25	1370
Years of Operation	351	93.0484	66.0773	6	366

Table 21: Descriptive statistics for comparison group in plant closing model.

Variable	Obs	Mean	Std. Dev.		Max
Retired Coal Generators Per Power Plant	1,224	0.04902	0.32232	0	4
Nameplate Capacity	1,224	727.608	733.462	27.2	3279.6
Years of Operation	1,224	100.872	84.1945	0	386

Table 22: Estimation of effect of state participation in RGGI on coal-fired power plant heat-rate. Model 1 presents results from fixed effects panel OLS regression. Model 2 presents coefficients from multilevel regression clustered at power plant level.

Variable	**Model 1**	**Model 2**
Participation in RGGI	0.277***	0.258***
	(0.086)	(0.084)
Coal Prices:		
Coal	0.134***	0.141***
	(0.026)	(0.027)
Coal Squared	0.002	0.003
	(0.002)	(0.001)
Coal Cubed	-0.002***	-0.002***
	(0.0005)	(0.000)
Coal Types:		
Bituminous Percent	-0.418*	-0.462**
	(0.217)	(0.204)
Subituminous Percent	-0.900***	-0.892***
	(0.329)	(0.276)
Lignite Percent	-1.608**	-0.892***
	(0.737)	(0.589)
Nameplate Capacity	-0.0004*	-0.001***
	(0.0002)	(0.000)
Time of Service	-0.003*	0.001
	(0.002)	(0.001)
Wald Chi-Sq		129.50***
Model F	8.23***	
N	1,343	1,343
Groups	181	181
Year Effects	Yes	Yes
Robust Errors	Yes	Yes

Robust errors presented in parentheses.
*p<.1 **p<.05 ***p<.01

Table 23: Panel OLS and multilevel analysis of the effect of participation in the RGGI on mean-centered genco coal percentage. Model 1 presents coefficients from panel linear regression. Model 2 presents coefficients from multilevel linear regression clustered around the power plant.

Variable	Model 1	Model 2
Participation in RGGI	-0.057*	-0.049**
	(0.030)	(0.019)
Coal Prices:		
Coal	0.002	-0.009
	(0.005)	(0.005)
Coal Squared	0.001	0.000
	(0.001)	(0.000)
Coal Cubed	-0.0001	0.000
	(0.0001)	(0.000)
Coal Types:		
Bituminous	0.240***	0.053***
	(0.063)	(0.014)
Subituminous	0.088**	0.028***
	(0.041)	(0.009)
Lignite	-	0.034***
	-	(0.009)
Nameplate Capacity	0.0000	0.000
	(0.000)	(0.000)
Time of Service	0.002***	0.000
	(0.001)	(0.00)
Constant	0.433***	0.592***
	(0.091)	(0.067)
Wald Chi-Sq		62.19***
Model F	4.92***	
N	1,622	1,622
Groups	203	14
Year Effects	Yes	Yes
Robust Errors	Yes	Yes

Robust errors presented in parentheses.
*p<.1 **p<.05 ***p<.01

Table 24: Analysis of the effect of participation in the RGGI on incidence of coal-fired generator closing. Unit of analysis is individual power plant. Model 1 presents incidence-rate ratios from panel poisson regression. Model 2 presents odds ratios from panel logistic regression.

Variable	**Model 1**	**Model 2**
Participation in RGGI	0.888	0.902
	(0.377)	(0.396)
Coal Price	1.271**	1.272**
	(0.148)	(0.149)
Nameplate Capacity	0.999**	0.999**
	(0.0003)	(0.0003)
Time of Service	1.007***	1.007***
	(0.001)	(0.002)
Wald Chi-Sq	38.81	36.08***
N	1,575	1,575
Groups	183	183
Year Effects	Yes	Yes
Robust Errors	Yes	No

Robust errors presented in parentheses
*p<.1 **p<.05 ***p<.01

Table 25: Generation by source fuel within RGGI member states and comparison group states between 1990 and 2000.

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
RGGI	Coal	25%	24%	24%	23%	23%	24%	25%	25%	23%	22%	24%
RGGI	Hydroelectric Conventional	12%	11%	11%	11%	11%	10%	12%	12%	11%	9%	9%
RGGI	Natural Gas	12%	14%	18%	18%	21%	28%	24%	27%	23%	24%	23%
RGGI	Nuclear	26%	29%	29%	32%	31%	27%	27%	22%	26%	29%	30%
RGGI	Other	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
RGGI	Other Biomass	2%	2%	2%	2%	2%	2%	3%	3%	3%	2%	3%
RGGI	Other Gases	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
RGGI	Petroleum	22%	19%	14%	13%	11%	8%	9%	11%	13%	12%	10%
RGGI	Pumped Storage	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	0%	0%	-1%
RGGI	Wood and Wood Derived Fuels	1%	2%	2%	2%	2%	2%	2%	2%	1%	1%	1%
RGGI	Wind	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
RGGI	Solar Thermal and Photovoltaic	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
RGGI	Geothermal	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
NonRGGI	Coal	54%	54%	54%	54%	54%	51%	53%	54%	54%	51%	51%
NonRGGI	Hydroelectric Conventional	6%	5%	4%	5%	4%	5%	5%	5%	5%	5%	4%
NonRGGI	Natural Gas	17%	17%	17%	18%	18%	18%	18%	18%	21%	20%	21%
NonRGGI	Nuclear	21%	22%	23%	21%	21%	24%	22%	20%	19%	22%	22%
NonRGGI	Other	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
NonRGGI	Other Biomass	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
NonRGGI	Other Gases	1%	1%	1%	1%	1%	1%	1%	1%	1%	0%	0%
NonRGGI	Petroleum	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
NonRGGI	Pumped Storage	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
NonRGGI	Wood and Wood Derived Fuels	0%	0%	0%	0%	1%	1%	0%	1%	0%	0%	0%
NonRGGI	Wind	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
NonRGGI	Solar Thermal and Photovoltaic	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
NonRGGI	Geothermal	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

CONCLUSION

The scope of this dissertation was on the developments of and achievements from the Regional Greenhouse Gas Initiative (RGGI), as well on the factors that led to its creation. Results from this emission trading market present data points for states seeking compliance with any future federal regulation on carbon dioxide emissions. While the status of the currently proposed federal regulation is uncertain, the momentum of public opinion as affected by scientific evidence appears to make such regulation increasingly likely in the coming years. Until a coherent federal policy begins, the decision to address climate-affecting emissions remains with the states. In this setting, the preceding essays will provide information for states seeking to join the RGGI itself, or implement similar policies.

The first essay examined the factors that explain why states would be willing to join the RGGI. While this information does not explain the effects that participation in the RGGI will have on a potential member's emissions, it does explain which states will be more likely to either join the RGGI or a similar exchange in the future. The results from this essay demonstrate that states with more liberal elected officials will be most likely to join. The results also demonstrate a non-linear relationship between per capita gross state product and the decision to join. Essentially, the likelihood of membership increases exponentially with increases in GSP.

The second essay focuses specifically on the state-level effects of participation in the RGGI on CO_2 emissions. These results are relevant for states whose leaders are selecting among different policy options for addressing anthropogenic climate change.

Based on the estimation, outcomes for RGGI member states vary with the ideological attitudes of their respective elected leaders. RGGI member states with highly liberal elected leaders have seen a statistically significant decline in emissions relative to less liberal member states. This finding supports the theory that government identity is an important factor in the outcomes from emission trading schemes.

The third essay examines the effects of participation in the RGGI on how power-generating companies adapt to such a policy. These companies have three strategies by they can reduce their emissions economically. The results of the estimation finds that coal-fired power plants within RGGI member states are not investing in capital to improve heat rate to the same degree as are those in non-RGGI states. The estimation does demonstrate that these RGGI power plants are substituting away from coal fuel sources, indicating a decrease in reliance on coal. Finally, the estimation does not find a significant difference between the incidence of coal-fired power plant closing in RGGI member states and outside. The implications of the findings paint a concerning picture for future outcomes from the RGGI. Chief among these concerns is the apparent lack of investment in power plant heat rate efficiency. Without this investment, any short-term achievements resulting from the substitution away from coal as a fuel source may be short lived if the prices of substitutes increase.

The RGGI provides a unique case study for research on the interaction between public policy and climate change. While it has only been in place for 6 years, its existence makes it the model for any national CO_2 exchange, as well as for any further regional expansions or new regional partnerships. Given the ratcheting nature of the

RGGI, there will be plenty of openings for future research on the accomplishments of the exchange.