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FEDERAL AND STATE ENVIRONMENTAL POLICY: ENVIRONMENTAL FEDERALISM, STRATEGIC INTERACTION, AND CONSTITUENT INTEREST

BY

BENJAMIN A. CHUPP

A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree
of
Doctor of Philosophy
in the
Andrew Young School of Policy Studies
of
Georgia State University

GEORGIA STATE UNIVERSITY
2009

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ACCEPTANCE

The dissertation was prepared under the direction of the candidate's Dissertation Committee. It has been approved and accepted by all members of that committee, and it has been accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Economics in the Andrew Young School of Policy Studies of Georgia State University.

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ABSTRACT

FEDERAL AND STATE ENVIRONMENTAL POLICY: ENVIRONMENTAL FEDERALISM, STRATEGIC INTERACTION, AND CONSTITUENT INTEREST

BY

BENJAMIN A. CHUPP

August 2009

Committee Chair: Dr. H. Spencer Banzhaf

Major Department: Economics

Environmental policy in the U.S. is often enacted at both the federal level and the state level. This dissertation uses unique data derived from a combination of a detailed simulation model of the U.S. electricity sector and an integrated assessment model of air pollution dispersion and valuation to examine three problems in state and federal environmental policy. These data represent the "taxes" (or shadow cost of abatement) on sulfur dioxide and nitrogen oxides that are efficient for each state when considering only their own costs and benefits, and also the level of federal uniform tax on the same pollutants that maximizes each state's net benefits. This data is used in three analyses.

First, we examine the case of environmental federalism. Differences in spillovers across states, together with differences in population density and local cost structures create substantial spatial heterogeneity in the economics of air pollution. Uniform federal control and state level control both have advantages and disadvantages, and it is unclear which is more efficient. For the case of sulfur dioxide (nitrogen oxides), when states choose their own level of pollution, 31.5% (76.2%) of the potential benefits under the nationally optimal scheme are lost. The uniform tax only results in a loss of 0.19% (2.32%) of the potential benefits.

The data derived, which are directly based on the costs and benefits of air pollution, provide a broad measure of constituent interest. These variables are used to explain state adoption of green electricity policies and federal legislative voting on environmental issues. In contrast to previous studies, it is found that constituent interest and ideology are both important determinants in the formation of environmental policy.

Lastly, it is widely known in the literature that states act strategically when choosing policies. This result also persists for state-level environmental stringency. We use unique weighing matrix specifications to distinguish between tax competition and competition based on spillover effects. It is also shown that higher marginal damages of pollution limit strategic behavior.

CHAPTER 1: INTRODUCTION

Environmental policy in the U.S. is often enacted at both the federal level and the state level. This dissertation uses unique data derived from the combination of a detailed simulation model of the U.S. electricity sector and an integrated assessment model of air pollution dispersion and valuation to examine three problems in state and federal environmental policy. These data represent a number of different “taxes” (or shadow costs of abatement) and abatement levels for efficient sulfur dioxide and nitrogen oxide emissions under various scenarios.

First, we examine the case of environmental federalism. Which level of government could regulate air pollution from stationary sources most efficiently? Air pollution from stationary sources is a transboundary problem; pollution in one jurisdiction often crosses over into neighboring jurisdictions. Differences in these spillovers across states, together with differences in population density and local cost structures create substantial spatial heterogeneity in the economics of air pollution. Consequently, the optimal instrument would be fully differentiated across states, reflecting the damages each state imposes on themselves and on other states. However, federal policy is usually not differentiated across states because of political constraints. On the other hand, policies enacted at the state level would likely ignore the interjurisdictional spillovers. Thus, there is a tradeoff inherent in policymaking (Oates, 2002). Chapter 2 of this dissertation determines whether interstate spillovers or uniformity is a bigger problem in the case of sulfur dioxide and nitrogen oxide emissions from electricity plants. For the case of sulfur dioxide, when states choose their own level of pollution, 31.5% of the potential benefits under the nationally optimal scheme are lost.

The uniform policy only results in a loss of 0.19% of the potential benefits. In the case of nitrogen oxides, the state level policies result in a loss of 76.2% of the optimal benefits, while the uniform policy causes a loss of 2.32% of the benefits.

Secondly, the estimates of states' benefits from reducing their own pollution and upwind pollution fill an important gap in the literature on the political economy of environmental policy adoption. Many articles have attempted to disentangle the effects of ideology, party affiliation, and constituent interest on environmental policy adoption and legislative voting on environmental issues (e.g., Vachon and Menz 2006; Anderson 2007). These papers generally find that ideology is the most important factor in this determination. However, constituent interest is measured in these studies by various demographic variables or membership in environmental groups. Demographic variables may not correlate well with true interest, while environmental group membership only accounts for those constituents who feel most strongly about the environment, i.e. those in the tail of the distribution. The variables derived, which are directly based on the costs and benefits of abating air pollution, provide a broad measure accounting for the state's entire population. In Chapter 3, these variables are used to explain state adoption of green electricity policies and federal legislative voting on environmental issues. In contrast to previous studies (Coates and Munger 1995; Vachon and Menz 2006), we find that constituent interest and ideology are both important determinants in the formation of environmental policy.

Lastly, it is widely known in the literature that states act strategically when choosing policies. This result also persists for state-level environmental stringency. However, the literature has been unable to determine whether the strategic interaction is due to tax competition or spillover competition. Tax competition results when states lower environmental standards in an attempt to attract industries to the state (the so-called "race to the bottom"). Spillover competition is when states strategically respond to spillovers from other states due to the policy decisions of those states. Using unique weighting matrices, Chapter 4 explores which of the two types of competition is driving the strategic interaction in state level environmental stringency. Additionally the derived measure of constituent interest is used to show that high marginal damages of pollution limit competitive behavior among the states. We find that tax competition may account for a higher degree of competition than spillover competition, and that higher marginal damages limit competitive behavior.

This dissertation contributes to the literature in a number of ways. First, the data derived in Chapter 2 are valuable measures of the state-to-state differences in marginal damages of pollution and the levels of abatement each state would choose if left to their own devices. The policies studied in Chapter 2 are the most politically feasible policies and this work provides an economic measurement of which policy is closer to the politically unfeasible optimum. This research can inform policymakers in the design of the scale and scope of tradable permit markets for sulfur dioxide and nitrogen oxide emissions. In addition, Helland and Whitford (2003) call this question of tradeoffs the most important unanswered question posed in Oates' review of environmental federalism (2002).

In addition to answering the above question in environmental federalism, the data derived is useful in a wide range of applications. It can be used as an ideal measurement of constituent interest, as defined by the level that is most beneficial for each state's constituency. The data is used in Chapter 3 to analyze how constituent interest affects adoption of environmental policies and legislative voting. In contrast to previous studies, we use a measure of constituent interest that has two advantages. First, it adequately measures what is in the best interest of the constituency in terms of aggregate health benefits from reduced air pollution. This measure is more broadly based than previous measures, and is broadly compatible with the median voter hypothesis. Secondly, our measure is very closely related to the policies under consideration, and it is shown in Chapter 3 that the data carries the most explanatory power in subcategories that are most closely linked to the subject matter. In addition to providing insight into the drivers of policy formation, this work shows that constituent interest cannot be loosely defined and needs to be tailored to the situation at hand. The data are also useful as a measure of constituent interest in examining whether states consider these health damages when competing over environmental policy as in Chapter 4. These are just some of the potential applications of the data that are derived in Chapter 2.

Historical Background

In order to discuss the current research on environmental policy, it is important to know how the existing policy framework came into being. In that spirit, let us consider a brief history of air pollution regulation in the United States. Federal air pollution policy was nonexistent prior to the 1950's. Before that time, policies were enacted at the state and local level to combat pollution. The earliest legislation took form (predictably) following the industrial revolution (Callan and Thomas 2007). The first federal legislation, the Air Pollution Control Act of 1955, provided no federal mandates, but simply made federal money available to states in order to conduct their own research and programs.

More significantly, the Clean Air Act of 1963 set forth emissions standards for stationary source emissions and created a committee to study the effects of pollutants from mobile sources. This legislation was quickly followed by the Motor Vehicle Air Pollution Control Act of 1965 and the 1965 Clean Air Act Amendments, which allowed the Department of Health, Education, and Welfare (HEW) to set federal standards for mobile-source emissions.

The 1970 Clean Air Amendments created National Ambient Air Quality Standards (NAAQS) for cities and imposed emissions limits for stationary sources and mobile sources. Both programs were set to be implemented through State Implementation Plans (SIPs). New sources were to face stricter standards than older sources. Additional Clean Air Amendments in 1977 provided increased segmentation of Air Quality Control Regions (AQCRs) in order to protect regions that were cleaner than the NAAQS required. These regions are called prevention of significant damage (PSD) areas.

Although this trend in increasing federal control was presumably based on the perception that state measures were inadequate, some have argued that it was unnecessary, as emissions were rapidly falling under state policies (List and Gerking 2000; Millimet 2003; Millimet and List 2003; Fomby and Lin 2006). In 1980, when Ronald Reagan became President, he began to transfer some responsibility for environmental regulation back to the states. By 1982, states were responsible for 95% of enforcement of national emissions standards for hazardous pollutants and 90% of enforcement of new source performance standards (Millimet and List, 2003). While some theories predict such decentralization would produce a race to the bottom (or a race to the top, in some cases) (Markusen, Morey, and Olewiler 1995; Kunce and Shogren 2002; Kunce and Shogren 2007), empirical analyses of Reagan's environmental federalism policies have found that there was no race to that bottom (List and Gerking 2000; Millimet 2003; Millimet and List 2003; Fomby and Lin 2006).

The 1990 Clean Air Act Amendments represent perhaps the most important reform in federal air pollution policy to date. In contrast to all previous legislation, they call for market-based policies for sulfur dioxide emissions and stratospheric ozone-depleting substances. All previous legislation had relied on command and control (CAC) regulation. The 1990 Amendments were not perfect, however, as even the tradable permit schemes are subject to a large degree of federal intervention.

Although the Clean Air Act was enacted at the federal level, there are many things that states can do beyond the federal legislation. States can require stationary sources to comply with best available control technology (BACT) rather than the federally required best available retrofit technology (BART). In the tradable permits markets, states can also retire permits, effectively reducing the total amount of emissions. Also, states can implement a number of policies designed to encourage "green" electricity generation. These include renewable portfolio standards, net metering rules, generation disclosure rules, and public benefit funds. These policies are detailed in Chapter 3. The one thing that states cannot do is set their own mobile source emissions standards. Only California has the right to set standards, while other states can adopt the standards that California sets.

Pollutants and Damages

The government defines the most widely harmful pollutants as "criteria pollutants." As of 2009, there were six criteria pollutants:

- Sulfur Dioxide (SO_2)
- Carbon Monoxide (CO)
- Nitrogen Dioxide (NO_2)
- Tropospheric Ozone (O_3)[1]
- Lead
- Particulate Matter (PM_{10} and $PM_{2.5}$) [2]

In addition to these six criteria pollutants, 188 additional pollutants are classified as hazardous air pollutants. These pollutants may be more harmful than the criteria pollutants, but they affect a much smaller proportion of the population. The NAAQS apply to the criteria pollutants, while hazardous air pollutants are covered by the National Emissions Standards for Hazardous Air Pollutants (NESHAP). Table 1 details the NAAQS in 2005. Pollutant concentrations are measured at remote air-monitoring stations generally located in urban regions with high pollutant concentrations and large populations. These stations report their data to the Environmental Protection Agency (EPA), which aggregates the data and determines which areas are in non-attainment. Table 2 summarizes the extent of non-attainment for the various criteria pollutants in 2004. Figure 1 shows non-attainment areas for 2007 on a map of the U.S.

---

[1] Note the difference between stratospheric ozone, which beneficially blocks ultraviolet radiation from the sun, and tropospheric ozone, which is a surface-level pollutant.

[2] PM_{10} consists of particulate matter with diameter less than 10 micrograms. $PM_{2.5}$ particles have diameter less than 2.5 micrograms.

Table 1—National Ambient Air Quality Standards in 2005

Pollutant	**Standard Value**		**Standard Type**[3]
Sulfur Dioxide (SO_2)			
Annual arithmetic mean	0.03 ppm	(80 μg/m3)	Primary
24-hour average	0.14 ppm	(365 μg/m3)	Primary
3-hour average	0.50 ppm	(1300 μg/m3)	Secondary
Carbon Monoxide (CO)			
8-hour average	9 ppm	(10 mg/m3)	Primary
1-hour average	35 ppm	(40 mg/m3)	Primary
Nitrogen Dioxide (NO_2)			
Annual arithmetic mean	0.053 ppm	(100 μg/m3)	Primary and Secondary
Ozone (O_3)			
1-hour average	0.12 ppm	(235 μg/m3)	Primary and Secondary
8-hour average	0.08 ppm	(157 μg/m3)	Primary and Secondary
Lead (Pb)			
	1.5 μg/m3		Primary and Secondary
Particulate Matter (PM-10)	*Particles with diameters of 10 micrometers or less*		
Annual arithmetic mean	50 μg/m3		Primary and Secondary
24-hour average	150 μg/m3		Primary and Secondary
Particulate Matter (PM-2.5)	*Particles with diameters of 2.5 micrometers or less*		
Annual arithmetic mean	15 μg/m3		Primary and Secondary
24-hour average	65 μg/m3		Primary and Secondary

Source: Adapted from Callan and Thomas (2007)

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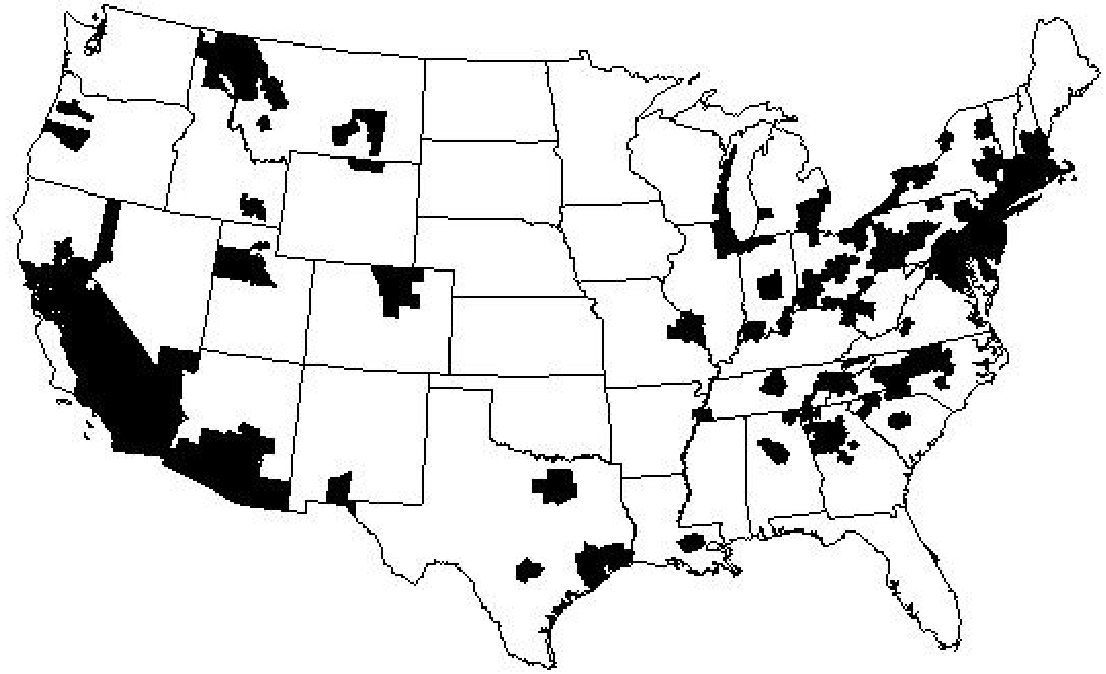
[3] Primary NAAQS are intended to protect public health, allowing a margin of safety; secondary NAAQS are intended to protect public welfare (includes factors other than health, like visibility and agricultural effects).

Table 2—Non-attainment Areas in 2004

Pollutant	**Number of Non-attainment Areas**	**Population (in thousands)**
Particulate Matter (PM-10)	58	29,187
Sulfur Dioxide (SO_2)	17	2,740
Carbon Monoxide (CO)	9	18,971
Nitrogen Dioxide (NO_2)	0	0
1-Hour Ozone (O_3)	65	111,187
8-Hour Ozone (O_3)	126	159,271
Lead (Pb)	2	4

Source: Adapted from Callan and Thomas (2007).

Figure 1—Non-Attainment Areas in June 2007



Areas marked in black are designated as non-attainment areas in at least one of the criteria pollutants.

The criteria pollutants present a range of potential damages for those who are exposed to unsafe levels. Although the majority of damages are from human health effects, there are additional damages to vegetation and the atmosphere. For example, sulfur dioxide converts in the atmosphere into fine particulate matter ($PM_{2.5}$ and PM_{10}), which can cause increases in acute chronic bronchitis and other respiratory problems. Exposed populations with previous history of cardiac or respiratory conditions suffer from increase mortality. In addition, sulfur dioxide can also combine with water in the atmosphere to produce acid rain. Table 3 summarizes the various effects of the pollutants from stationary sources on people, vegetation, and the atmosphere.

$PM_{2.5}$ is the most damaging pollutant when it comes to human health. It is the main driver of health damages and accounts for the majority of damages in damage-cost studies of the electricity sector (Desvouges, Johnson, and Banzhaf 1998; Muller and Mendelsohn 2007). In the Muller and Mendelsohn (2007) study, $PM_{2.5}$ only accounted for 6% of air pollution by weight, but was responsible for 23% of the aggregate damages. In addition, pollutants like sulfur dioxide and nitrogen oxides are converted to $PM_{2.5}$ in the atmosphere, causing damages from SO_2 and NO_x emissions to be very high as well. Muller and Mendelsohn attribute 26% of total damages ($19.5 billion dollars per year) to SO_2, mainly based on its conversion to fine particulate matter. Thus, it is important to limit sulfur dioxide and nitrogen oxide emissions based not only on their individual damages, but also on their conversion to $PM_{2.5}$ in the atmosphere.

Table 3—Pollutants and their Damages

Pollutant	Effects on Humans	Effects on Plants	Effects on the Atmosphere	Percentage from Stationary Sources
Sulfur Oxides, particulates	Worsens bronchitis and other respiratory problems. Causes increased mortality among patients with previous histories of cardiac or respiratory conditions.	Diminishes growth of plants with leaves of high physiological activity, including alfalfa, grains, squash, cotton, grapes, white pine, apple, and endive.	Particulates in the air block radiation and may reduce the earth's temperature. Sulfur oxides combine with water in the air to produce sulfuric acid, which reduces visibility and forms corrosive acid rain.	68% (SO_2)
Carbon Dioxide	-	-	Carbon dioxide traps heat in the atmosphere and causes global climate change.	40%
Mercury	Chronic exposure causes tremors, cognitive impairment, and sleep problems. Mercury emissions build up in fish and cause birth defects.	-	-	40%
Nitrogen Oxides	Causes respiratory tract and lung infections and eye and nose irritation. Converts to particulate matter in the atmosphere.	Restricts plant growth. Forms acid rain, which kills trees.	NO_2 reduces visibility. NO_x forms acid rain, killing trees and acidifying lakes, killing fish. NO_x in the upper atmosphere depletes ozone, causing increased ultraviolet levels.	22%

Adapted from Stutz (1996), Palmer, Burtraw, and Shih (2007)

Stationary Source Emissions

Stationary sources, including electricity-generating plants, emit the majority of the annual sulfur dioxide emissions in the U.S. This sulfur dioxide is converted in the atmosphere into sulfates, which are a main component of fine particulate matter, which is the most harmful pollutant to health as mentioned above. Sulfur dioxide also causes acid rain. Stationary sources are responsible for much of the emissions in the United States. Roughly 68% of sulfur dioxide emissions and 22% of nitrogen dioxide emissions come from electricity plants (Palmer, Burtraw, and Shih 2007). Additionally, electricity plants release 40% of the nation's carbon dioxide and 40% of mercury.

The traditional way to control stationary source emissions was to implement uniform technology-based standards, a command-and-control strategy. Differing standards apply to new and old sources. New sources are required to submit to stricter regulations called New Source Performance Standards (NSPS). The EPA controls these regulations for new sources, while the states control the standards for existing sources. Policies are also differentiated by whether or not the area is in attainment. For prevention of significant damage (PSD) areas, new or modified sources must comply with the best available control technology (BACT), while existing facilities must install the best available retrofit technology (BART). In non-attainment areas, new or modified sources must meet the lowest achievable emissions rate (LAER), while existing sources must use reasonably available control technology (RACT).

In contrast to these command and control policies, some pollutants are controlled by market-based instruments. Title IV of the 1990 Clean Air Act Amendments (CAAA) created a sulfur dioxide cap-and-trade system. The law established a cap of 9.5 million tons of SO_2 annually for the electricity sector starting in 2000 (Phase II), with the cap decreasing to 8.95 million tons beginning in 2010. These caps were further reduced by the Clean Air Interstate Rule (CAIR) in 2005. When fully implemented, CAIR mandates reductions of sulfur dioxide emissions of 70% and nitrogen oxide emissions of 60%.[4] In order to limit emissions to the cap level, the EPA issues tradable permits to firms allowing them to emit one ton of sulfur dioxide for each permit that they own. If a firm does not use all of their permits, they are allowed to sell their permits on the tradable permits market. Firms that do not have enough permits are allowed to buy permits in the market in order to emit more sulfur dioxide. By setting the cap at the efficient level, the tradable permit scheme generates the same outcome as a Pigouvian tax on emissions. However, the most important difference is the allocation of rents. Under the Pigouvian tax, the government collects the tax revenue. Under a tradable permit scheme, the rent accumulates to the firms who are allocated permits.

Similar programs exist for nitrogen oxide emissions. Previously, NOx emissions had been under the control of state implementation plans (SIP's). However, recent regulation, called the Clean Air Interstate Rule (CAIR) has been created to impose a market-based mechanism on the emissions of these pollutants.

Now that the institutional framework has been discussed, the rest of the work can be presented. Chapter 2 contains the analysis of environmental federalism, while Chapter 3 uses the data as constituent interest variables in the analyses of green electricity policies

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[4] CAIR has been subject to a number of legal challenges. On July 11, 2008, the Supreme Court remanded the rule. This was followed by a December 23, 2008 ruling allowing the rule to remain in place until a suitable revision could be written.

and legislative voting. Chapter 4 expounds the strategic interaction analysis. Chapter 5 concludes.

CHAPTER 2: ENVIRONMENTAL FEDERALISM

Environmental federalism, like other forms of federalism, refers to a transfer of responsibility to subnational governments. However, in the case of environmental federalism, two main problems arise. First, states are likely to ignore interstate spillovers. Secondly, states may lower their environmental standards in an attempt to attract industries to the state. On the other hand, state policies can account for geographic heterogeneity in damages, while, for political reasons, federal policies generally do not do so. The optimal solution involves a fully differentiated system where each state is responsible for all damages that spill over into other jurisdictions. With both federal and state level policies suffering from potential drawbacks, it is natural to question which of the two policies is closer to the fully differentiated solution. Helland and Whitford (2003) call this the most important question posed in Oates' (2002) review of environmental federalism.

Using a detailed simulation model of the U.S. electricity sector and an integrated assessment model of pollution damages, this study will determine the cap on sulfur dioxide (SO_2) and nitrogen oxide (NO_x) pollution that a welfare-maximizing state would impose upon itself along with the per-unit "tax" (marginal abatement costs)[5] on emissions that would generate that level. Then, these state levels are compared to the first-best case where "taxes" are fully differentiated across states and the nationally efficient uniform tax. The benefits of a national uniform tax (or shadow price) are similarly compared to the first-best case.

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[5] I will use the term "tax" as convenient shorthand. However, the broader interpretation of this term is the shadow value of emissions to industry or the marginal cost of abatement.

Implicit in this discussion is the hypothesis that states will ignore benefits or damages that accrue outside of their own borders when making abatement decisions. Empirical evidence seems to confirm this hypothesis. Sigman (2005) finds evidence that states ignore interstate spillovers in the case of water pollution. Helland and Whitford (2003) find that plants located in border counties (counties which border another state) emit more pollution than those that are entirely interior, suggesting that states are less environmentally stringent when pollution is more likely to travel out of state.

In the literature on environmental federalism, much attention has been paid to the theory that states will lower environmental standards to attract industry. Many theoretical papers focus on this potential “race to the bottom,” with some supporting the conclusion, and other refuting it (Oates and Schwab 1988; Wellisch 1995; Markusen, Morey, and Olewiler 1995; Levinson 1997; Kunce and Shogren 2002, 2005, 2007; Glazer 1999; Djikstra 2003; Kunce 2004; Roelfsema 2007).

Other empirical work on the issue has found that the level of governance has little effect on pollution outcomes (e.g., Rose-Ackerman 1995). List and Gerking (2000) find no evidence that Reagan’s implementation of “New Federalism,” with its significant transfer of responsibility to state governments, had a negative effect on aggregate emissions. These results are duplicated in similar analyses by Millimet (2003), Millimet and List (2003), and Fomby and Lin (2006). Sigman (2007) finds that nations with decentralized governments correspond with higher levels of pollution internationally, but the effect is mild.

Dinan, Cropper, and Portney (1999) examine the case of public drinking water quality, which is almost surely a local public good with little or no spillover effects. In this case, as discussed in Oates (2002), it is most efficient for regulation to be undertaken at the subnational level, since each subnational government will be able to (and has incentive to) mandate the efficient level. Since there are economies of scale in the reduction of pollutants in drinking water, small systems will undoubtedly have a higher cost of cleaning (per-capita) and will therefore have a lower efficient level of abatement. The authors measure the change in the number of cancer cases as a benefit, intentionally assuming the worst-case scenario for cancer-causing isotopes. They do this in order to provide an upper bound on benefits, which will, in turn, provide a lower bound on welfare losses. On the cost side, they assume that jurisdictions remove only enough pollutant to reach the limit, and that they use the cheapest available technology. They find that some households may lose up to $774 dollars per year from requiring the blanket regulation vs. allowing each system to choose their own optimum. Thus, federal uniform legislation is less efficient than local control in this situation. This chapter examines the same problem in the context of air pollution.

Data

We follow the approach of Banzhaf, Burtraw, and Palmer (2004), who use the Haiku model developed by Resources for the Future to analyze costs of abatement of SO_2 and NO_x in the electricity sector. The Haiku model is a detailed simulation model of the continental U.S. electricity industry. The model determines the market equilibrium resulting from regional electricity demand curves and endogenously determined supply curves. The Haiku model allows the user to input a per-unit tax on a pollutant and observe what the resultant level of pollution would be relative to the baseline. By inputting several levels of “taxes” (or, more generally, the marginal abatement costs induced by any incentive-based instrument), one can construct a curve that can represent the industry's marginal cost of abatement.

We also use the Tracking and Analysis Framework (TAF) integrated assessment model to analyze the benefits of pollution abatement. TAF includes spillover matrices that determine how much pollution spills over from each state to each other state. TAF also includes measures of health benefits for reductions in each pollutant. Plotting the results of the model for several levels of pollution abatement results in a curve representing the marginal benefits of pollution abatement.

Given marginal cost and marginal benefit curves, Banzhaf, Burtraw, and Palmer (2004) proceed to find the optimal level of pollution and the optimal uniform tax for the entire U.S. However, the data generated by each model is broken down by state. Thus, the data can be used to find the optimal abatement and tax for each state that would result if states could set their own taxes. Additionally, one can use the data to determine which national uniform tax level generates the most benefits for each state. Before discussing these procedures, let us consider each model in more detail.

Haiku

The Haiku model was developed at Resources for the Future by Dallas Burtraw, Ranjit Bharvirkar, David Evans, Karen Palmer, Anthony Paul, and others (Paul and Burtraw 2002). It has been used in a multitude of peer-reviewed articles (Palmer and Burtraw 2005; Burtraw, Kahn, and Palmer 2006; Palmer, Burtraw, and Shih 2007). In essence, the model is a simulation of regional electricity markets along with interregional electricity trade in the United States. Haiku is very versatile, being able to simulate changes in the electricity market arising from many forms of public policy, including environmental legislation and market competition legislation. Haiku accomplishes this by calculating market equilibria in 13 National Electricity Reliability Council (NERC) subregions.

The demand side of the market is the aggregate of three sectoral electricity demand functions (commercial, industrial, and residential). The supply side is based on 64 model plants types, into which are mapped all actual plants in the continental U.S. The model plants differ by six fields: plant technology, fuel type, coal demand region, SO_2 scrubbers, relative efficiency, and existence status. Individual plants also differ by age. The model accounts for developments in wind, solar, and hydroelectric power. Electricity supply is also a function of endogenous fuel prices for each fuel type.

Haiku divides the year into 3 seasons to capture seasonal variation in electricity demand: winter, summer, and spring/fall. Within seasons, time is subdivided into three time blocks accounting for variations in demand, from low to peak periods. Electricity markets clear in all 117 markets (13 regions x 3 seasons x 3 time blocks) based on marginal or average cost pricing as appropriate.

Haiku acknowledges that power plants are very long-term investments, and to reflect this, the model solves for a 20-year time horizon, discounting future revenues and costs back to the decision-making point. The model does not solve for every year, however. It solves for every fifth year and interpolates the results to intermediate years.

Haiku’s data mainly comes from the Energy Information Administration (EIA) and the Federal Energy Regulatory Committee (FERC), with some additional information from the Environmental Protection Agency (EPA). The demand elasticities assumed in the model are primarily collected from academic literature.

The main feature of Haiku that is useful for our purposes is its ability to simulate emissions taxes. The model incorporates the tax as an increased cost of emitting the pollutant. Thus, by instituting a range of emissions taxes and solving the model for each tax, one retrieves the pollution abatement from each level of taxation. This can be used to construct a marginal cost of abatement curve. Since prices and quantities are duals, the "tax" level used as an input in Haiku is also interpretable as the marginal cost of abatement when emissions are capped at the associated pollution level.

While Haiku solves for an extended time horizon and many years, we only consider the projected emissions for the year 2010. Consequently, it is important to note that our data are based on a static short-run equilibrium rather than a dynamic equilibrium.

Tracking and Analysis Framework (TAF)

Integrated assessment models bring together contributions from many different areas of science. Models may combine information from any number of scientific sources, including, but not limited to, meteorology, ecology, biology, medicine, chemistry, and economics. All of the information works together allowing one model to compute all of the relevant effects together.

Integrated assessment models make extensive use of transfer methods, which are the transfer of research from one study to another, taking account of the circumstances of the new context (Desvousges, Johnson, and Banzhaf 1998; Navrud and Ready 2007). There are many times when designing and executing an entirely new study is not a worthwhile endeavor. In these cases, it may be feasible to assimilate information from a previous reliable study.

Several integrated assessment models have been developed in recent years. Desvousges, Johnson, and Banzhaf (1998) develop an integrated assessment model of air pollution in order to study new power plant locations in Minnesota. Rowe, Lang, and Chestnut (1996) use the New York State Environmental Externalities Cost Study and computerized externality model (EXMOD) to measure externalities from electricity production in New York. Muller and Mendelsohn (2007) use an integrated assessment model of air pollution called the Air Pollution Emissions Experiments and Policy analysis model (APEEP) to examine the marginal damages of releasing one additional ton of emissions from any of 10,000 sources. They use these marginal damages to calculate gross aggregate damages. The EPA uses a model called BENMAP to estimate, value, and graphically display increases in air pollution. In addition to air pollution, integrated assessment models have been used to study climate change (Kelly and Kolstad 2000; Schellnhuber et al. 2004; Haurie and Viguier 2005).

The Tracking and Analysis Framework (TAF) is a peer-reviewed integrated assessment model that serves to collect models of pollution transportation and deposition, human health effects from pollution, and the valuation of these effects (Bloyd et al. 1996). TAF consists of several modules, each of which was developed by a team of experts in their respective field. Here, the analysis is limited to health effects, which account for the vast majority of benefits in these integrated assessment models (Krupnick and Burtraw 1996; Rowe, Lang, and Chestnut 1996; Desvousges, Johnson, and Banzhaf 1998; Muller and Mendelsohn 2007).

Perhaps the most important features of TAF are the seasonal source-receptor matrices, which track pollutants from their source to the locations that they damage. The source-receptor matrices in TAF are simplified versions of the Advanced Source Trajectory Regional Air Pollution model (ASTRAP), which is based on 11 years of weather data. TAF identifies a source centroid and a receptor centroid for each state based on electricity generation patterns and population respectively. These centroids are used to compute reduced form source-receptor matrices of state-to-state pollution flows.

Health effects in the TAF model consist of changes in health status that result from increased air pollution as computed from estimated epidemiological relationships. Effects are summarized in a number of ways: as statistical lives lost, days of acute morbidity of various types, and number of chronic disease cases (such as asthma and emphysema). TAF then assigns monetary values to these damages based on academic studies. Most importantly, the value of a statistical life in TAF is taken from a meta-analysis by Mrozek and Taylor (2002) and equals \$2.32 million (in 2000 dollars). This value is on the low end of the low end of the range in the literature, and compares to the value of \$6.11 million (in 2000 dollars) used by the EPA in its benefit-cost analyses. Values for short-term morbidity effects are taken from a meta-analysis by Johnson, Fries, and Banzhaf (1997). The values used in TAF for various health effects are summarized in Table 4.

TAF takes a baseline emissions scenario and a policy emissions scenario to calculate the total yearly benefits of the emissions reduction by state. These numbers can be divided by the abated emissions to get average benefits per ton.

Methodology

The points that Haiku generates are graphed in order to represent the marginal cost of abatement. The tax levels and corresponding emissions should construct an

Table 4—Monetary Values of Health Incidents from TAF

Health Problem	**Value per Case (2000 dollars)**
Phlegm Day	$3.52
Eye Irritation Day	$3.52
Adult Chronic Bronchitis (PM)	$8,990.89
Adult Chronic Bronchitis (Sulfate)	$256,995.26
Respiratory Hospital Admissions (PM)	$8,733.37
Respiratory Hospital Admissions (Sulfate)	$16,226.44
Cardiac Hospital Admissions	$16,226.44
Asthma Attack	$40.73
Restricted Activity Day (PM)	$70.63
Restricted Activity Day (Sulfate)	$69.52
Lower Respiratory Symptoms	$12.75
Croup	$5.70
Acute Cough	$4.88
Adult Chest Discomfort	$11.08
Emergency Room Visit	$246.48
Acute Respiratory Symptoms	$3.65
Chronic Cough	$2,929.96
Child Chronic Bronchitis	$182.76
Acute Bronchitis	$5.48
Upper Respiratory Symptoms	$3.69
Value of a Statistical Life (VSL)	$2,317,687.31

All values are per case or per day if noted.

upward-sloping marginal cost of abatement (MCA) curve for each state's emissions. Taxes vary from $500 per ton of sulfur dioxide up to $6,500 per ton. For NO_x, the taxes range from $700 to $1500 per ton.

Data from Haiku on each state's emissions are inputted into TAF to define the marginal benefit curves. By varying one state's emissions and leaving all other states at their baseline levels and looking at the change in total damages, we can construct marginal benefit curves for the damages a state imposes upon itself and the total damages aggregated over all states in the analysis. The epidemiological literature suggests that the effects are virtually constant. Hence, TAF uses constant damage estimates according to the state where the damage occurs, and the curves that result are horizontal lines corresponding to the damages inflicted by each ton of sulfur dioxide emitted.

The information that is observed from the Haiku and TAF models is a series of points corresponding to the hypothetical emissions taxes inputted into the model. However, the Haiku data are rather noisy, reflecting a myriad of reasons that emissions vary. We wish to obtain smooth lines connecting the points provided by Haiku. One way to do this is to use the locally weighted scatterplot smoothing (Lowess) method introduced by Cleveland (1979). This is a variant of the local polynomial estimation that uses a variable bandwidth parameter determined by the distance from each point to its nearest neighbors. It uses a tricubic kernel and downweights observations with larger than normal residuals. Lowess is considered superior to standard kernel regression in that it uses a variable bandwidth and is robust to outliers.

Intuitively, the process estimates a linear regression for each point based on the nearest neighbors as determined by the bandwidth. Then, it uses the results of the regression to predict the value at each level. Then, these predicted values are connected by linear segments to form the smoothed piecewise linear curves.[6] Figure 2 shows an example of an unsmoothed and smoothed MCA curve for Connecticut (SO_2). The jagged line is the unsmoothed data, while the other line has been smoothed with the Lowess process. The unsmoothed data is full of reversals, which do not comply with economic theory. The reversals are due to small amounts of interregional trade in electricity and simulation error in solving the Haiku model. The graph shows one of the worst cases, as Connecticut is a small state. More typical cases are shown in Figure 3 for New York and Figure 4 for Texas.

Figures 5-7 show fully constructed graphs with (smoothed) costs and benefits for three states: Kansas, North Carolina, and California. The upward-sloping- line is the MCA curve. The lower dashed line represents the marginal benefits accruing only within each respective state from its own abatement. The upper dashed line represents the benefits for the entire nation that result from abatement in each respective state. By finding the intersection points, the equilibria are revealed. The intersection of the MCA curve and the lower dashed line represents the level of abatement that would result if the state only cared about its own benefits. The intersection with the upper dashed line represents the nationally optimal level of abatement in each state. When aggregated, the equilibria from each state's graphs represent the total level of abatement for the country under the various scenarios.

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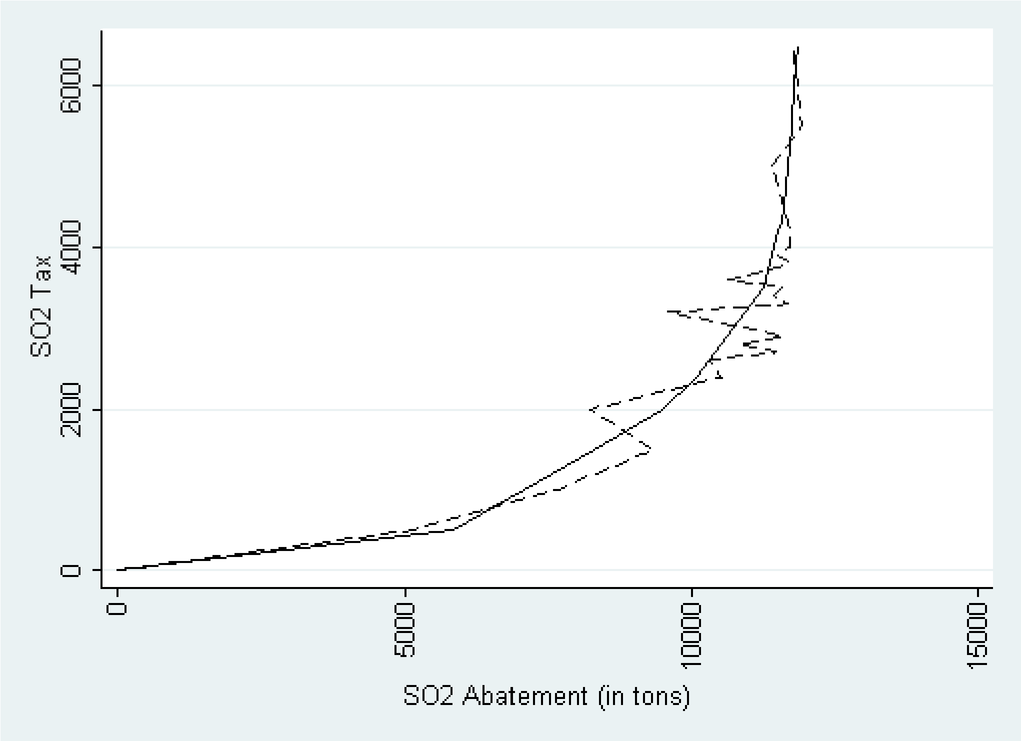
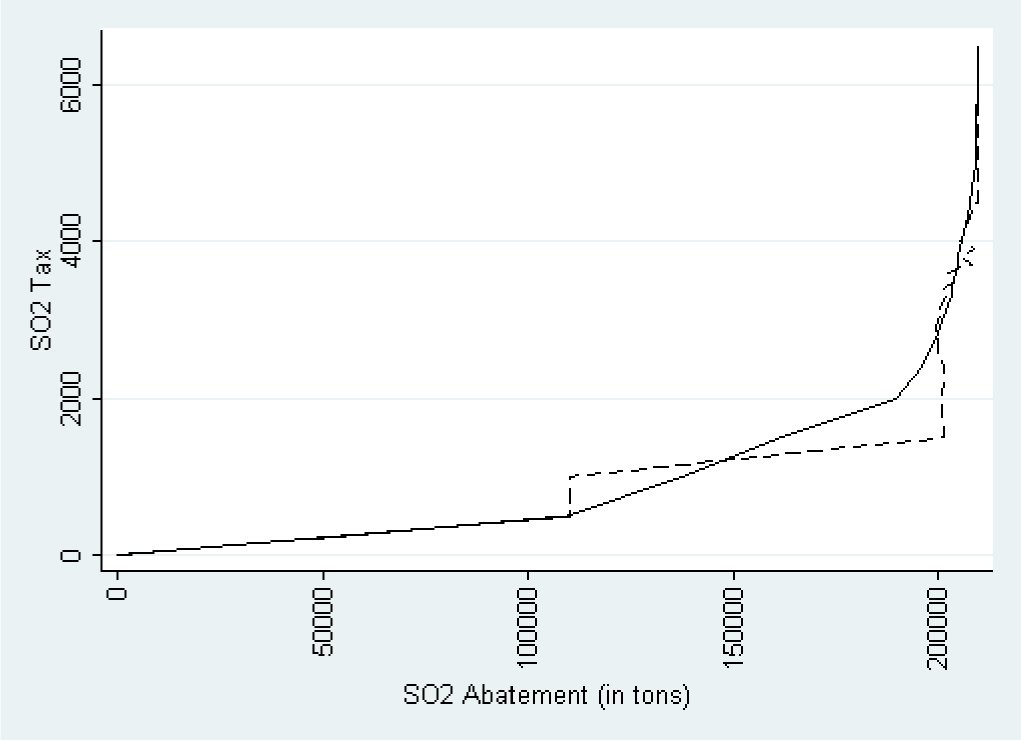
[6] Any reversals still present after smoothing are eliminated by removing the point prior to the reversal and all subsequent points until a higher level of abatement is achieved. Then, a line segment connects the points on either side of the gap. This occurs in only four cases.

Figure 2—Raw and Smoothed MCA Curves for Connecticut



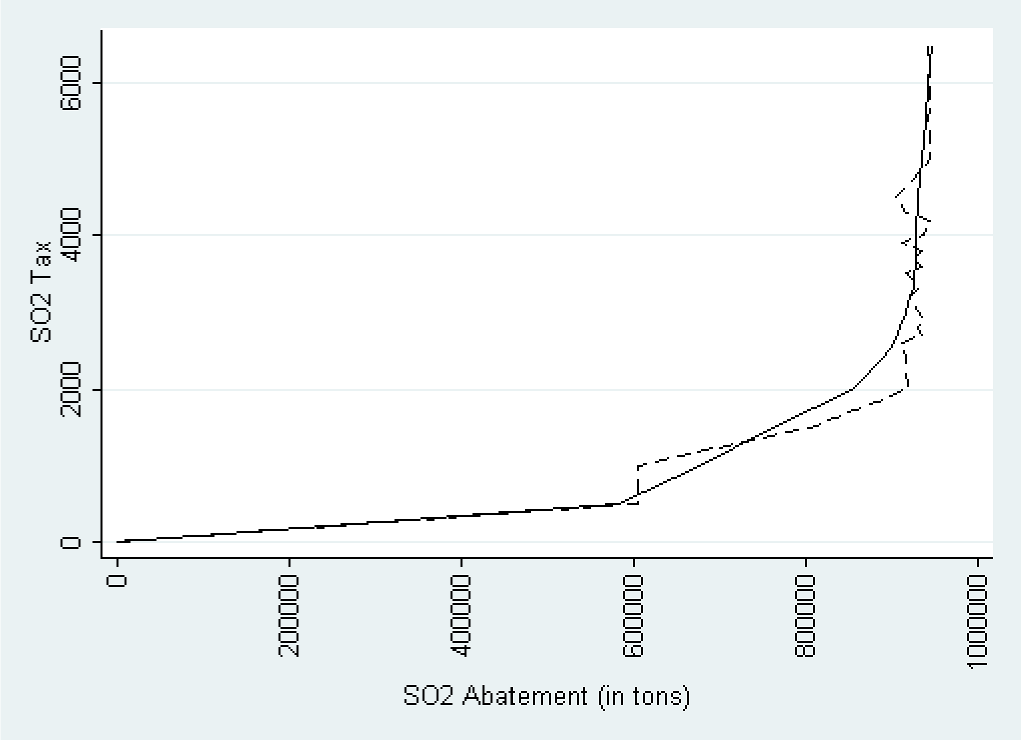
The dashed line represents the raw, unsmoothed Haiku data, while the solid line reflects application of the Lowess smoother.

Figure 3—Raw and Smoothed MCA Curves for New York



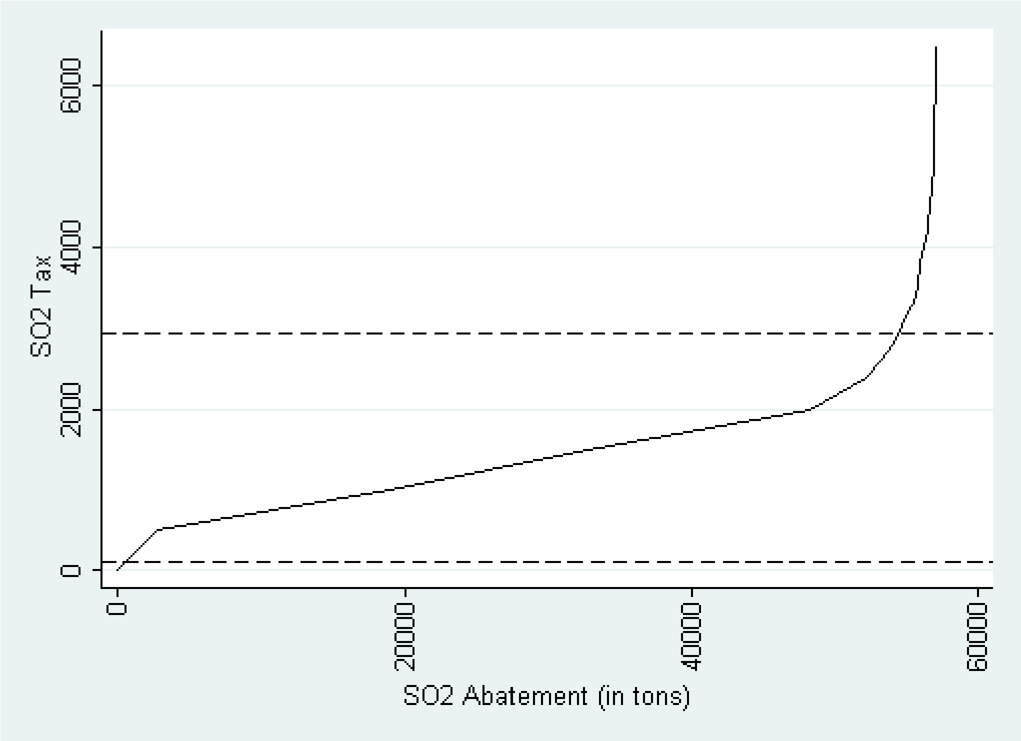
The dashed line represents the raw, unsmoothed Haiku data, while the solid line reflects application of the Lowess smoother.

Figure 4—Raw and Smoothed MCA Curves for Texas



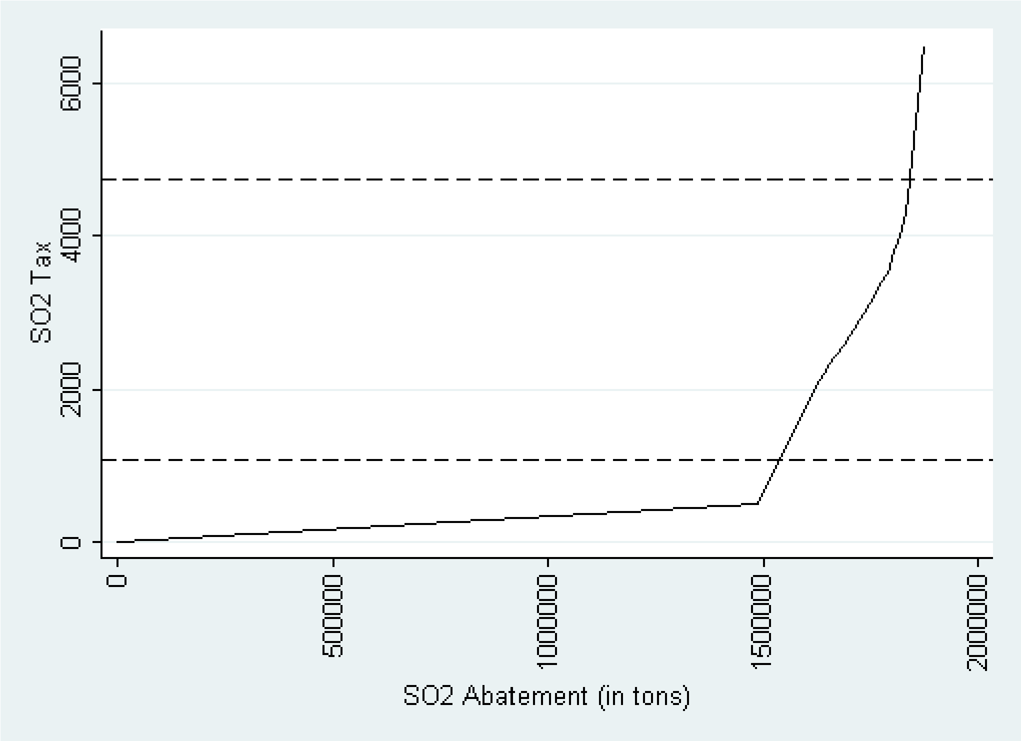
The dashed line represents the raw, unsmoothed Haiku data, while the solid line reflects application of the Lowess smoother.

Figure 5—MCA and MB for Sulfur Dioxide for Kansas



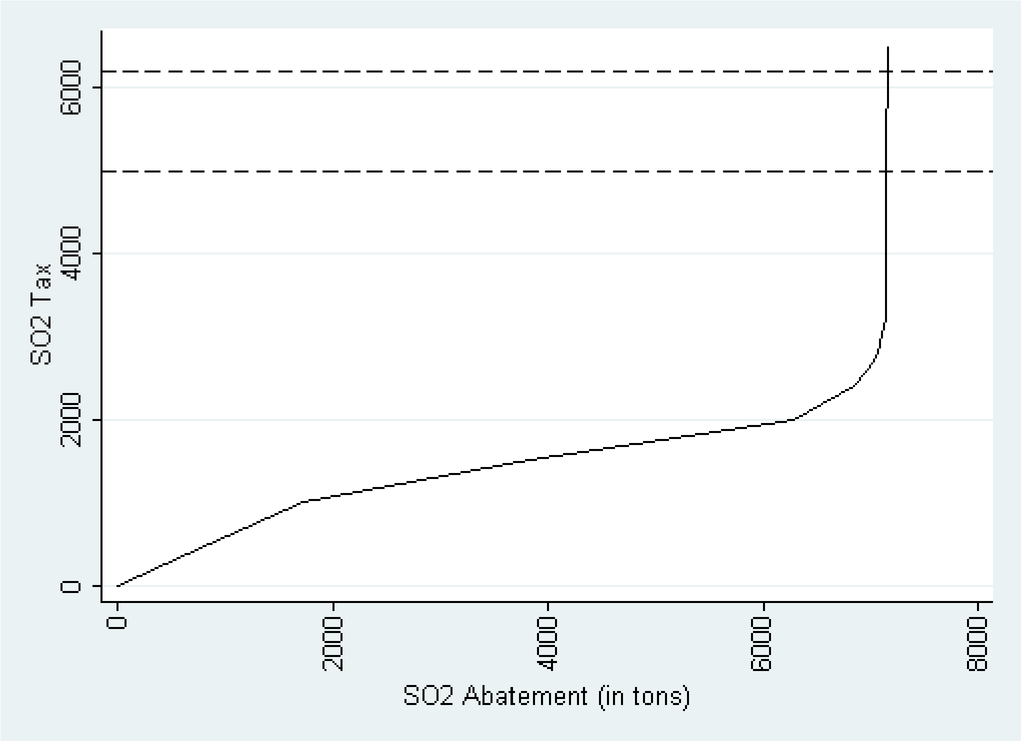
The solid line represents the marginal cost of abatement curve. The upper dashed line represents the marginal benefits that accrue to the entire nation based on Kansas' abatement of sulfur dioxide (SO2), while the lower dashed line represents the benefits that accrue only within the state of Kansas.

Figure 6—MCA and MB for Sulfur Dioxide for North Carolina



The solid line represents the marginal cost of abatement curve. The upper dashed line represents the marginal benefits that accrue to the entire nation based on North Carolina's abatement of sulfur dioxide (SO2), while the lower dashed line represents the benefits that accrue only within the state of North Carolina.

Figure 7—MCA and MB for Sulfur Dioxide for California



The solid line represents the marginal cost of abatement curve. The upper dashed line represents the marginal benefits that accrue to the entire nation based on California's abatement of sulfur dioxide (SO2), while the lower dashed line represents the benefits that accrue only within the state of California.

Finally, we must calculate the nationally optimal uniform “tax” and abatement. This requires aggregating the marginal cost curves to a national marginal cost of abatement curve. Benefits are no longer constant, as differing marginal abatement will occur at different locations with differing damages. However, there is no consistent trend in benefits and smoothing results in a roughly horizontal line. For SO_2, we calculate the optimal uniform tax to be \$3,912 (shown in Figure 8). For NO_x, the uniform tax is \$622.50 (as seen in Figure 9).[7]

This data can now be used to answer the questions that we set out to answer. By aggregating the state emissions under each scenario, the total levels of emissions (and their monetary values) can be compared to see how emissions differ when states pick their own levels of emissions.

Results

The individually optimal state taxes, the nationally optimal taxes, and their respective levels of abatement for SO_2 are presented in Table 5.[8] Table 5 shows the marginal benefits and optimal abatement (in tons of SO_2) under the state level policy, the national uniform policy, and the fully differentiated first best policy. The first column shows the “tax” that would induce the level of abatement shown in the third column.

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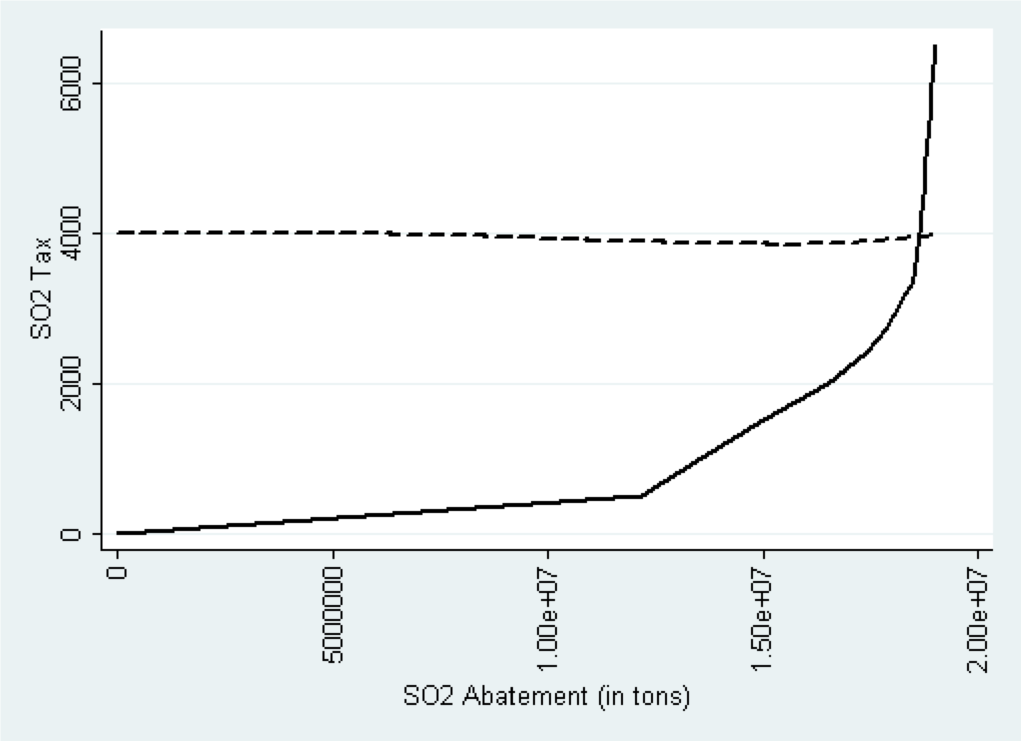
[7] These estimates are slightly different than those in Banzhaf, Burtraw, and Palmer (2004). That paper had an inconsistency insofar as ancillary benefits of NO_x reductions from SO_2 "taxes" (or vice versa) were included in the net benefit function, but general equilibrium shifts in abatement cost curves were ignored. My partial equilibrium approach is more straight-forward and more consistent. Sensitivity analyses suggest this would not qualitatively affect the results found here.

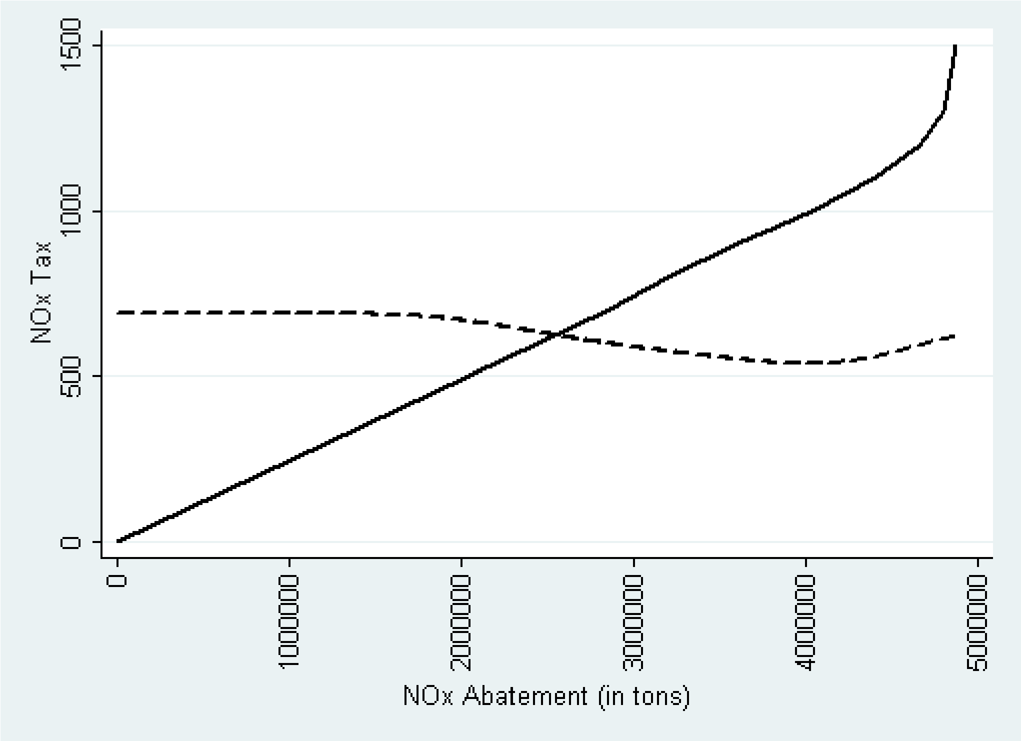
[8] The District of Columbia, Rhode Island, Vermont, and Idaho are excluded from the analysis. The first three do not contribute any significant level of emissions, while Idaho does not emit any sulfur dioxide and barely any nitrogen oxides in any specification. Benefits accruing to these states from other state’s emissions are included in those state’s calculations.

Figure 8—National Uniform SO_2 Policy



The dashed line represents the national marginal benefit (MB) curve for sulfur dioxide abatement. Notice that, unlike the state MB curves, this curve is not horizontal. State-specific marginal damages are constant, but since different states abate at different points in the range of abatement, the national MB curve is not constant. This line has been smoothed with the Lowess smoother. The solid line represents the national MCA curve. The point of intersection determines the efficient national uniform "tax", which is $3,912 per ton of sulfur dioxide.

Figure 9—National Uniform NO_x Policy



The dashed line represents the national marginal benefit (MB) curve for nitrogen oxide (NOx) abatement. Notice that, unlike the state MB curves, this curve is not horizontal. State-specific marginal damages are constant, but since different states abate at different points in the range of abatement, the national MB curve is not constant. This line has been smoothed with the Lowess smoother. The solid line represents the national MCA curve. The point of intersection determines the efficient national uniform "tax", which is $622.50 per ton of nitrogen oxides.

Table 5—Taxes and Abatement for SO_2

	State Level “Tax”	First Best Tax	State Level Abatement	First Best Abatement	Uniform Tax[9] Abatement	State Abatement as a % of First Best	Uniform Tax Abatement as a % of First Best
AL	$343.58	$4,133.10	8334.8	283160	283160.4	2.94%	100.00%
AZ	$247.80	$1,707.51	1087.7	7465.8	13555.05	14.57%	181.56%
AR	$375.59	$4,637.93	158670	334470	333959.3	47.44%	99.85%
CA	$4,975.46	$6,199.27	7127.3	7149.8	7166.879	99.69%	100.24%
CO	$291.53	$1,632.33	6061.4	44902	69039.04	13.50%	153.75%
CT	$1,060.46	$3,739.77	7224.8	11353	11259.71	63.64%	99.18%
DE	$81.56	$2,526.79	19444	146720	148458.4	13.25%	101.18%
FL	$1,240.30	$3,528.00	257900	389960	389953.7	66.13%	100.00%
GA	$482.79	$3,825.17	445870	902190	902171.9	49.42%	100.00%
IL	$837.04	$4,428.95	1664600	2107100	2107099	79.00%	100.00%
IN	$435.29	$4,271.14	978530	1478700	1476633	66.18%	99.86%
IA	$139.51	$3,184.11	1799.5	34705	37136.59	5.19%	107.01%
KS	$113.87	$2,943.90	616.25	54528	55786.02	1.13%	102.31%
KY	$307.69	$4,362.10	74165	403580	403803.2	18.38%	100.06%
LA	$657.81	$4,122.66	140300	208060	207808.7	67.43%	99.88%
ME	$302.32	$1,091.30	1262.6	2605.3	4037.399	48.46%	154.97%
MD	$654.99	$3,874.41	605860	736320	736188.2	82.28%	99.98%
MA	$1,063.06	$2,304.91	6568.2	10954	12122.31	59.96%	110.67%
MI	$534.50	$3,580.13	1050300	1352700	1353118	77.64%	100.03%
MN	$399.84	$2,973.92	727.35	12275	14245.81	5.93%	116.06%
MS	$293.67	$3,893.92	1089.9	46223	46222.98	2.36%	100.00%
MO	$260.87	$3,682.91	26545	376200	376008.8	7.06%	99.95%
MT	$52.39	$1,104.10	31.026	924.62	5966.1	3.36%	645.25%
NE	$52.60	$1,584.08	382.27	10996	20290.7	3.48%	184.53%
NV	$126.13	$2,389.29	4054.3	104360	111395.4	3.88%	106.74%
NH	$134.77	$1,474.36	225.96	7487.8	12846.39	3.02%	171.56%
NJ	$2,297.02	$4,922.04	81956	94464	92428.47	86.76%	97.85%
NM	$99.16	$1,633.95	84.195	933.88	1448.964	9.02%	155.16%
NY	$1,249.50	$3,889.20	149600	205350	203749.7	72.85%	99.22%
NC	$1,071.42	$4,753.78	1537000	1842500	1789921	83.42%	97.15%
ND	$19.34	$1,109.55	16.703	958.21	6674.862	1.74%	696.60%
OH	$549.61	$3,874.56	491990	1055500	1043603	46.61%	98.87%
OK	$261.44	$3,455.63	130680	412000	412091	31.72%	100.02%
OR	$621.09	$3,196.00	802.22	11456	11882.51	7.00%	103.72%
PA	$859.59	$3,843.79	388580	703080	698024.4	55.27%	99.28%
SC	$462.80	$3,529.74	434380	582110	581632.2	74.62%	99.92%
SD	$28.87	$1,414.55	38.331	1884.9	3858.676	2.03%	204.72%
TN	$383.81	$4,393.99	57789	306270	306326.5	18.87%	100.02%
TX	$628.08	$3,194.46	606090	921870	927067.9	65.75%	100.56%
UT	$236.24	$1,648.95	481.14	9093.2	20527.72	5.29%	225.75%
VA	$1,040.73	$4,929.50	538930	642740	629965.3	83.85%	98.01%
WA	$731.53	$1,726.98	2550.6	16900	32015.49	15.09%	189.44%
WV	$101.57	$3,691.71	283930	1691100	1691029	16.79%	100.00%
WI	$373.50	$3,436.60	538100	943180	943228.56	57.05%	100.01%
WY	$26.08	$1,286.52	143.83	9405.9	25394.4	1.53%	269.98%
Total			10711919.4	18525885.4	18560302.6	57.82%	100.19%

All abatement measures are in tons of sulfur dioxide abated from the baseline. The first two columns show the value of the state-level and optimal “taxes” while the next three columns show state abatement under the three different policies. The final two columns show the state policy and uniform policy abatement as a percentage of the optimal abatement.

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[9] The nationally uniform tax is $3,912 per ton of SO_2.

Thus, the number in the first column represents the benefit accruing to each state from the abatement of one additional ton of sulfur dioxide. The third column gives the equilibrium quantity of abatement that each state should choose given the marginal benefit estimates from the first column. These two columns are for the state level policy. Columns 2 and 4 show the same information for the fully differentiated first best optimal policy. The fifth column shows abatement under the nationally optimal uniform "tax." The last two columns show the state level and uniform tax abatement levels as a percentage of each state's first best optimal abatement. Note that all abatement is relative to the baseline emissions.[10] Table 6 shows the net benefits (total benefits – total costs) for each state and each policy. The total benefits of each policy are calculated by multiplying abatement by the optimal policy marginal benefits. Costs, as measured by the area under the marginal abatement curve up to the abatement level, are subtracted from the total benefits to get net benefits. Column 1 shows the national net benefits achieved when a state acts in its own interests. Column 2 shows a state's contribution to national benefits when it behaves optimally, and Column 3 shows a state's contribution when it complies with a national uniform policy. Tables 7 and 8 show the same information for NO_x taxes, abatement, and net benefits.

Two trends emerge when looking at the results. First, larger states, like California, tend to have higher state-optimal "taxes" compared to smaller states. California and Texas would select higher levels of abatement than would smaller states with the same population density. Since emissions in these states have farther to go

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[10] The baseline for the SO_2 model assumes the nationally optimal NO_x tax of \$900 per ton as derived in Banzhaf, Burtraw, and Palmer (2004), but there are no policies in effect for SO_2. Similarly, the NO_x baseline includes a \$3,000 per ton SO_2 tax and no policies for NOx.

Table 6—Net Benefits of SO_2

	State Net Benefits[11]	Optimal Net Benefits	Uniform Tax Net Benefits
AL	$33,016,753	$661,028,298	$661,028,298
AZ	$1,722,498	$6,391,725	$573,964
AR	$706,103,362	$1,305,728,466	$1,305,634,156
CA	$34,483,447	$34,485,744	$34,477,369
CO	$9,010,639	$31,005,685	$21,002,010
CT	$24,492,181	$31,380,594	$31,375,460
DE	$48,338,057	$303,794,021	$303,106,444
FL	$803,722,133	$996,720,290	$996,701,970
GA	$1,597,896,943	$2,602,325,127	$2,602,331,630
IL	$6,921,572,918	$8,073,744,024	$8,073,744,024
IN	$3,966,470,718	$5,374,877,882	$5,374,810,768
IA	$5,604,278	$60,972,390	$58,279,284
KS	$1,779,092	$88,499,986	$87,853,729
KY	$312,105,142	$1,308,859,577	$1,308,855,956
LA	$541,137,044	$713,810,411	$713,789,372
ME	$1,187,025	$1,909,834	$381,291
MD	$2,191,571,450	$2,497,197,282	$2,497,213,514
MA	$12,215,991	$15,238,952	$14,500,879
MI	$3,496,625,444	$4,011,629,201	$4,011,731,564
MN	$2,017,672	$16,127,884	$14,128,508
MS	$4,083,957	$96,555,836	$96,555,836
MO	$94,300,466	$918,321,033	$918,312,248
MT	$33,443	$375,060	-$4,057,525
NE	$595,494	$8,876,294	-$4,260,891
NV	$9,431,228	$118,046,805	$115,377,440
NH	$317,921	$4,387,117	$1,678,970
NJ	$341,020,573	$365,267,429	$364,535,077
NM	$133,396	$877,975	$547,414
NY	$519,436,239	$628,597,109	$628,568,301
NC	$6,896,616,405	$7,545,447,495	$7,532,570,699
ND	$18,371	$531,592	-$9,102,678
OH	$1,780,222,678	$2,923,193,583	$2,922,867,427
OK	$434,499,547	$1,093,557,983	$1,093,469,228
OR	$2,314,769	$17,618,432	$17,177,875
PA	$1,370,518,302	$1,979,018,950	$1,978,933,386
SC	$1,432,739,626	$1,706,878,513	$1,705,129,316
SD	$53,668	$1,334,581	-$1,264,515
TN	$242,834,499	$947,151,775	$947,139,955
TX	$1,777,032,495	$2,293,320,237	$2,292,121,469
UT	$736,544	$4,648,263	-$2,774,690
VA	$2,508,986,398	$2,774,857,978	$2,770,717,810
WA	$3,471,904	$9,202,889	-$4,757,596
WV	$1,033,766,266	$5,462,105,096	$5,462,272,608
WI	$1,748,745,698	$2,695,094,557	$2,694,695,095
WY	$183,164	$4,894,636	-$6,031,187
Totals	$40,913,165,839	$59,735,888,591	$59,621,941,265
Difference from Optimal NB	$18,822,722,751 (31.5%)		$113,947,326 (0.19%)

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[11] Net benefits presented here are the nation-wide benefits of reduced pollution in the given state minus the state's costs of attaining that level of pollution.

Table 7—Taxes and Abatement for NO_x

	State Level "Tax"	First Best Tax	State Level Abatement	First Best Abatement	Uniform Tax[12] Abatement	State Abatement as a % of First Best	Uniform Tax Abatement as a % of First Best
AL	$60.27	$679.71	10879	123000	112000	8.84%	91.06%
AZ	$62.85	$323.42	66.079	340.04	654.48	19.43%	192.47%
AR	$38.07	$649.78	486.39	8302.5	7953.9	5.86%	95.80%
CA	$348.10	$475.30	708.14	966.88	1266.3	73.24%	130.97%
CO	$42.06	$306.38	97.34	709.05	1440.6	13.73%	203.17%
CT	$101.62	$500.60	29.878	147.19	183.03	20.30%	124.35%
DE	$13.52	$472.44	251.41	8783.1	11573	2.86%	131.76%
FL	$223.88	$524.38	26662	62448	74133	42.69%	118.71%
GA	$105.84	$673.81	23220	148000	137000	15.69%	92.57%
IL	$136.11	$744.45	54964	286000	251000	19.22%	87.76%
IN	$77.91	$774.49	24464	243000	195000	10.07%	80.25%
IA	$33.96	$591.34	1765	30735	32354	5.74%	105.27%
KS	$21.71	$461.21	1634.6	34722	46865	4.71%	134.97%
KY	$52.62	$778.82	16963	226000	201000	7.51%	88.94%
LA	$73.80	$561.33	3322.3	25268	28022	13.15%	110.90%
ME	$20.53	$153.64	2.3352	17.479	70.819	13.36%	405.17%
MD	$120.99	$719.06	11363	65778	58464	17.27%	88.88%
MA	$135.83	$345.93	320.77	816.89	1470	39.27%	179.95%
MI	$90.99	$641.83	16927	119000	116000	14.22%	97.48%
MN	$50.90	$487.31	969.28	9279.4	11854	10.45%	127.75%
MS	$45.65	$624.23	1276.5	17455	17407	7.31%	99.73%
MO	$53.73	$678.10	9992.8	126000	116000	7.93%	92.06%
MT	$7.74	$201.33	20.8	540.78	1672	3.85%	309.18%
NE	$11.10	$338.55	321.52	9807.7	18034	3.28%	183.88%
NV	$17.28	$365.87	112.78	2387.9	4062.7	4.72%	170.14%
NH	$20.47	$281.25	42.909	589.56	1304.9	7.28%	221.33%
NJ	$224.55	$648.86	7175.9	20736	19893	34.61%	95.93%
NM	$18.30	$330.07	363.13	6549.6	12352	5.54%	188.59%
NY	$186.58	$640.20	8565.1	29389	28576	29.14%	97.23%
NC	$104.71	$622.00	25319	150000	151000	16.88%	100.67%
ND	$4.11	$251.57	26.573	1625.6	4022.5	1.63%	247.45%
OH	$132.17	$771.03	29426	168000	139000	17.52%	82.74%
OK	$38.48	$507.90	96.069	1268	1554.1	7.58%	122.56%
OR	$34.37	$278.45	32.317	261.82	585.31	12.34%	223.55%
PA	$150.04	$709.64	39210	184000	163000	21.31%	88.59%
SC	$68.68	$607.82	7054.9	62432	63939	11.30%	102.41%
SD	$5.70	$296.35	27.247	1416.5	2975.3	1.92%	210.05%
TN	$69.46	$752.85	13201	143000	118000	9.23%	82.52%
TX	$132.46	$528.41	934.02	3726.1	4389.6	25.07%	117.81%
UT	$31.07	$286.88	158.52	1463.6	3175.9	10.83%	216.99%
VA	$96.98	$673.84	9856.2	68484	63266	14.39%	92.38%
WA	$68.79	$213.44	16.34	50.696	147.85	32.23%	291.64%
WV	$22.85	$710.85	8123.9	249000	221000	3.26%	88.76%
WI	$59.29	$604.64	9620.6	98119	101000	9.81%	102.94%
WY	$4.98	$264.01	3.2595	172.76	407.36	1.89%	235.80%
Total			366072.907	2739789.15	2545068.65	13.36%	92.89%

All abatement measures are in tons of nitrogen oxides abated from the baseline. The first columns show the value of the state-level and optimal "taxes" while the next three columns show state abatement under the three different policies. The final two columns show the state policy and uniform policy abatement as a percentage of the optimal abatement.

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[12] The nationally uniform tax is $622.50 per ton of NO_x.

Table 8—Net Benefits of NO_x

	State Net Benefits	Optimal Net Benefits	Uniform Tax Net Benefits
AL	$7,066,766	$41,906,795	$41,154,944
AZ	$19,295	$54,988	$7,963
AR	$306,789	$2,697,399	$2,692,586
CA	$213,326	$229,774	$207,717
CO	$27,776	$108,618	-$7,031
CT	$13,439	$36,843	$34,658
DE	$117,075	$2,074,749	$1,865,397
FL	$10,996,446	$16,373,310	$15,799,658
GA	$14,417,009	$49,922,505	$49,805,623
IL	$37,177,548	$111,273,212	$108,614,399
IN	$17,994,051	$94,032,645	$90,190,209
IA	$1,013,742	$9,087,480	$9,062,157
KS	$736,149	$8,007,026	$7,027,597
KY	$12,764,914	$96,692,257	$94,082,653
LA	$1,742,295	$7,091,697	$7,007,590
ME	$335	$1,343	-$11,161
MD	$7,483,184	$24,263,072	$23,841,895
MA	$89,177	$141,295	$50,974
MI	$10,094,291	$38,059,292	$38,407,789
MN	$447,670	$2,260,938	$2,087,065
MS	$767,697	$5,447,856	$5,448,093
MO	$6,507,646	$42,681,457	$42,625,468
MT	$4,107	$54,438	-$183,794
NE	$107,067	$1,660,221	$492,555
NV	$40,289	$436,836	$221,928
NH	$11,629	$82,908	-$39,130
NJ	$3,850,480	$6,727,448	$6,715,959
NM	$116,537	$1,080,941	$232,453
NY	$4,684,362	$9,407,490	$9,400,006
NC	$14,423,026	$46,524,638	$47,071,642
ND	$6,630	$204,480	-$240,041
OH	$20,743,827	$66,405,600	$64,035,633
OK	$46,945	$322,012	$305,623
OR	$8,443	$36,452	-$19,200
PA	$24,883,315	$65,916,967	$65,038,617
SC	$4,045,843	$18,973,539	$18,962,527
SD	$7,997	$209,896	-$44,328
TN	$9,479,993	$53,794,207	$52,010,842
TX	$431,686	$984,455	$953,204
UT	$43,013	$209,941	-$77,403
VA	$6,163,582	$23,073,259	$22,939,162
WA	$2,926	$5,410	-$14,463
WV	$5,682,039	$89,795,746	$88,204,048
WI	$5,531,812	$29,663,596	$29,626,562
WY	$852	$22,805	-$19,244
Totals	$230,313,021	$968,037,834	$945,569,402
Difference from Optimal NB	$737,724,813 (76.2%)		$22,468,432 (2.32%)

before crossing into another jurisdiction, the in-state damages are the majority of the total damages. Therefore, these states choose a level of abatement closer to the optimum.

Secondly, the optimal abatement tends to occur where the marginal cost of abatement is highly inelastic. This allows a little bit of flexibility in the tax (or induced marginal cost) so that policies that induce anything in the neighborhood of the optimal marginal cost yield virtually the same abatement as the optimal policy. Figure 6 for North Carolina illustrates this case. The optimal marginal abatement cost occurs in a region where abatement is inelastic, so any perturbation in the uniform tax around the optimal tax still yields a reasonably efficient outcome.

When states choose their own levels in the SO_2 case, the resulting arrangement represents a loss of 31.5% of the benefits that the fully differentiated optimal solution could provide. This represents a loss of over $18 billion per year. The uniform pollution “tax,” on the other hand, generates a loss of only 0.22% of the potential benefits under the fully differentiated system. This suggests that an optimally chosen uniform tax would reasonably approximate the fully optimal solution. On the other hand, the substantial loss of the state policies suggests that air pollution should be regulated at the federal level.

In the case of NO_x, the contrast is even more severe. The state policies result in a loss of 76.2% of the potential benefits, while the uniform policy results in a loss of 2.32%. The uniform policy again approximates the fully differentiated solution fairly well.

However, even though the totals are very close, the distribution of benefits is quite different because the uniform tax will cause some states to over-abate while other states will under-abate.[13] If a state overabates enough, their costs might exceed their total benefits (even including benefits accruing from other states). This will lead some states to benefit more from the state-level policy than the uniform policy. Ten states benefit more from the state-level policy for SO_2 as shown in Figure 10.

Sensitivity Analysis

The TAF model makes some restrictive modeling judgments that might need to be relaxed. One such assumption is that the willingness to pay for the health effects in the model is constant across the entire population. However, the VSL literature finds a clear relationship between income and willingness-to-pay (WTP) for health risk reduction. This relationship can be used to adjust the benefits derived from TAF to take account of state-to-state differences in income. First, we take the calculated income elasticity from the VSL literature. Mrozek and Taylor (2002) discuss several income elasticities derived in the literature. Their three best estimates are 0.36, 0.46, and 0.49. Miller (2000) presents similar results, citing 0.36 and 0.46 as appropriate values. Viscusi and Aldy (2003) suggest measures from 0.5 to 0.6. For good measure, we also consider a wider range of values, from 0.15 and 0.75. These elasticities are multiplied by the percentage difference between each state’s per-capita income and national average per-capita income. The resulting value represents how much each WTP figure should be adjusted. Tables 9 and 10 show the resulting “taxes” for each elasticity value. In addition, the nationally uniform tax levels must also be adjusted.

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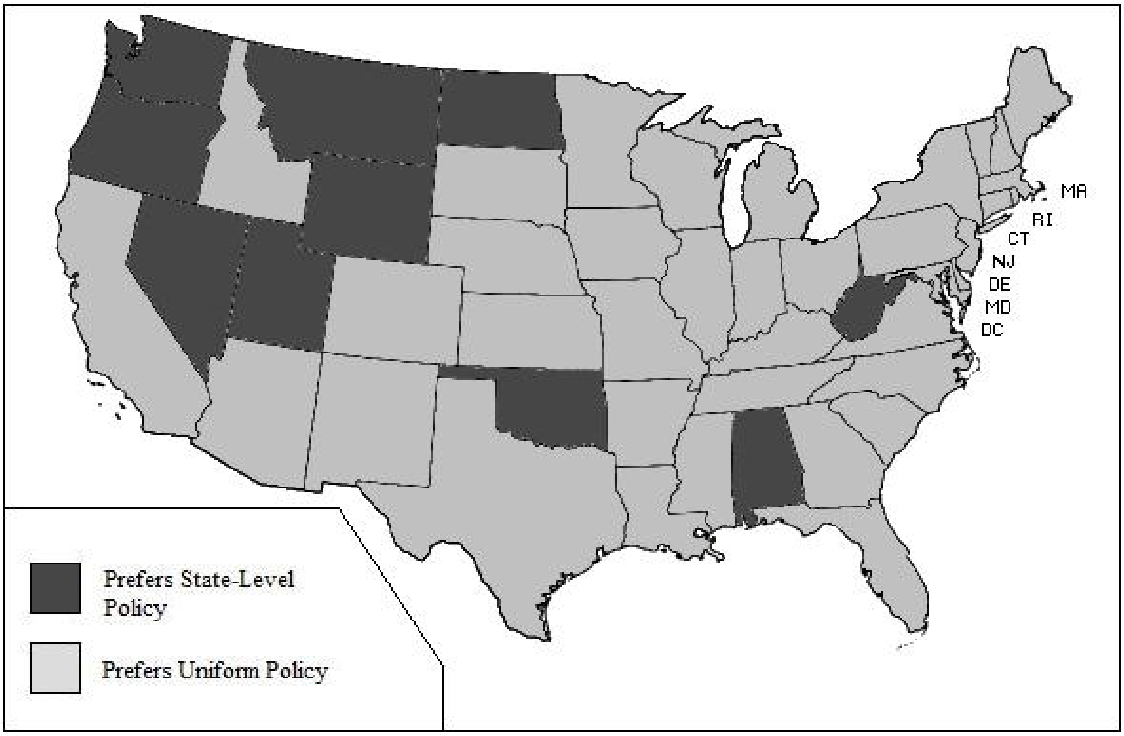
[13] As noted in Table 1, the majority of states overabate under the uniform tax. However, those that overabate by large percentages are low-emissions states, so that the large percentage numbers are small in absolute terms. Those states that underabate do so in small percentage terms but in large absolute terms.

Figure 10—Distributional Effects of the SO_2 Policies



The darker states experience higher net benefits under their own respective state-level policies than they do under the national uniform policy.

Table 9—Optimal SO_2 Taxes under Differing Income Elasticities

State	$\eta = 0$	$\eta = 0.15$	$\eta = 0.36$	$\eta = 0.46$	$\eta = 0.49$	$\eta = 0.75$
AL	$4,133.10	$4,114.02	$4,090.17	$4,078.82	$4,075.41	$4,045.89
AZ	$1,707.51	$1,697.88	$1,684.39	$1,677.97	$1,676.05	$1,659.35
AR	$4,637.93	$4,605.22	$4,559.43	$4,537.63	$4,531.08	$4,474.39
CA	$6,199.27	$6,229.79	$6,272.52	$6,292.87	$6,298.97	$6,351.87
CO	$1,632.33	$1,629.52	$1,625.58	$1,623.71	$1,623.15	$1,618.28
CT	$3,739.77	$3,839.73	$3,979.68	$4,046.32	$4,066.32	$4,239.59
DE	$2,526.79	$2,567.54	$2,624.60	$2,651.76	$2,659.91	$2,730.55
FL	$3,528.00	$3,520.90	$3,510.96	$3,506.23	$3,504.81	$3,492.50
GA	$3,825.17	$3,821.49	$3,816.34	$3,813.88	$3,813.15	$3,806.77
IL	$4,428.95	$4,210.55	$4,214.80	$4,216.83	$4,217.44	$4,222.71
IN	$4,271.14	$4,272.90	$4,275.37	$4,276.54	$4,276.90	$4,279.95
IA	$3,184.11	$3,186.13	$3,188.97	$3,190.32	$3,190.73	$3,194.24
KS	$2,943.90	$2,934.61	$2,921.61	$2,915.42	$2,913.56	$2,897.46
KY	$4,362.10	$4,360.49	$4,358.25	$4,357.18	$4,356.86	$4,354.07
LA	$4,122.66	$4,074.88	$4,007.98	$3,976.13	$3,966.57	$3,883.75
ME	$1,091.30	$1,100.87	$1,114.27	$1,120.64	$1,122.56	$1,139.14
MD	$3,874.41	$3,929.29	$4,006.12	$4,042.70	$4,053.68	$4,148.79
MA	$2,304.91	$2,356.78	$2,429.40	$2,463.99	$2,474.36	$2,564.27
MI	$3,580.13	$3,598.87	$3,625.10	$3,637.60	$3,641.35	$3,673.83
MN	$2,973.92	$2,980.59	$2,989.92	$2,994.37	$2,995.70	$3,007.26
MS	$3,893.92	$3,862.66	$3,818.89	$3,798.05	$3,791.79	$3,737.60
MO	$3,682.91	$3,678.37	$3,672.01	$3,668.98	$3,668.08	$3,660.20
MT	$1,104.10	$1,100.54	$1,095.56	$1,093.19	$1,092.48	$1,086.32
NE	$1,584.08	$1,579.82	$1,573.85	$1,571.01	$1,570.16	$1,562.77
NV	$2,389.29	$2,389.74	$2,390.35	$2,390.65	$2,390.73	$2,391.50
NH	$1,474.36	$1,499.33	$1,534.29	$1,550.94	$1,555.94	$1,599.22
NJ	$4,922.04	$5,045.46	$5,218.25	$5,300.54	$5,325.22	$5,539.15
NM	$1,633.95	$1,624.90	$1,612.23	$1,606.20	$1,604.39	$1,588.70
NY	$3,889.20	$3,962.27	$4,064.58	$4,113.30	$4,127.91	$4,254.57
NC	$4,753.78	$4,776.67	$4,808.70	$4,823.96	$4,828.53	$4,868.20
ND	$1,109.55	$1,109.15	$1,108.59	$1,108.33	$1,108.25	$1,107.56
OH	$3,874.56	$3,895.93	$3,925.86	$3,940.11	$3,944.39	$3,981.44
OK	$3,455.63	$3,429.38	$3,392.63	$3,375.13	$3,369.88	$3,324.38
OR	$3,196.00	$3,205.92	$3,219.80	$3,226.41	$3,228.40	$3,245.58
PA	$3,843.79	$3,888.56	$3,951.24	$3,981.09	$3,990.04	$4,067.65
SC	$3,529.74	$3,530.64	$3,531.89	$3,532.49	$3,532.66	$3,534.21
SD	$1,414.55	$1,414.14	$1,413.56	$1,413.28	$1,413.20	$1,412.49
TN	$4,393.99	$4,386.87	$4,376.89	$4,372.14	$4,370.72	$4,358.37
TX	$3,194.46	$3,170.27	$3,136.41	$3,120.28	$3,115.44	$3,073.51
UT	$1,648.95	$1,640.82	$1,629.44	$1,624.02	$1,622.39	$1,608.30
VA	$4,929.50	$4,985.66	$5,064.28	$5,101.72	$5,112.95	$5,210.29
WA	$1,726.98	$1,733.46	$1,742.53	$1,746.85	$1,748.15	$1,759.38
WV	$3,691.71	$3,719.76	$3,759.04	$3,777.74	$3,783.35	$3,831.98
WI	$3,436.60	$3,445.41	$3,457.73	$3,463.60	$3,465.36	$3,480.63
WY	$1,286.52	$1,282.50	$1,276.89	$1,274.21	$1,273.41	$1,266.45

Table 10—State-Level SO_2 Taxes under Differing Income Elasticities

State	η = 0	η= 0.15	η = 0.36	η = 0.46	η = 0.49	η = 0.75
AL	343.5809	335.302	323.9503	318.5447	316.923	302.8684
AZ	247.7987	245.5396	242.3769	240.8709	240.4191	236.5033
AR	375.5853	363.3636	346.2532	338.1054	335.661	314.4768
CA	4975.46	5014.32	5068.723	5094.63	5102.401	5169.758
CO	291.5327	296.5201	303.5024	306.8274	307.8249	316.4697
CT	1060.46	1113.36	1187.42	1222.687	1233.267	1324.961
DE	81.55593	82.52953	83.89256	84.54162	84.73634	86.4239
FL	1240.304	1240.045	1239.683	1239.511	1239.459	1239.011
GA	482.7937	481.3411	479.3074	478.339	478.0485	475.5307
IL	837.0388	803.569	815.304	820.8921	822.5685	837.0975
IN	435.2898	431.6905	426.6514	424.2518	423.5319	417.293
IA	139.5079	137.6535	135.0573	133.821	133.4501	130.2357
KS	113.8696	113.0143	111.8168	111.2466	111.0756	109.593
KY	307.6862	300.2161	289.7579	284.7778	283.2837	270.3354
LA	657.8107	636.4418	606.5254	592.2795	588.0057	550.9663
ME	302.3202	297.6566	291.1276	288.0185	287.0858	279.0023
MD	654.9938	673.3219	698.9813	711.2	714.8656	746.6343
MA	1063.058	1095.301	1140.442	1161.937	1168.386	1224.274
MI	534.4954	536.6532	539.6742	541.1128	541.5443	545.2846
MN	399.8446	404.3205	410.5869	413.5708	414.466	422.2244
MS	293.6705	281.9696	265.5884	257.7879	255.4477	235.1663
MO	260.8717	257.8789	253.689	251.6939	251.0953	245.9079
MT	52.38943	50.77457	48.51377	47.4372	47.11423	44.31514
NE	52.59966	51.87817	50.86809	50.3871	50.2428	48.99222
NV	126.131	126.4833	126.9766	127.2114	127.2819	127.8926
NH	134.7686	136.8821	139.8412	141.2502	141.6729	145.3365
NJ	2297.017	2383.51	2504.601	2562.263	2579.562	2729.483
NM	99.15804	96.17737	92.00444	90.01733	89.4212	84.25471
NY	1249.496	1265.141	1287.045	1297.475	1300.604	1327.723
NC	1071.423	1061.894	1048.553	1042.2	1040.294	1023.776
ND	19.34157	18.82844	18.11006	17.76797	17.66535	16.77592
OH	549.6087	547.3783	544.2559	542.769	542.323	538.4571
OK	261.4378	254.2784	244.2553	239.4824	238.0505	225.641
OR	621.0938	618.3015	614.3923	612.5308	611.9724	607.1324
PA	859.5877	855.3648	849.4528	846.6376	845.793	838.4733
SC	462.8003	453.8217	441.2517	435.266	433.4703	417.9074
SD	28.87139	28.06391	26.93343	26.39511	26.23362	24.83398
TN	383.8149	377.9636	369.7717	365.8708	364.7005	354.5581
TX	628.0798	619.4821	607.4454	601.7136	599.9941	585.0915
UT	236.2431	230.6585	222.84	219.117	218	208.3201
VA	1040.731	1058	1082.177	1093.69	1097.144	1127.077
WA	731.5348	738.58	748.4434	753.1402	754.5493	766.7611
WV	101.5725	97.94474	92.86588	90.44738	89.72182	83.43371
WI	373.5039	372.6838	371.5356	370.9889	370.8248	369.4033
WY	26.08348	25.63889	25.01646	24.72006	24.63114	23.86052

Net benefits and percentage losses are summarized by η value in Table 11. For SO_2, assuming a larger income elasticity (η) causes the state policy net benefits to fall slightly while the uniform policy benefits rise slightly, further exacerbating the difference between the two policies. This result is somewhat counterintuitive. As the income elasticity rises, so does state level heterogeneity in damages.[14] Since heterogeneity in damages is the rationale for the possible superiority of state-level policies, it would seem that higher income elasticity should improve the position of the state policies relative to the uniform policy. However, the result is driven by the fact that lower-income states tend to be downwind from higher income states in general. Thus, abatement increases in high income states, but the benefits from that abatement are experienced by lower income downwind states. In addition, when low income states reduce abatement, more pollution is spread downwind into high income states. For the case of nitrogen oxides, the situation is similar. Higher values of the income elasticity worsen both policies relative to the optimal situation, but the state policies are clearly still less advantageous.

Conclusions

With the first-best situation unattainable, the two feasible options should be compared to see which is closer to the optimum. State differentiated policies can account for heterogeneity in damages, while a uniform national policy can control for interstate pollution spillovers. Using Haiku, a model of the U.S. electricity market, and TAF, an integrated assessment model of air pollution transport and valuation, this paper has

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[14] The standard deviation of state level benefits is 801.44 when $\eta = 0$, but rises to 860.43 when $\eta = 0.75$.

Table 11—Net Benefits and Percentage Losses by η Value

		SO$_2$			**NO$_x$**		
		State	Uniform	Optimal	State	Uniform	Optimal
η = 0	Net Benefits	$40,913,165,839	$59,621,941,265	$59,735,888,591	$230,313,021	$945,569,402	$968,037,834
	Percent Loss	31.51%	0.19%		76.21%	2.32%	
η = 0.15	Net Benefits	$40,525,917,345	$59,380,399,884	$59,495,532,449	$230,509,160	$951,163,853	$973,335,159
	Percent Loss	31.88%	0.19%		76.32%	2.28%	
η = 0.36	Net Benefits	$40,547,365,962	$59,697,208,459	$59,813,565,764	$230,803,697	$956,009,220	$980,395,891
	Percent Loss	32.21%	0.19%		76.46%	2.49%	
η = 0.46	Net Benefits	$40,557,740,147	$59,847,639,336	$59,964,710,787	$230,951,331	$957,766,940	$982,425,062
	Percent Loss	32.36%	0.20%		76.49%	2.51%	
η = 0.49	Net Benefits	$40,560,953,938	$59,892,942,679	$60,010,046,090	$230,995,938	$959,011,166	$984,603,813
	Percent Loss	32.41%	0.20%		76.54%	2.60%	
η = 0.75	Net Benefits	$40,587,147,128	$60,284,470,780	$60,404,498,955	$231,407,348	$968,701,965	$993,987,291
	Percent Loss	32.81%	0.20%		76.72%	2.54%	

shown that the uniform federal policy performs better than the state-level policies for the cases of sulfur dioxide and nitrogen oxides from electricity plants. The state-level policies capture only 68.5% of the optimal benefits from SO_2 abatement and 23.8% of the benefits of NO_x. The national uniform policy, on the other hand, accounts for 99.8% of the sulfur dioxide benefits and 97.7% of the benefits of NO_x abatement. Sensitivity analysis confirms that these results are robust to several measures of income elasticity.

CHAPTER 3: CONSTITUENT INTEREST, GREEN ELECTRICITY POLICIES, AND LEGISLATIVE VOTING

States have long had the ability to enact their own environmental legislation that is more stringent than federal legislation. In addition, at the federal level, some state's legislators vote for increased national environmental stringency while others vote to reduce it. How do we explain these interstate differences in policy preferences? There are several factors at work. Political factors such as the ideology and political party of elected officials certainly play a part. Social variables like race, age, and sex can also affect preferences. Finally, economic interests such as specific industry production, potential to meet regulation, income, and other factors influence these decisions.

Political scientists and economists have often tried to disentangle the effects of ideology, party affiliation, and constituent interest (Kalt and Zupan 1984, 1990; Kau and Rubin 1979, 1981; Peltzman 1984; Coates and Munger 1995; Vachon and Menz 2006; Anderson 2007). Most of these studies find that ideology is an important determinant of policy-making. However, these studies use measures of constituent interest that are somewhat problematic. Some of the studies rely on local demographic variables, past voting history of the constituency, or environmental interest group membership to proxy for interest. While these measures are sometimes good proxies, they can be inherently limited. Local demographic characteristics may not correlate well with interest, while past voting history is not as much a measure of interest as it is a measure of constituent ideology over a wide range of policies. Environmental interest group membership as used by Anderson (2007) is a good option, but it only measures the interest of the most avid environmentalists. Moreover, it ignores the strength of opposing interests. In analyses that focus on a wider spectrum, a more objective, broad-based approach is necessary. In these cases, constituent interest should be measured by the actual costs and benefits of the proposed policies in the context where the decision is being made. Put in other terms, an economist advising a government would recommend policies to maximize net benefits. This chapter tests whether such benefits are a factor in observed patterns across states.

Air pollution regulation provides an excellent example of these factors. Air pollution affects the entire population, and damages are affected by many factors, such as atmospheric transportation and population density. In addition, air pollution is a transboundary problem—pollution from one jurisdiction travels into other jurisdictions. Accordingly, regulation of air pollution has typically occurred at the federal level. For example, the 1990 Clean Air Act Amendments, enacted at the federal level, call for market-based policies for sulfur dioxide emissions and stratospheric ozone-depleting substances. Although the Clean Air Act was enacted at the federal level, there are many things that states can do beyond the federal legislation. States can require grandfathered stationary sources to comply with best available control technology rather than the federally required best available retrofit technology. In the tradable permits markets, states can also retire permits, effectively reducing the total amount of emissions. In addition, states can implement a number of policies designed to encourage “green” electricity generation. These include renewable portfolio standards, net metering rules, generation disclosure rules, and public benefit funds.

This split of federal policies and state policies creates a dichotomy in the study of policy adoption. States may wish to encourage more stringent federal policies in order to restrict transboundary pollution spillovers from their neighbors, while adopting state-level policies to suite their own costs and benefits. These situations provide ideal circumstances to test different measures of constituent interest.

Using Haiku, a detailed simulation model of the U.S. electricity market, and the Tracking and Analysis Framework (TAF), an integrated assessment model of air pollutant transmission and benefits, we construct reliable measures of constituency interest based on the actual costs and benefits of sulfur dioxide pollution.[15] We then use these measures in new analyses of two areas where the ideology/constituent interest debate is well developed: state adoption of more stringent green electricity policies and legislative roll-call voting on environmental issues.

Although most studies in these areas have found that ideology and party affiliation dominate while constituent interest is often not significant (see, for example, Coates and Munger 1995; Clinton 2006; Vachon and Menz 2006), our analyses suggest that constituent interest is important in both areas. Importantly, in the case of legislative roll-call voting, our measure of air quality interest proves most important when explaining votes related to energy issues and air pollution issues, while displaying a lesser effect on other environmental bills.

Economic Interests

We use the Haiku and TAF to generate indicators of constituent interests in the following way. First, we use the data derived in Chapter 2 for the policies most efficient

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[15] For more information on Haiku and TAF, see the discussion in Chapter 2.

at the state level as our first measure of constituent interest.[16] Since the within-state marginal benefit measure represents the interest of each state in determining the efficient level of sulfur dioxide pollution from its own electricity plants, it is an ideal measure to use in explaining adoption of state-level green electricity policies. We will test two measures: the raw efficient "tax" level for each state, which measures only the benefits side of the issue, and the abatement generated by that level as a percentage of the state's abatement under the current going price in the sulfur dioxide trading market. These variables are present in Table 12. The first column of data represents each state's "tax" level, while the second column is the percentage measure.

The second measure that we construct is a measure of which uniform "tax" (or shadow cost of abatement) each state would like to see imposed at the national level. To derive this measure, we take the output from Haiku for each tax level and run the data through TAF. This gives the state-level benefits of each tax level. These benefits include not only the benefits from that state's abatement, but also the benefits accruing because less pollution is flowing into that state from upwind states. For each state, we then calculate the state abatement that results from each tax level. We then measure the cost of attaining that abatement by calculating the area under the MCA curve up to that abatement level. Then, total costs are subtracted from total benefits to get the net benefits of each tax level for each state. Then, the tax level that provides the highest level of net benefits represents the tax level that each state would find most beneficial at the federal level. These tax levels are given in the third column of Table 12.

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[16] "Interest" in this sense refers strictly to what is in the best "interest" of the health of the population. It does not include measures of non-use value or altruistic value.

Table 12—Constituent Interest Variables

	State Level "Tax"	State Abatement as a % of Sulfur Trading Levels	State's Most Beneficial Uniform Tax
AL	$343.58	90.41%	$2,000
AZ	$247.80	98.84%	$2,000
AR	$375.59	65.21%	$2,000
CA	$4,975.46	1534.77%	$6,000
CO	$291.53	76.72%	$1,500
CT	$1,060.46	226.92%	$6,500
DE	$81.56	21.46%	$6,000
FL	$1,240.30	249.18%	$2,400
GA	$482.79	127.05%	$2,000
ID	-	-	$6,000
IL	$837.04	36.71%	$2,000
IN	$435.29	193.87%	$2,000
IA	$139.51	114.55%	$2,400
KS	$113.87	29.96%	$2,000
KY	$307.69	80.97%	$2,000
LA	$657.81	193.40%	$2,000
ME	$302.32	291.83%	$6,500
MD	$654.99	188.30%	$6,000
MA	$1,063.06	79.55%	$6,500
MI	$534.50	184.85%	$2,600
MN	$399.84	105.22%	$2,700
MS	$293.67	68.65%	$2,000
MO	$260.87	77.28%	$2,000
MT	$52.39	13.79%	$2,000
NE	$52.60	190.11%	$2,000
NV	$126.13	5.09%	$500
NH	$134.77	13.84%	$6,500
NJ	$2,297.02	35.46%	$6,500
NM	$99.16	339.62%	$6,000
NY	$1,249.50	26.09%	$6,500
NC	$1,071.42	33.19%	$2,400
ND	$19.34	253.42%	$2,000
OH	$549.61	188.42%	$2,400
OK	$261.44	68.80%	$2,000
OR	$621.09	228.81%	$2,000
PA	$859.59	218.10%	$2,400
RI	-	-	$6,500
SC	$462.80	121.79%	$2,400
SD	$28.87	7.60%	$2,000
TN	$383.81	101.00%	$2,000
TX	$628.08	191.85%	$2,000
UT	$236.24	62.17%	$2,000
VT	-	-	$6,500
VA	$1,040.73	193.12%	$6,000
WA	$731.53	269.51%	$2,000
WV	$101.57	98.29%	$500
WI	$373.50	26.73%	$2,000
WY	$26.08	6.86%	$500

Values in the first column represents the state's efficient "tax" or shadow price of abatement. The second column shows their abatement at this level as a percentage of their abatement at the current sulfur dioxide trading price.
The third category shows the state's most beneficial national uniform "tax" level.

Since these uniform tax levels represent the level that each state would find most beneficial if implemented at the federal level, it is a good measure of constituent interest in the case of legislative voting on national environmental issues related to energy and air pollution. Analysis of legislative roll-call voting on these issues is presented in Section 4.

Analysis of State Green Electricity Policies

States have adopted a wide range of green electricity policies (Menz 2005). Four main types of policies are renewable portfolio standards, net metering rules, public benefit funds, and generation disclosure rules (Vachon and Menz 2006). The levels of "taxes" that the states find most efficient for themselves should indicate which states adopt such policies. States that experience higher marginal abatement costs in our model should be the ones that we observe to adopt more stringent environmental policies in their electricity sector, ceteris paribus.

Okazaki (2006) examines the effects of adopting these policies on the amount of renewable energy used in the state, controlling for a state's potential to generate renewable energy and other socioeconomic variables. He finds evidence that adopting these policies increases the amount of renewable energy generated. We adopt his measure of renewable energy potential, as discussed below. Other studies have attempted to disentangle the effects of political, social, and economic factors when explaining state adoption of more stringent environmental policies (Lester et al. 1983; Lester and Lombard 1990; Ringquist 1993, 2002). Vachon and Menz (2006) use a variety of political, social, and economic variables to explain which states adopt green electricity policies. They find that income, education, environmental interest groups, and legislative voting influence the adoption of these regulations.

However, what studies of this type are missing is a clear, objective measure of the policy that is in the true best interest of the state. My variables measure the states' interest in air quality, and provide a measurement of constituent interest that is based on health benefits that has not been used in the previous literature. Following Vachon and Menz (2006), we examine four state-level policies: renewable portfolio standards, net metering rules, public benefit funds, and generation disclosure rules.

Renewable portfolio standards (RPS) are requirements on the percentage of electricity generation (or sometimes electricity sales) that must come from qualifying renewable sources. Renewable portfolio standards are designed to stimulate the use of renewable sources used by electricity suppliers. As of 2005, 19 states had adopted renewable portfolio standards (Vachon and Menz 2006).

Net metering rules (NMR) allow consumers to use their own renewable electricity systems to replace commercially available power. For example, a consumer may install solar panels to power their house while using the power company's electricity as a back-up system when they do not generate enough. Consumers may even be able to sell excess power generated on the grid. When net metering rules are in effect, power companies must allow consumers this opportunity. Thirty-three states had net metering rules in effect in 2005.

Public benefit funds (PBF) are taxes levied on electricity consumption. The tax revenues are used to sponsor renewable electricity programs. Public benefit funds are the least widely adopted policy, with only 15 states adopting them by 2005.

Lastly, generation disclosure rules require utilities to disclose information to consumers on their fuel sources and emissions. Similar in spirit to ecolabeling, it is expected that increased knowledge will cause consumers to seek renewable sources while utilities are encouraged to adopt them. As of 2005, 24 states had generation disclosure rules in effect. Table 13 contains information on which states adopted each of these four policies.

In addition to the above named policies, some states have implemented state level legislation that targets emissions. In 2002, North Carolina passed the Clean Smokestacks Act, designed to cut NO_x emissions by 77% and SO_2 emissions by 73% by the year 2013 (NCDENR 2002). Similar programs have been implemented in California, Texas, and New York. However, since these programs are widely diverse, it is impossible to quantify them in order to include a separate analysis of their adoption.

Data and Methodology

Logit models are used to determine the effect of the constituent interest variables on adoption of each of the four green electricity policies.

The probability of state *i* adopting policy *j* is

$$p_{ij} = \frac{e^{u_{ij}^1}}{e^{u_{ij}^1} + e^{u_{ij}^0}} \qquad (1)$$

where u_{ij}^1 is the observed social welfare of adopting policy *j* for state *i* and u_{ij}^0 is the social welfare of not adopting the policy. True social welfare is measured by $v_{ij} = u_{ij} + \varepsilon_{ij}$. ε_{ij} is an iid type I extreme value error. Normalizing $u_{ij}^0 = 0$, we have

$$p_{ij} = \frac{e^{u_{ij}^1}}{1 + e^{u_{ij}^1}}\,. \qquad (2)$$

Table 13—State Adoption of Green Electricity Initiatives

State	Renewable Portfolio Standards	Net Metering Rules	Public Benefit Funds	Generation Disclosure Rules	Proportion of Renewable Energy
Alabama					2.7
Alaska					.1
Arizona	X			X	.0
Arkansas		X			3.4
California	X	X	X	X	12.4
Colorado	X	X		X	.5
Connecticut	X	X	X	X	4.6
Delaware		X	X	X	.0
Florida				X	2.7
Georgia		X			2.6
Hawaii	X	X			6.3
Idaho					5.3
Illinois	X		X	X	.5
Indiana		X			.1
Iowa	X	X		X	2.7
Kansas					.8
Kentucky		X			.5
Louisiana		X			2.8
Maine	X	X	X	X	20.4
Maryland	X	X		X	1.6
Massachusetts	X	X	X	X	4.3
Michigan				X	2.4
Minnesota	X	X	X	X	3.7
Mississippi					3.4
Missouri					.2
Montana		X	X	X	.2
Nebraska					.3
Nevada	X	X			3.4
New Hampshire		X			4.0
New Jersey	X	X	X	X	2.3
New Mexico	X	X			3.3
New York	X	X	X	X	2.0
North Carolina					1.5
North Dakota		X			.7
Ohio		X	X	X	.3
Oklahoma		X			1.4
Oregon		X	X	X	2.3
Pennsylvania	X	X	X	X	1.4
Rhode Island	X		X	X	2.1
South Carolina					1.9
South Dakota					2.1
Tennessee					.6
Texas	X	X		X	1.1
Utah		X			.5
Vermont		X		X	7.4
Virginia		X		X	3.7
Washington		X		X	2.3
West Virginia					.2
Wisconsin	X	X	X		2.1
Wyoming		X			1.4

An “X” indicates that the state in the first column had that policy in effect as of 2005.
Adapted from Vachon and Menz (2006)

u_{ij}^{1} is an index given by

$$u_{ij}^{1} = \alpha + \beta X + \gamma \cdot CI_{i}, \qquad (3)$$

where *X* represents the various social, political, and demographic variables, including renewable potential, which represents each state's potential to generate renewable energy. This variable is obtained from the Union of Concerned Scientists and reflects the technical potential of a state to generate renewable electricity. Economic factors such as transmission costs are not factored into renewable potential. This data was previously used by Okazaki (2006). *CI* represents the constituent interest variables derived in the state level analysis above. Median income is drawn from the 2000 Census. Baseline emissions from the Haiku model are included as a proxy for economic interest in polluting industries. State level constituent ideology is measured by the Cook partisan voting index (PVI), which is based on the state's voting history in the last two presidential elections.[17] State political ideology is measured by party control of state government, as evidenced by the party affiliation of the state governor. State adoption of green electricity policies is adapted from Vachon and Menz (2006). Table 14 presents summary statistics of these data, which represent a cross-section for the year 2005.

Congressional Voting Analysis

If Congress responds to differences in environmental damages faced by their constituencies, the estimate on what level of "tax" each state would prefer the whole country to have should predict how legislators from each state vote on national air quality

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[17] The Cook PVI score consists of a letter (D or R) and a number. The D signifies that the state leans toward the Democratic party, while an R implies Republican leanings. To simplify the analysis, I transform all D PVI scores into negative numbers so that the variable represents a consistent scale.

Table 14—Summary Statistics for Green Electricity Analysis

Variable	**Description**	**Mean**	**Standard Deviation**
Statetax	State's efficient tax level (in hundreds of dollars)	5.890404	7.947005
Stpctg	State's efficient abatement level as a multiple of abatement at 2008 SO2 trading price	1.517638	2.268343
Statecorn	State production of corn (in 100,000's of bushels)	11.36674	21.78749
Renewpot	State's renewable potential (multiple of current energy use)	18.14911	41.29916
Baseline	Baseline emissions from Haiku (in 100,000's of tons of SO_2)	4.226192	5.660708
PVIScore	State's Cook partisan voting index (higher values indicate a more conservative base)	1.533333	8.423431
PctUrban	Percent of population living in urban areas	0.718179	0.141383
PctBlack	Percent of population that is African-American	0.106757	0.096211
PctAsian	Percent of population that is Asian	0.021222	0.019202
PctHisp	Percent of population that is Hispanic	0.079779	0.09258
PctOver65	Percent of population that is older than 65	0.126488	0.0167
Medincome	Median income (in 10,000's of dollars)	4.103662	0.630447
PctGas	Percentage of housing units that use natural gas in home heating	0.529682	0.182024
PctElec	Percentage of housing units that use electricity in home heating	0.252633	0.157751
Popdens	Population density (people per square mile)	173.7924	227.4489
DemConU	Percentage of Democratic control in the upper house of the state legislature	0.512567	0.138428
DemConL	Percentage of Democratic control in the lower house of the state legislature	0.528922	0.131912
Govdem	=1 if state has a Democratic governor, 0 otherwise	0.577778	0.495291

legislation. The central hypothesis is that legislators with a higher modeled national uniform tax preference are more likely to vote in favor of more stringent national air standards. This case differs from the previous because it depends on interstate spillovers. A state like New Hampshire may have little reason to regulate its own pollution (see Table 7), yet its federal representatives may have good reasons to regulate upwind states.

Mehmood and Zwang (2001) find that party affiliation, geographic location, and percentage of urban population are important factors in explaining congressional voting. Therefore, we control for these factors in our analysis. Anderson (2007) finds a link between congressional voting and environmental interest group membership in the district. Coates and Munger (1995) find that a legislator's ideology is much more important in his or her voting pattern than constituent interest, while constituent interest can become an important factor during re-election years. However, in these previous studies, constituent interest is measured by variables that reflect different aspects of constituent interest. My variables measure the potential damages from pollution, and are free from ideological considerations. My analysis provides a new and unique measure of constituent interest based on economic estimates of costs and benefits and is better suited to this analysis. In particular, we use the level of federal regulation that maximizes net benefits for each state.

Data and methodology

One important decision is which votes are to be included in the analysis. This decision is inherently subjective. To avoid subjectivity in our decision, we take those votes that are deemed of environmental significance by the League of Conservation Voters (LCV), a prominent environmental group. This is a common metric used in previous studies (e.g., Anderson 2007). Using LCV data from 2003-3007, we observe 65 different roll-call votes in the House of Representatives on environmental issues and 51 roll-call votes in the Senate. We then classify these votes according to their subject matter: 27.4% of the votes are about energy, 38.8% about land or resource usage, 13.8% related to air pollution, 6.7% about environmental policy procedure, 5.0% on water issues, 6.9% on environmental funding, and 9.6% in other areas. Note that these percentages do not add to 100% as some bills fall into more than one category. My measure of constituent interest is most relevant for votes involving energy and air pollution, and it is expected that the tax variable would have a greater effect on these categories than on others, such as water. Therefore, we also create interaction terms between the tax variable and each category to split up the effect. This provides a test of the validity of the constituent interest variable.

Since each legislator casts votes on many different bills, the dataset is a panel. However, since representatives and senators may be newly elected (or fail to be reelected) within the time period, the panel is unbalanced. Over the five-year period, we observe 556 different members in the House of Representatives and 112 different members of the Senate. Some representatives and senators cast votes over the full panels, while the minimum number of votes cast is two. For each voting opportunity, we observe one of three outcomes: a vote in favor of the environment, a vote against, or a failure to vote. Since some legislators decide not to vote when they could vote (about 2.6% of the sample), this could lead to sample selection issues. As discussed below, our results are robust to different ways of handling this issue.

A number of variables related to the legislator should be included. We record party affiliation, tenure in Congress, and age from the House of Representatives and Senate web pages. In addition, we obtained a measure of ideology from Poole and Rosenthal (1997). This value is based on an extensive computer model of historical voting; lower values represent a more liberal member and higher values a more conservative member. In our sample, the lowest value is -1.093 (Sen. Feingold, D-WI), while the highest value is 1.364 (Rep. Paul, R-TX).

In addition to representative-specific variables, we must include variables significant at the state and local level. At the state level, we include state corn production as a proxy for interest in biofuels. In addition, we include renewable energy potential as in Okazaki (2006).

At the local level, we have a variety of data broken down by Congressional district or state. Variables at the local level include median income, ethnic variables, age, unemployment, and population density. These variables are obtained from the 2000 Census. We also include a measure of the ideology of the district, as measured by the Cook partisan voting index (PVI). Summary statistics for the House of Representatives voting data is given in Table 15. Summary statistics for the Senate voting data is given in Table 16.

It is possible that some of the effect of the level of federal “tax” preferred is captured indirectly through the party affiliation variable, Democrat. States that are more susceptible to emissions damages may be more likely to elect Democratic leaders who will vote in favor of environmental legislation. However, if this is the case, then the results will be biased toward zero, so that any effect found carries a stronger conclusion.

Table 15—Summary Statistics for House of Representatives Voting Analysis

Variable	**Description**	**Mean**	**Standard Deviation**
voteres	=1 if vote for environmental policy, 0 otherwise	0.4875	0.4999
Ordvoteres	=2 if vote for environmental policy, 1 if no vote recorded, 0 otherwise	0.9805	0.9869
Voted	=1 if a vote was recorded, 0 otherwise	0.9743	0.1584
Democrat	=1 if a Representative is a Democrat	0.4747	0.4994
Statecorn	State corn production (in bushels)	1,134,611	2,197,781
Renewpot	State's renewable potential (% of current energy use)	487.98	1,582.0
Tax	State's most beneficial uniform national tax	3,471.1	1,955.4
Energy	=1 if vote is classified as Energy-related, 0 otherwise	0.26145	0.43943
Landres	=1 if vote is classified as land use or resource-related, 0 otherwise		
Pollution	=1 if vote is related to air pollution		
Envpolpro	=1 if vote is related to environmental policy procedures		
Water	=1 if vote is classified as water-related		
Envfund	=1 if vote is related to environmental funding		
Other	=1 if vote does not fit into any one of the above categories		
Dnomscore	Legislator ideology as measured by the D-Nominate score (higher values are more conservative)	0.06916	0.50403
Pviscore	Ideology of the Congressional District	-1.4565	14.233
Pcturban	Percent of population that lives in urban areas	0.78964	0.19814
Pctblck	Percent of the population that is black	0.12094	0.14883
Pctasian	Percent of the population that is Asian	0.036302	0.05314
Pcthisp	Percent of the population that is Hispanic	0.12536	0.16411
Pctmale	Percent of the population that is male	0.49009	0.010103
Pctover65	Percent of the population that is over 65	0.12444	0.031809
Unemploy	Congressional District's unemployment rate	0.058618	0.023330
Medincome	Median income in the Congressional district	43,405	10,916
Pctgas	Percent of housing units heated by natural gas, bottled gas, or kerosene	0.57985	0.22851
Pctoil	Percent of housing units heated by heating oil	0.088790	0.15060
Popdens	Population density (people per square mile)	2,392.9	6844.1

Table 16—Summary Statistics for Senate Voting Analysis

Variable	**Description**	**Mean**	**Standard Deviation**
voteres	=1 if vote for environmental policy, 0 otherwise	0.4384358	0.4962508
Ordvoteres	=2 if vote for environmental policy, 1 if no vote recorded, 0 otherwise	0.8799564	0.9801757
Voted	=1 if a vote was recorded, 0 otherwise	0.9749455	0.1563076
Democrat	=1 if a Senator is a Democrat	0.4653595	0.4988529
Statecorn	State corn production (in bushels)	1,136,674	2,172,925
Renewpot	State's renewable potential (% of current energy use)	1,814.911	4,118.877
Tax	State's most beneficial uniform national tax	3,015.556	1,908.663
Energy	=1 if vote is classified as Energy-related, 0 otherwise	0.3529412	0.4779367
Landres	=1 if vote is classified as land use or resource-related, 0 otherwise	0.3137255	0.4640568
Pollution	=1 if vote is related to air pollution	0.1372549	0.3441537
Envpolpro	=1 if vote is related to environmental policy procedures	0.0980392	0.2974001
Water	=1 if vote is classified as water-related	0.0784314	0.02688785
Envfund	=1 if vote is related to environmental funding	0.1176471	0.3222248
Other	=1 if vote does not fit into any one of the above categories	0.2156863	0.4113424
Dnomscore	Legislator ideology as measured by the D-Nominate score (higher values are more conservative)	0.0316806	0.4562987
Pviscore	Ideology of the state	1.533333	8.400915
Pcturban	Percent of population that lives in urban areas	0.718179	0.1410048
Pctblck	Percent of the population that is black	0.106757	0.0959543
Pctasian	Percent of the population that is Asian	0.0212218	0.0191511
Pcthisp	Percent of the population that is Hispanic	0.797791	0.0923322
Pctmale	Percent of the population that is male	0.4907226	0.0065128
Pctover65	Percent of the population that is over 65	0.1264884	0.0166551
Medincome	Median income in the state	41,036.62	6,287.621
Pctgas	Percent of housing units heated by natural gas, bottled gas, or kerosene	0.529682	0.1815374
Pctoil	Percent of housing units heated by heating oil	0.0905853	0.1478487
Popdens	Population density (people per square mile)	173.7924	226.841

Several approaches can be taken to analyze the data. The first method used is random and fixed effects logit and probit models.

The probability of Representative *j* voting "pro-environmental" on issue *i* is

$$p_{ij} = \frac{e^{u_{ij}^{1}}}{e^{u_{ij}^{1}} + e^{u_{ij}^{0}}} \tag{4}$$

where u_{ij}^{1} is the structural component of utility of voting "yes" for vote *i* by Representative *j* and u_{ij}^{0} is the utility of voting "no." True utility is equal to $v_{ij} = u_{ij} + \varepsilon_{ij}$, where ε_{ij} is an iid logit error. Normalizing $u_{ij}^{0} = 0$, we have

$$p_{ij} = \frac{e^{u_{ij}^{1}}}{1 + e^{u_{ij}^{1}}}. \tag{5}$$

u_{ij}^{1} can be decomposed as

$$u_{ij}^{1} = \alpha_{j} + \beta \cdot x_{ij} + \gamma Tax_{j}, \tag{6}$$

where α_{j} is a random effect for the Representative in question. Separate regressions are run for each category of House votes.

However, voting for or against each bill does not exhaust the options available to the legislators. Some choose not to vote. If ignored, this could lead to a potential sample selection bias. There are two main ways to overcome this issue. First, the sample selection issue can be addressed directly similar to Heckman (1979) by estimating a two-stage model with a first-stage probit selection equation to determine voting, and a second-stage probit model of vote result. Additional variables affecting the selection equation are legislator age and tenure in the House.

A second way to control for non-voting behavior is to assume an ordered structure to the voting process (as pioneered by Deacon and Shapiro 1975). If a legislator feels strongly enough about a bill, they are more likely to vote in that case. Therefore, non-voting is evidence of near-indifference.[18] Thus, we can structure the model as an ordered response model, with the choice variable, *d*, being represented by

$$d = 0 \text{ if } u_{ij} < \theta_0,\ d = 1 \text{ if } \theta_0 \le u_{ij} \le \theta_1, \text{ and } d = 2 \text{ if } u_{ij} > \theta_1. \qquad (7)$$

Thus, large deviations in latent utility produce pro-environmental and anti-environmental voting while mid-range utility represents near-indifference and non-voting. Thus, we estimate ordered probit and ordered logit models, as well as non-selection models.

Results

Green electricity policy adoption

Table 17 presents the results of the green electricity policy adoption analysis. The results show that constituent interest, as measured by the state's efficient level of abatement as a percentage of abatement under the current sulfur dioxide trading price, is an important factor in the adoption of green electricity policies. The t-statistics in both the logit and probit model are significant at the 5% level. The signs are consistent with the hypothesis that constituent interest is a factor in the determination of these policies. In the case of the logit model with the state "tax" variable as the variable of interest, an increase in the optimal "tax" of $100 causes the probability of policy adoption to rise by 2.5% (holding all other variables at the mean).

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[18] This logic is similar to the analysis of demand in Bergstrom, Rubinfeld, and Shapiro (1982).

Table 17—Results for Green Electricity Analysis

	Model 1	Model 2	Model 3	Model 4
Variable	Logit	Logit	Probit	Probit
StateCorn	0.0292746 (1.42)	0.0289966 (1.57)	0.0126537 (1.29)	0.0134111 (1.42)
Renewpot	0.0130233 (1.20)	0.0130065 (1.28)	0.00551315 (0.99)	0.00600965 (1.10)
Baseline	-0.0961424 (-1.58)	-0.10577 (-1.80)*	-0.0627964 (-2.02)**	-0.0679323 (-2.17)**
Pviscore	-0.00409728 (-0.06)	0.0486498 (0.65)	-0.00764108 (-0.20)	0.0221155 (0.55)
pcturban	14.1867 (1.61)	12.5983 (1.56)	6.56759 (1.57)	6.08128 (1.49)
pctblack	-7.75285 (-1.54)	-4.45032 (-0.94)	-4.74165 (-1.71)*	-2.85676 (-1.09)
pctasian	-14.6682 (-0.30)	-23.617 (-0.48)	-3.37995 (-0.13)	-10.317 (-0.39)
pcthisp	-2.12472 (-0.40)	1.64733 (0.33)	-0.957235 (-0.35)	1.084 (0.40)
pctover65	-32.0349 (-1.19)	-11.2267 (-0.42)	-17.0489 (-1.17)	-5.57602 (-0.38)
medincome	-1.8484 (-1.60)	-1.0051 (-0.93)	-0.943629 (-1.51)	-0.498778 (-0.82)
pctgas	-6.57793 (-1.63)	-6.67739 (-1.78)*	-3.12381 (-1.59)	-3.31921 (-1.73)*
pctelec	-10.9522 (-2.78)***	-11.3648 (-3.12)***	-5.68476 (-2.92)***	-6.13543 (-3.23)***
popdens	0.00491595 (0.95)	0.00416562 (0.84)	0.00316137 (1.16)	0.00262724 (0.97)
demconu	1.26597 (0.50)	1.61093 (0.62)	0.565306 (0.38)	0.832319 (0.55)
demconl	6.4502 (1.24)	7.29599 (1.38)	3.11329 (1.16)	3.68575 (1.32)
govdem	0.689655 (1.06)	0.744432 (1.19)	0.320156 (0.97)	0.365985 (1.12)
RPS Fixed Eff.[19]	1.679364	-4.357587	1.398153	-1.164009
NMRFixed Eff.	3.9805	-2.02507	2.689621	-0.794682
PBF Fixed Eff.	1.09288	-4.94799	1.057797	-2.452328
GDR Fixed Eff.	2.52919	-3.49793	1.85845	-1.63986
State Tax	0.286731 (2.36)**		0.158642 (2.44)**	
StPctg		1.25636 (2.53)**		0.729288 (2.67)***
N	180	180	180	180

t-statistics based on robust standard errors in parentheses
***= significant at the 1% level
** = significant at the 5% level
* = significant at the 10% level

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[19] Models with random effects present similar results. Magnitudes are similar, and State Tax and StPctg are always significant at the 5% level.

In addition, the policy-specific fixed effects accurately match the frequency with which these policies are adopted. Net metering rules are the most popular, followed by generation disclosure rules, renewable portfolio standards, and public benefit funds. We suspect that the relative adoption is due to the political attractiveness of the various policies. Net metering transfers power to consumers, even though many will never use it; lobbyists for the power companies probably do not complain too much since not many consumers take advantage of the rule. Generation disclosure rules impose little in the way of excess costs, but rather encourage the spread of information. Renewable portfolio standards start to impose extra costs on the generators, and are likely to be met with resistance by lobbyists. Lastly, public benefit funds impose taxes on electricity, which is often not politically favorable. Variables that capture these cost effects on producers and consumers would probably reduce the policy-specific fixed effects to be the same, but that is not the focus of this analysis.

Political ideology, both in the government (measured by whether the governor of the state is a Democrat), and of the state's citizenry (measured by the state's Cook partisan voting index), is also important. In both cases, the effect is statistically significant and of the expected sign. States with Democratic governors are more likely to adopt green electricity policies, and states with a higher PVI score (indicating a more conservative ideology) are less likely to adopt. Economic interests, especially the baseline emissions, also prove important. A state with higher baseline emissions is less likely to mandate any of these policies, presumably because they have a greater interest in polluting industries. State corn production is statistically insignificant, but of the expected sign. Higher production of corn indicates a greater potential to gain from the increased production of biofuels, and a positive sign would reflect this consideration. Renewable potential, while also statistically insignificant, is always of the correct sign, assuming that states with a higher potential for renewable energy generation are more likely to adopt these policies.

One interesting fact that bears mentioning is the case of North Carolina. North Carolina does not have any of these four policies in place. Rather, they have chosen to choose a different policy option through the Clean Smokestacks rule discussed above. In this case, one might expect the residuals for North Carolina's observations to predict adoption of the policies. However, the residuals are never large enough to predict a positive outcome for any of the four policies. This suggests that the Clean Smokestacks legislation was probably prompted by different factors than those that motivate adoption of the other green electricity policies.

These results are robust to the inclusion of other demographic variables, such as race, urban population and other factors. These results are omitted, but are available from the author upon request.

Congressional voting analysis

Table 18 presents the results of the panel logit analysis of the House of Representatives voting data, while Table 19 presents the same results for the Senate data. The columns represent each of the categories in which the votes are classified. Separate regressions are estimated for each category in order to allow all coefficients to vary across categories. This arrangement presents several important observations. First, constituent interest as measured by the tax variable is significant in all but one category (environmental funding). However, the coefficient is greatest for the categories of energy

Table 18—Results for House of Representatives Voting Analysis: Panel Logit Results

	Category of Vote						
	Energy	Air Pollution	Land and Resources	Env. Policy	Water	Env. Funding	Other
	N=7164	N=3765	N=10897	N=1672	N=1248	N=1642	N=2123
Variable							
d2003	-2.491247 (-14.65)***	-3.764443 (-13.34)***	-2.023152 (-13.79)***	-	-	-	-
d2004	-2.05996 (-12.49)***	-3.971373 (-12.74)***	-2.028934 (-12.66)***	-0.146011 (-0.45)	-	0.583340 (2.24)**	-
d2005	-1.68966 (-13.27)***	-3.7959 (-14.25)***	-2.365491 (-14.66)***	-0.839242 (-2.26)**	-1.194702 (-6.89)***		-0.130354 (-0.75)
d2006	-1.471825 (-10.97)***	-2..770571 (-9.45)***	-2.459075 (-14.73)***	-	0.201229 (1.29)		-0.004349 (-0.03)
democrat	-0.735086 (-1.48)	-2.034854 (-3.25)***	0.602696 (1.44)	-0.280352 (-0.30)	0.662606 (1.52)	2.906729 (4.92)***	-1.794245 (-4.20)***
renewpot	-0.000087 (-1.71)*	-0.000061 (-1.12)	-6.39e-6 (-0.14)	6.09e-6 (0.11)	-0.000098 (-1.67)*	-0.000028 (-0.44)	-1.26e-6 (-0.04)
dnomscore	-5.726503 (-9.30)***	-8.458938 (-10.13)***	-4.718558 (-9.05)***	-8.925457 (-6.19)***	-0.560864 (-1.12)	-3.398792 (-4.48)***	-5.691954 (-9.78)***
pviscore	-0.025798 (-2.23)**	-0.012504 (-0.92)	-0.055408 (-4.88)***	-0.013429 (-0.73)	0.001006 (0.11)	-0.046902 (-2.67)***	-0.007192 (-0.75)
pcturban	1.12493 (2.20)**	0.864218 (1.48)	1.486187 (3.11)***	1.240593 (1.69)*	1.188531 (2.60)***	-0.601216 (-1.01)	0.636714 (1.71)*
tax	0.0002707 (5.49)***	0.0002723 (4.77)***	0.000164 (3.46)***	0.0002047 (2.36)**	0.0001316 (3.23)***	0.0000397 (0.68)	0.0001335 (3.72)***

t-statistics in parentheses
*** = significant at the 1% level
** = significant at the 5% level
* = significant at the 10% level

Table 19—Results for Senate Voting Analysis: Panel Logit Results

	Category of Vote						
	Energy	Air Pollution	Land and Resources	Env. Policy	Water	Env. Funding	Other
	N=1582	N=613	N=1402	N=439	N=354	N=523	N=967
Variable							
d2004	-0.2306538 (-0.64)	-	0.5577316 (1.48)	-	-	0.737274 (1.04)	-0.3276303 (-0.83)
d2005	-0.283881 (-1.50)	1.763458 (4.48)***	0.8643842 (4.12)***	-	0.9057079 (2.94)***	1.066294 (1.18)	0.5406193 (1.71)*
d2006	-1.130363 (-4.42)***	-	1.052886 (2.71)***	1.408014 (4.39)***	-	1.824839 (2.01)**	2.630463 (5.94)***
democrat	0.4139401 (0.54)	0.8897988 (0.65)	0.3507242 (0.51)	3.481172 (3.61)***	0.1107816 (0.14)	-0.8462275 (-0.66)	-0.2188183 (-0.33)
renewpot	2.91e-6 (0.07)	-0.0000404 (-0.63)	0.000069 (2.10)**	8.35e-6 (0.17)	-0.0000156 (-0.39)	0.0000315 (0.35)	0.0000971 (2.33)**
dnomscore	-3.605528 (-3.72)***	-5.783033 (-3.11)***	-4.759212 (-5.07)***	0.4386523 (0.39)	-2.284918 (-2.28)**	-12.99794 (-5.10)***	-7.61877 (-7.35)***
pviscore	-0.0914559 (-2.56)***	-0.082475 (-1.24)	-0.0977908 (-3.05)***	-0.140676 (-2.77)***	-0.0283806 (-0.93)	0.0417753 (0.77)	-0.0316005 (-1.16)
pcturban	0.7686714 (0.66)	-0.0806484 (-0.04)	-0.0233779 (-0.02)	-1.130783 (-0.79)	2.134223 (1.88)*	1.842461 (0.82)	-1.670458 (-1.63)
tax	0.0001943 (1.97)**	0.0004983 (2.72)***	-0.0000702 (-0.82)	0.0000661 (0.54)	-0.0000445 (-0.46)	0.0003374 (1.75)*	-0.0000804 (-0.87)

t-statistics in parentheses
*** = significant at the 1% level
** = significant at the 5% level
* = significant at the 10% level

and air pollution, the two categories where theory predicts the biggest response. In the case of energy-related bills, the coefficient is 0.0002707 (House of Representatives), which is slightly lower than the coefficient for air pollution bills, which is 0.0002723. In addition, these categories show the highest t-statistics. The effect by category ranks from highest effect to lowest effect as follows: air pollution, energy, environmental policy procedure, land and resource policy, other policies, water policy, and environmental funding. There is still a positive and significant response in the categories that are not directly related to our measure of constituent interest, suggesting that our measure is a reasonable proxy for interest in the other categories. The results in the Senate confirm the House of Representatives results, showing the highest coefficient estimate for air pollution votes, with only energy and environmental funding showing any other significance. These results confirm that although our variable can be a suitable proxy in a number of categories, the most adequate measures of constituent interest must be properly targeted to the policies in question.

Political variables, like the ideology of the politician (their D-Nominate score) and ideology of the district (Cook PVI), are also strongly significant, suggesting that politicians determine their voting behavior through a combination of constituent interest, their own ideology, and the ideology of their district. Politicians with a higher D-Nominate score are more conservative, and the negative coefficient on this variable reflects that conservatives tend not to favor environmental policies. The Cook PVI score, which represents district ideology, is also positively related to with how conservative the district is. Thus, the negative coefficient is expected. After conditioning on ideology, the effect of party affiliation of the Representative is more sporadic. This is consistent with the findings of Anderson (2007). Party affiliation is significant in only three cases: air pollution, environmental funding, and other. In the case of environmental funding, it is significantly positive and of great magnitude. This is consistent with the fiscally liberal ideals of much of the Democratic Party, and when combined with a low value for the politician's ideology suggests that party affiliation is more important than ideology in this case. The coefficient in the case of air pollution voting is negative and significant, implying that Democrats, *ceteris paribus*, are less likely to vote for these propositions. However, the coefficient on Representative ideology is very high in this category, and the collinearity between these two variables might be leading to the seemingly odd result. Omitting ideology from the regression yields a positive and significant coefficient on Democratic affiliation.

More parsimonious regressions (with just political party, ideology, and constituent interest) as well as models with more variables (such as race, sex, unemployment, percentage of urban population, Representative age and tenure, and household heating fuel choice) were estimated, with little change in the results. The tax variable continues to be most important for the energy and air pollution categories, as predicted. Pooled models with interaction terms for the categories also generated similar results with fixed or random effects, as did models with no panel effects. The ordered logit and ordered probit model results are also very similar to the panel logit results. In addition, the models with selection equations showed test statistics that failed to reject the null hypothesis that there was no sample selection problem (in all but one category, land and resource policy, which is not one of the categories of interest).[20]

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[20] These results are omitted, but are available from the author upon request.

Conclusions

This paper has derived new measures of constituent interest in the context of air pollution. This measure is obtained from a model of the U.S. electricity sector and an integrated assessment model of air pollution transfer and valuation. These measures of constituent interest are used in two models: state adoption of green electricity policies and Congressional voting on environmental issues.

In each case, constituent interest is shown to be an important factor in the determination of the choices. In contrast to previous literature, we find that both constituent interest and political ideology are significant. In the Congressional voting analysis, our results show the most significant effects in the categories of energy and air pollution. These are the categories most directly related to our constituent interest variable. This suggests that constituent interest cannot be measured by a broad, categorical measure, but should be tailored to the situation at hand.

Future studies that attempt to disentangle the effects of constituent interest, ideology, and demographics should carefully define a measure of constituent interest that is appropriate for the situation at hand. This paper has shown that measures that the traditional measures are not adequate and might understate the effect of constituent interest. Past studies that have not found a constituent interest effect may need to be reevaluated with a more appropriate measure in order to determine if constituent interest is a valid concern in the determination of policy.

CHAPTER 4: STRATEGIC INTERACTION AMONG STATES

The fact that emissions of harmful pollutants often cross state lines creates a situation where states may engage in strategic interaction. This possibility is greatest for air pollution since air pollutants can often travel long distances before causing damage. If California releases an extra ton of sulfur dioxide, it is possible that other states will react in a number of different ways. First of all, other states may emit more, feeling that if California emits more, it would be politically acceptable if they do as well. Alternatively, downwind states may decrease their emissions to reduce damages, compensating for California's emissions. Thirdly, if California's emissions have increased due to some loosening of environmental regulation, other states may also lower their stringency in an effort to compete for mobile capital. All of these are examples of strategic interaction in the specific area of air pollution. This chapter explains which of these situations is the main driver of strategic interaction in environmental stringency. We find that, in general, tax competition explains a larger amount of competition than spillover competition. Furthermore, we show that higher marginal damages from pollution limit competitive behavior among states.

Many empirical papers have found evidence that governments compete strategically in the formation of fiscal policies. There are two basic models that generate these results: the spillover model and the resource-flow model (Brueckner 2003). While these models generate the same results, they are motivated by different assumptions. In the spillover model, the assumption is that governments strategically respond to other governments' policies because their policies spill over from one jurisdiction to another. For example, one city might spend less on park services if the adjacent city has already invested in parks. The park benefits spill over because they are available to both cities. Alternatively, governments might consider other governments' policies because of competition to have the "best" policies. Similarly, they might use other governments' policies as a benchmark on which they base their own policies. This type of competition is called spillover competition, in which yardstick competition is a specific case with political motivations.

In contrast, the resource-flow model assumes that the strategic behavior occurs due to competition over a fixed supply of resources. A good example of this behavior is state competition in attracting industries to locate in-state (Tasto 2007). One way that states accomplish this is by reducing taxes on firms, thus giving rise to the term, "tax competition."

In the cases we have mentioned above, the source of the strategic interaction is fairly clear. However, in many cases, both spillover competition and tax competition might be driving the results. The stringency of environmental regulation is one of these cases. Elements of both spillover models and resource-flow models are present in the case of strategic interaction in environmental stringency as described in the introductory paragraph to this chapter.

Fredrikkson and Millimet (2002) find evidence that states react strategically to other states' environmental stringency, but they are unable to disentangle the effects of spillover and tax competition. We propose a method for distinguishing between the two types of competition. All strategic interaction models use weighting matrices to model the pattern of interaction among states. We exploit this aspect of the models by specifying two different weighting matrices: one that corresponds to spillovers and one that represents tax competition. Previous papers (e.g., Fredriksson and Millimet 2002) state that the ideal weighting matrix for spillover competition would account for state-to-state pollution flows. We construct this weighting matrix using TAF's source-receptor matrix. Since tax competition focuses on competition between states for mobile capital, it is presumed that this competition will occur between states with similar industrial structure. Thus, we use a weighting matrix based on Crone's (1999) classification of states into regions defined over industrial composition. We estimate the model with each weighting matrix and compare the results with those resulting from the more traditional contiguity-based weighting matrix.

Secondly, we examine whether increased damage from pollution changes a state's strategic response to other state's policies. If a state is subject to higher marginal damages from pollution, then that state should be less likely to engage in a race-to-the-bottom. However, higher damages would be unlikely to change a state's behavior in upward competition. We use the within-state marginal damages estimated in Chapter 2 interacted with the strategic response to test for these effects.

Section 2 reviews the literature on these models and previous attempts to disentangle the two forms of competition. Section 3 presents the econometric model used to test the hypothesis. Section 4 discusses the methodology of the two tests and the data used in the analysis. Section 5 presents the results and Section 6 concludes.

Literature Review

The seminal paper in the empirical literature on strategic interactions in policy-making is Case, Hines, and Rosen (1993). They test whether states' budgets are influenced by their "neighbors," which is not necessarily defined by contiguity (which states are directly adjacent), but may also be determined by varying degrees of similarity. The authors set up a theoretical model of strategic policy-making, which supports their assertion that states respond to the policies of other states.

Case, Hines, and Rosen specify three options for the weighting matrix used to determine which other states are a state's "neighbors": matrices based on contiguity, similar income, and similar racial composition. They estimate the model with each weighting matrix, and note that the highest log-likelihood reflects the best weighting matrix. They find that the log-likelihood is maximized when using the weighting matrix based on racial composition. In addition, they perform tests using linear combinations of the matrices and find that the racial composition weighting matrix is dominant. All of the weighting matrices show evidence of strategic interaction. The authors, in an attempt to deflect possible criticism that there is some inherent trick to the weighting matrix process that generates positive results, construct an absurd weighting matrix and run the model. No strategic interaction is found. They also break down state spending by categories, but omit the category on environmental spending.

The class of model specified in Case, Hines, and Rosen (1993) is referred to as a "spillover model" by Brueckner (2003). Brueckner specifies two kinds of strategic interaction models: the spillover model, and the resource-flow model. Although based on different theoretical models, both models result in reaction functions that are estimated identically. However, the spillover model can explain spillover and yardstick competition, while resource-flow models focus on tax competition.

Other examples of spillover-type models include Murdoch, Rahmatian, and Thayer (1993), who examine the case of spillovers in city-level recreation expenditures (if one city invests in particularly attractive parks, nearby cities may attempt to free-ride). Kelejian and Robinson (1993) test a similar situation with spillovers in county-level police expenditures. Environmental spillover models also fall into this category (Murdoch, Sandler, and Sargent 1997; Fredriksson and Millimet 2002). Besley and Case (1995) present a model directly based on yardstick competition, noting that constituents may look at the taxes and expenditures of nearby jurisdictions to determine the efficacy of their own government when it comes time for reelection. Bivand and Szymanski (1997; 2000) estimate reaction functions for local garbage collection costs in Britain.

Resource-flow models generate reaction functions based on the assumption that many jurisdictions are competing for a fixed amount of mobile capital. In order to attract capital, the jurisdictions lower their taxes, reduce environmental stringency, or otherwise compete to make their jurisdiction more appealing to the mobile capital. The standard theoretical papers on environmental federalism fit into this category of models (Oates and Schwab 1988; Wellisch 1995; Markusen, Morey, and Olewiler 1995; Levinson 1997; Kunce and Shogren 2002, 2005, 2007; Glazer 1999; Djikstra 2003; Kunce 2004; Roelfsema 2007). Additional resource-flow models (tax competition models) include Brett and Pinkse (2000), who focus on property tax competition; Buettner (2001), who looks at local business taxes in Germany; and Hayashi and Boadway (2001), who look at provincial corporate income taxes in Canada. In addition, country analyses of local tax choices have been conducted for the U.S., Belgium, and the U.K. by Ladd (1992), Heyndels and Vuchelen (1998), and Revelli (2001, 2002) respectively.

Since both the spillover model and the resource-flow model (Brueckner 2003) generate reaction functions, it is possible that both tax competition and spillover competition are in effect. One weakness of all of these papers is that they are unable to distinguish between the two effects. Some papers have attempted to reinforce the results they obtained by estimating some of the structural equations from the theoretical models that generate the reaction function (Besley and Case 1995; Brett and Pinkse 2000). However, these papers only highlight why their reason is the effective reason; they do not explicitly model both sources and attempt to disentangle the effects.

Fredriksson and Millimet (2002) analyze whether environmental stringency, as measured by pollution abatement cost per unit of emissions or the Levinson (2001) index of environmental compliance costs, is strategically determined across states. This situation allows for both tax competition and spillover competition. Several important issues arise when considering environmental policy issues in this context. One such issue is the choice of the weighting matrix. Fredriksson and Millimet use a weighting matrix based on population and income, noting that they are important determinants of state emissions of harmful pollutants. However, they note in a footnote that the ideal weighting matrix in this case would be one that assigned weights according to air pollution transfers. For example, a state would weight most highly the states that spill the most pollution into their borders. Their income/population matrix is supposed to proxy for this. However, we have the benefit of having TAF’s source/receptor matrices. We can therefore construct a weighting matrix based on actual pollution transmission.

Fredriksson and Millimet (2002) also estimate the model with asymmetric transmission. Low-stringency states may react to the policies of high-stringency states, but not vice-versa. They also use panel data to determine how long the lag is in the strategic interaction. They find that the lag takes place in two to five years.

Empirical Model

Theoretical models of spillover competition and tax competition abound in the literature beginning with Oates and Schwab (1988). Many of these models predict a “race-to-the-bottom,” while some predict a “race-to-the-top.” However, both classes of models involve strategic interaction.

The interactions are captured in strategic response functions. The standard form for these response functions is

$$E_{it} = X_{it}\beta + \phi\sum_{j=1}^{n} w_{ij}E_{jt} + f_i + h_t + u_{it}\,, \tag{8}$$

where E_{it} represents the stringency of environmental policy of state *i* in year *t*, X_{it} is a vector of demographic, political, and/or social variables, f_i is a state-level fixed effect, h_t is a time dummy, and u_{it} is a random error. Other states’ policies enter the reaction function as a weighted average, where the weights w_{ij} are determined beforehand and are assumed exogenous. The parameter of interest is ϕ: if $\phi = 0$, then there is no evidence of strategic interaction.

Case, Hines, and Rosen (1993) discuss one of the econometric difficulties in estimating these models. Some states’ policies may be correlated due to correlated random shocks. If one state experiences a random shock to their environmental enforcement, due to a change in economic conditions for example, it is likely that their neighbors (whether geographic or socioeconomic) experience similar shocks. Thus, OLS estimation of the reaction functions is likely to show a positive value for ϕ even if all correlation is due to random error. These correlated errors are an example of spatial error dependence (Anselin 1988).

Several other econometric issues have arisen in the literature. First of all, the policy variables are always endogenous by assumption. Since the policies are jointly determined (by strategic interaction), the weighted linear combination of policy variables that appears on the right-hand side of the equation is correlated with the error term. To get around this issue, some papers estimate a reduced-form rearrangement of the model that must be estimated through non-linear maximum likelihood methods (Case, Hines, and Rosen 1993; Murdoch, Rahmatian, and Thayer 1993; Besley and Case 1995; Bivand and Szymanski 1997, 2000; Murdoch, Sandler, and Sargent 1999). In effect, the model is inverted so that the offending variables are removed from the right hand side of the equation.

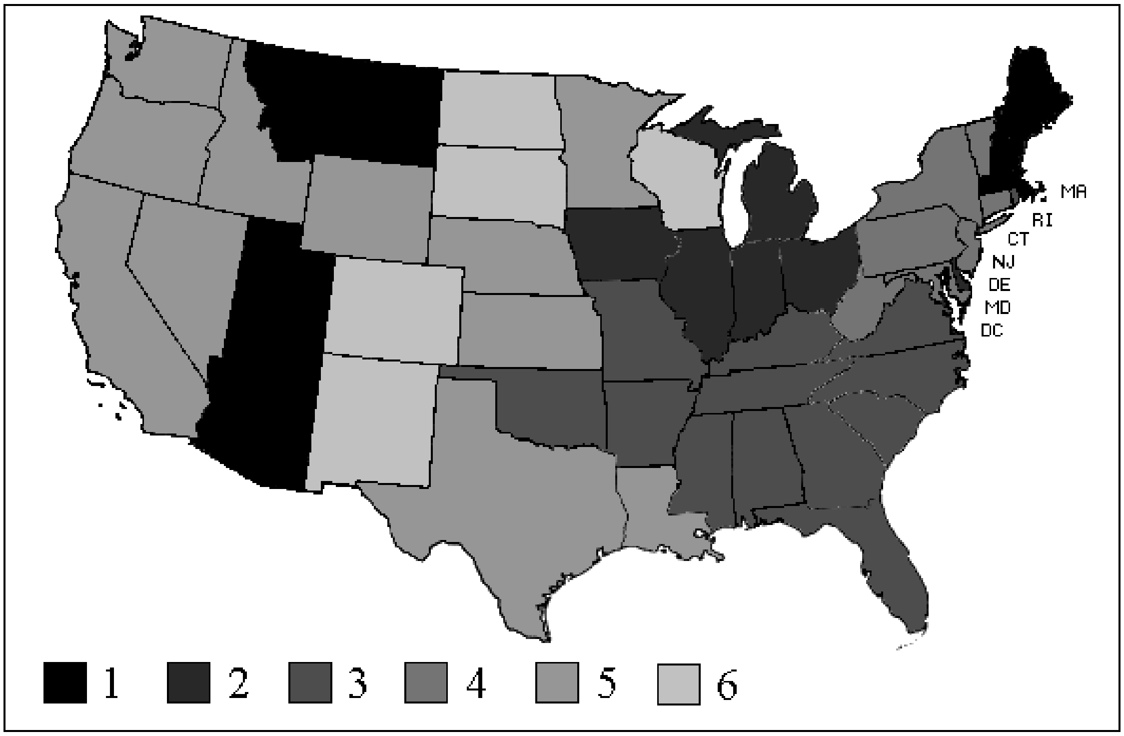
A second method to counteract this endogeneity is to use instrumental variables. The weighted averages of the policies are regressed on the weighted values of the other dependent variables (or a subset of these variables) and the fitted values are then used as instruments. Additionally, one may use higher orders of the weighting matrix to construct additional instruments; for example, W^2X or W^3X. Kelejian and Prucha (1998) show that the instrumental variables approach produces unbiased estimates even in the presence of spatial error dependence. In addition, some papers avoid the endogeneity issue entirely by assuming that policy responses occur with a lag, so that lagged values are used for the weighted average (see, for example, Fredriksson and Millimet 2002).

Another econometric problem may exist if there are correlations between the jurisdictional attributes and the error term. This results if households sort endogenously across communities. For example, households with unobserved tastes for environmental control and with higher income may both sort into stringent control states, biasing the estimated effect of income. Such “Tiebout bias” was first pointed out by Goldstein and Pauly (1981) and is a special case of selection bias. While one option is to instrument for the offending variables, a better option is to use panel data and to estimate jurisdiction level fixed effects. This solution assumes changes in u_{it} are uncorrelated with changes in x_{it}, but accounts for any correlation in levels.

Data and Methodology

In contrast to previous work, this chapter uses distinct weighting matrices to capture both tax competition and spillover competition. For the case of tax competition, we use a weighting matrix based on industry composition as defined in Crone (1999). Crone uses cluster analysis to define regions by economic activity in different sectors. This is ideal for specifying tax competition given the hypothesis that states compete to attract industry. Thus, their main competitors should be those states who have similar industrial structure. Crone regions are shown in Figure 11. Since these regions are not based on

Figure 11—Crone Regions



As defined in Crone (1999).

contiguity or any sort of pollution flows, the reactions among states in a region should be mostly independent of spillover effects.

For the case of spillover competition, we use the source-receptor matrix from the Tracking and Analysis Framework (TAF) model (Bloyd et al. 1996). This matrix is based on actual pollution spillovers from state to state, as defined by the Ambient Source Trajectory Regional Air Pollution (ASTRAP) model, which is based on eleven years of meteorological data and has been validated by historical emissions data. Once the source-receptor matrix is extracted from TAF, it needs to be calibrated with pollution levels. We use EPA data on sulfur dioxide emissions from 1976 to calibrate the weighting matrix. This year is used since it is the year before the range of independent variables, thus avoiding endogeneity of the weighting matrix elements. In the final matrix, each state assigns a weight to a neighbor based on the percentage of its damages that are caused by that neighbor. These weighting matrix specifications are compared to the baseline case, which uses the standard contiguity matrix.

As in Fredriksson and Millimet (2002), our dependent variables are the Levinson index as discussed in Levinson (2001) and unadjusted pollution abatement and control expenditures (PACE) per dollar of state manufacturing output for the years 1977-1994, excluding 1987.[21] The Levinson index compares actual pollution abatement costs to the predicted abatement costs for each state. The predicted abatement costs are based on national abatement expenditure by industry and the individual state’s industrial composition. Thus, a value less than one implies that the state’s abatement costs are lower than what would be expected of a state with that industrial composition, while a

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[21] Levinson Index data is not available for 1987.

Table 20—Summary Statistics for Strategic Interaction

Variable	Definition	Mean	Standard Deviation
Index	Levinson’s index of environmental stringency (2001)	1.022371	0.3589778
PACE	Per capita abatement cost of emissions	0.0076315	0.0162409
Pcinc	Per capita income	\$14,336.95	2,387.18
Pcsq	Per capita income squared	2.11×10^8	7.25×10^7
Pccube	Per capita income cubed	3.20×10^{12}	1.72×10^{12}
Popd	Population density (people per square mile)	59.11087	79.84464
Urb	Percent of population that lives in an urban area	0.673099	0.133909
MD	Within-state marginal damages from sulfur dioxide pollution (as derived in Chapter 2)	589.04	792.98

value greater than one indicates higher than expected costs. The Levinson index can be thought of as PACE per unit of manufacturing scaled to eliminate differences across states due to manufacturing size and composition.

Explanatory variables include state per-capita income, per-capita income squared, per-capita income cubed, population density, and urbanicity. Table 20 displays summary statistics for this data. We use the IV approach to estimate simultaneous models, with weighted values of these variables as the instruments.[22] We also estimate models with 1, 2, and 5-year lags to examine the timing effects.

Additionally, we test for the effects of heterogeneous marginal damages of pollution on competition. States that experience higher marginal damages from air pollution may be less likely to participate in downward competition (the race-to-the-bottom) because

engaging in the “race” would endanger the health of the state’s population. Empirically, we specify the interaction by

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[22] I use 1st, 2nd, and 3rd orders of the weighting matrices to construct instruments.

$$E_{it} = X_{it}\beta + \phi\sum_{j=1}^{n} w_{ij}E_{jt} + \theta \cdot MD_i \cdot \sum_{j=1}^{n} w_{ij}E_{jt} + f_i + h_t + u_{it}, \qquad (9)$$

where MD_i is the state-specific measure of within-state marginal damages as derived in Chapter 2. A value of $\theta > 0$ implies that higher marginal damages induce higher competition, while $\theta < 0$ implies the opposite. We additionally estimate an equation of the form

$$E_{it} = X_{it}\beta + \phi\sum_{j=1}^{n} w_{ij}E_{jt} + \theta_h \cdot High_i \cdot \sum_{j=1}^{n} w_{ij}E_{jt} + \theta_l \cdot Low_i \cdot \sum_{j=1}^{n} w_{ij}E_{jt} + f_i + h_t + u_{it}, \quad (10)$$

where *High* and *Low* are dummy variables indicating if state *i* is one of the fifteen states with the highest marginal damages or the fifteen with the lowest marginal damages. This allows the separation of the strategic interaction by high and low damage states.

Results

Table 21 shows the first attempts to disentangle the effects of spillover and tax competition. This model incorporates interactions without a lag, and uses the IV approach. The parameters reflect the estimated value of ϕ using the specified weighting matrix for the dependent variable shown in the column heading. The coefficients for the Levinson Index estimations show that there is higher strategic interaction among neighbors in Crone regions than there is among neighbors in the TAF specification (although the coefficients are not statistically different). This implies that tax competition may be a larger source of strategic interaction than spillover competition. For the case of PACE, the effects are reversed. The weighting matrix based on pollution flows shows a higher coefficient than the Crone region specification. The difference is likely due to the nature of the two dependent variables. The Levinson Index accounts for

Table 21—Estimates of Strategic Interaction (IV Approach)

Dependent Variable	Variable	Weighting Matrix		
		TAF	Crone	Contiguity
Levinson Index	Strategic Interaction	0.9143286 (17.24)***	0.9710324 (13.34)***	0.8614535 (12.50)***
	Per-Capita Income	0.0000694 (0.30)	-0.0000172 (-0.07)	0.0000168 (0.07)
	Income Squared	-0.9441298 (-0.63)	-0.2795516 (-0.17)	-0.7587819 (-0.48)
	Income Cubed	0.3056314 (0.97)	0.169455 (0.49)	0.2659303 (0.79)
	Population Density	-0.0074925 (-2.31)**	-0.0095825 (-2.70)***	-0.002132 (-0.60)
	Urbanicity	2.192758 (2.73)***	2.620154 (2.95)***	0.9804533 (1.16)
	n	810	810	810
	R^2	0.1055	0.0591	0.2718
PACE	Strategic Interaction	0.8634168 (3.13)***	0.7997279 (3.65)***	0.5991041 (2.94)***
	Per-Capita Income	1.06e-7 (0.01)	0.0000197 (1.33)	-4.39e-6 (-0.31)
	Income Squared	-0.0074593 (-0.08)	-0.1228391 (-1.30)	0.0162494 (0.18)
	Income Cubed	0.0014114 (0.08)	0.0233394 (1.17)	-0.0029777 (-0.16)
	Population Density	-0.0000607 (-0.30)	-0.0000801 (-0.40)	-0.0000978 (-0.49)
	Urbanicity	0.0298987 (0.58)	0.0364387 (0.70)	-0.0088306 (-0.18)
	n	810	810	810
	R^2	0.0944	0.0749	0.0855

t-statistics in parentheses.
All regressions use 1st, 2nd, and 3rd order weighted values of the five independent variables as instruments.

sectoral makeup while PACE does not, and it is likely that this affects the results for the Crone region specification. Both specifications show more interaction than the estimation based on the traditional contiguity matrix, which is expected since contiguity is not expected to predict either form of competition, but would rather pick up other spatial elements.

The first stage results show that the instruments are valid, with R^2 values generally around 0.75 within groups and 0.15 overall.[23] Tests for overidentification show that the instruments do not belong in the second-stage estimation with only a few exceptions, noted at the end of this section. F-tests confirm that the instruments are jointly significant in all specifications.

Tables 22 through 24 shows the model estimated with a one, two, and five year lags on the policy variables, eliminating the need for the IV approach. In the one year lag model (Table 22) none of the coefficients is significant for the Levinson index, while all are negative and significant for PACE. This suggests that PACE, which does not account for sectoral changes, is picking up some time effects that may be industry specific. The Levinson index accounts for these factors. If this is not the case, then the negative coefficients on the lagged variable given the simultaneous results suggests that there is a large positive effect initially, but that the effect is dampened in the next year. The results are very similar for the two and five year lags (Tables 23 and 24), except that the effect seems to fade around the fifth year. This suggests that a distributed lag model may be appropriate in future research.

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[23] Thus, the regressions explain 75% of the variance within each group (state), and 15% of the overall variance (both within and among groups).

Table 22—Estimates of Strategic Interaction (1-Year Lag)

	Independent Variable	
Weighting Matrix	Levinson index	PACE
Contiguity	-0.1047067	-0.2303505
	(-1.43)	(-2.56)**
TAF (Spillover Comp.)	-0.1579506	-1.041319
	(-0.94)	(-4.00)***
Crone (Tax Comp.)	-0.1382775	-0.2234062
	(-1.37)	(-1.79)*
t-statistics in parentheses *: significant at the 10% level **: significant at the 5% level ***: significant at the 1% level		

Table 23—Estimates of Strategic Interaction (2-Year Lag)

	Independent Variable	
Weighting Matrix	Levinson index	PACE
Contiguity	-0.0024783	-0.2747746
	(-0.05)	(-4.42)***
TAF (Spillover Comp.)	-0.0006779	-0.8391646
	(-0.01)	(-4.79)***
Crone (Tax Comp.)	-0.0357744	-0.189523
	(-0.54)	(-1.79)*
t-statistics in parentheses *: significant at the 10% level **: significant at the 5% level ***: significant at the 1% level		

Table 24—Estimates of Strategic Interaction (5-Year Lag)

	Independent Variable	
Weighting Matrix	Levinson index	PACE
Contiguity	0.0029892	-0.0808906
	(0.37)	(-3.74)***
TAF (Spillover Comp.)	0.0081051	-0.1952533
	(0.51)	(-3.73)***
Crone (Tax Comp.)	0.0017595	0.020858
	(0.15)	(0.50)
t-statistics in parentheses *: significant at the 10% level **: significant at the 5% level ***: significant at the 1% level		

Table 25—Effects of Marginal Damages

Dependent Variable	Weighting Scheme	Base Model	MD Interaction		High State/Low State Interaction		
		ϕ	ϕ	Interaction	ϕ	High	Low
Index	TAF-EPA	0.9143286 (17.24)***	0.9384592 (16.63)***	-0.000045 (-1.12)	0.717100 (0.71)	0.850428 (1.16)	3.110782 (4.04)***
Index	Crone	0.9710324 (13.34)***	0.9824279 (13.46)***	-0.000023 (-0.49)	0.172186 (0.36)	-0.30638 (-0.54)	1.403221 (2.50)**
PACE	TAF-EPA	0.8634168 (3.13)***	0.9264182 (3.42)***	-0.000135 (-1.59)	0.112627 (0.31)	0.760936 (3.75)***	0.659730 (3.78)***
PACE	Crone	0.7997279 (3.65)***	0.8904973 (4.14)***	-0.000133 (-1.60)	0.162246 (0.70)	0.803901 (3.85)***	0.785255 (4.12)***
t-statistics in parentheses *: significant at the 10% level **: significant at the 5% level ***: significant at the 1% level							

Table 25 presents the results of the marginal damage effects. The columns show the estimates of the strategic interaction (ϕ), the effects of marginal damages (θ), and a specification using dummy variables for high marginal damage and low marginal damage states. The base model does not include marginal damages and is provided for reference. The MD interaction model, which adds the interaction term with the state-level marginal damages and the policy variable, shows that higher marginal damages lower the level of strategic interaction, although these results are slightly less than significant at the 10% level. F-tests confirm that the marginal damage interaction and the strategic interaction are jointly significant. This is consistent with the hypothesis that states do not engage in as much strategic interaction when the effects may be more harmful to their citizens. In specifications with dummy variables for the fifteen states with the highest marginal damages and the 15 states with the lowest marginal damages, the low damage states compete much more when using the Levinson index. For the case of PACE, both high and low marginal damage states compete more than the mid-range states. This is a potentially troublesome result, but it might be the case that low marginal damage states are competing with downward pressure (race to the bottom) while high marginal damage states are competing upward (race to the top). In both cases, the coefficient would be positive. It will be more illustrative to estimate the model with asymmetric effects to separate upward and downward competition.

Table 26 presents the results of the marginal damage analysis with asymmetric effects. The “up” and “down” subscripts refer to the estimates when a states’ neighbors have higher or lower stringency respectively while the “high” and “low” labels still refer to high or low marginal damages. First of all, the base model with asymmetric transmission shows that, in general, competition is stronger when a states’ neighbors have lower standards than it does. However, there is still upward competition present. When the MD interaction terms are added in the next set of columns, it is shown that the coefficients are typically larger in magnitude and statistically stronger in the case of downward competition than upward competition. This shows that marginal damages limit the race to the bottom, while not affecting the race to the top. When looking at the last set of columns for the high/low state interactions, a number of interesting trends emerge. Low marginal damage states compete downwardly more than high marginal damage states, suggesting that the marginal damages again limit the race to the bottom. Low marginal damage states also compete more in the upward direction, but this is probably due to the fact that high marginal damage states are presumably already in the inelastic area of their marginal cost of abatement curve (see Figure 6 for an example) and therefore face higher costs of upward competition.

Table 26—Effects of Marginal Damages with Asymmetric Transmission

Dependent Variable	Weighting Scheme	Base Model		MD Interaction				High State/Low State Interaction					
		ϕ_{up}	ϕ_{down}	ϕ_{up}	ϕ_{down}	MD_{up}	MD_{down}	ϕ_{up}	ϕ_{down}	$High_{up}$	$High_{down}$	Low_{up}	Low_{down}
Index	TAF-EPA	1.574172 (1.70)*	1.858376 (1.83)*	1.865855 (1.86)*	2.08035 (1.94)*	-0.000541 (-1.24)	-0.000636 (-1.49)	0.654315 (0.65)	0.655276 (0.59)	0.921377 (1.24)	0.946562 (1.18)	2.931972 (3.72)***	3.24818 (4.05)***
Index	Crone	0.649416 (2.10)**	0.626347 (1.55)	0.676649 (1.97)**	0.701024 (1.61)	-0.000057 (-0.21)	-0.000177 (-0.52)	0.128198 (0.26)	0.380990 (0.69)	-0.203053 (-0.36)	-0.823781 (-1.30)	1.487952 (2.63)***	1.090929 (1.77)*
PACE	TAF-EPA	0.563442 (1.78)*	4.142766 (6.63)***	0.723718 (2.23)**	5.460112 (7.31)***	0.0000301 (0.19)	-0.000837 (-2.80)***	-0.003678 (-0.01)	3.120166 (3.30)***	0.649473 (2.24)**	0.479239 (0.51)	0.446529 (1.7)*	1.102142 (1.11)
PACE	Crone	0.643524 (2.96)***	2.991 (2.54)**	0.749778 (3.28)***	3.253464 (2.68)***	-0.000224 (-1.40)	0.000069 (0.12)	-0.222411 (-0.70)	2.686366 (2.00)**	0.650551 (2.04)**	1.563253 (1.46)	1.195834 (3.97)***	-1.15244 (-1.15)

t-statistics in parentheses
*: significant at the 10% level
**: significant at the 5% level
***: significant at the 1% level

However, it must be noted that all of these results should be taken with slight suspicion. As is customary in analyses of this type, a weighting matrix with no theoretical basis was tested to look for some inherent process that biases the results toward significance as discussed in Case, Hines, and Rosen (1993). An alphabetically based weighting matrix returned significant estimates of strategic interaction. It is possible that there is some strong source of spatial correlation that has not been accounted for in this model. However, tests for overidentification show that models using the nonsense weighting matrix use instruments that actually belong in the second-stage estimation.[24] Thus, it is more likely that there is some random process attached to the alphabetical weighting matrix that causes the weighted values of the X variables to become significantly correlated with the dependent variables. When these instruments are removed from the nonsense estimation, the results are no longer significant.

Conclusions

Strategic interaction in environmental stringency can take any of a myriad of forms. The spillover model shows that environmental stringency by be affected by spillover competition, and the resource-flow model implies that tax competition may come into effect. It is also likely that both are present in varying degrees. Using ideally specified weighting matrices, we have shown that tax competition may have a stronger effect than spillover competition. In addition, we find that there is not consistent evidence that there are any lagged effects in the interaction, and that there is no large difference between tax competition and spillover competition in this case.

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[24] Models using the other three weighting matrices are not overidentified.

Furthermore, we show that strategic interaction among the states is tempered by the effect of marginal damages. States with higher marginal damages of pollution are less likely to compete as much. Asymmetric results confirm that this mainly affects the race to the bottom and not the race to the top.

Some slight suspicion is warranted due to the problems with the nonsense weighting matrix. However, further testing implies that the problem lies with that weighting matrix and not with the overall results.

Future work will focus this strategic interaction into the area of renewable energy funding. Renewable energy is a complicated case, as tax competition is influenced by the creation of “green” jobs and the potential loss of jobs and tax revenue from conventional sources. Spillover competition is also present for a number of reasons. First of all, renewable energy sources cause fewer emissions of harmful pollutants, leading to spillover effects as discussed above. However, there is also a spillover effect in the sense that electricity generated from renewable sources is often sold on the grid, and may not stay in the state where it was generated. The specifications introduced in this chapter as a means of disentangling the types of competition present are valid in a number of areas, and future research will exploit this technique.

CHAPTER 5: CONCLUSIONS

This dissertation presents answers to several important questions related to the interplay of state and federal environmental policies. Chapter 2 analyzes a potential conundrum in the environmental federalism literature. Political limitations limit the applicability of the optimal solution to interjurisdictional air pollution, leaving policymakers with a choice between two suboptimal options. State-determined policies can account for state specific differences in willingness to pay for benefits and the cost of pollution abatement, but are likely to ignore interstate spillovers of air pollution. Federal policies are likely to be uniform, which allows control of spillovers, but cannot account for heterogeneity in costs and damages. This work finds that the uniform federal policy comes much closer to the optimal policy for both sulfur dioxide and nitrogen oxides. Furthermore, the uniform policy captures over 99% of the benefits provided by the optimal policy for sulfur dioxide.

This work has important implications for policy. First, national uniform policies, such as a national cap-and-trade system or national uniform pollution tax are likely to be very efficient alternatives to the politically unrealistic optimal policy. Second, while recent regulations (like CAIR) have focused on regional cap-and-trade systems in order to allow for heterogeneity by region, regional markets are unlikely to be superior to a federal uniform system, especially if there are economies of scale in the administration of these programs. With over 99% of the benefits already captured, a regional system simply will not result in a large enough change in benefits to justify the added cost. Furthermore, regional systems like CAIR, which focus on East/West divisions, would likely cause a decrease in efficiency due to increased emissions in Western states.

Chapter 3 explains the influence of constituent interest on the formation of policy. In previous studies, constituent interest is measured by environmental interest group membership or other demographic variables. Demographic variables likely have their own effects and are not good proxies for constituent interest. Environmental group membership and other similar measures are narrowly focused are likely to be substantially correlated with ideology measures, making separation of the effects difficult. My measure is based on actual costs and benefits of air pollution, and represents the policy that is in the best interest of the health of the state population. We derive two measures for use in two analyses. First, we use within-state marginal damages of pollution as a measure of constituent interest in explaining which states adopt green electricity policies. Unlike previous studies, we find that constituent interest has a significant effect. Second, we use each state’s most beneficial national uniform policy as a measure of constituent interest in analyzing federal legislative voting on environmental issues. Again, we find that constituent interest is an important predictor of environmental voting, particularly in the cases that are most related to our measure.

Chapter 3 adds to the literature in a number of ways. It proposes a new measure of constituent interest that takes a different perspective than previous measures. This measure is broadly based and conforms to economic theory. It shows that constituent interest in this form is a significant factor in determining economic policy. Secondly, splitting the legislative votes into categories shows that the constituent interest variable is greatest in magnitude and significance in the categories of energy and air pollution, suggesting that constituent interest measures are highly contextual. Otherwise, the effects of constituent interest may be understated due to measurement error. This is an important implication for all studies of the determinants of policy.

Chapter 4 examines the case of strategic interaction in environmental policy. Two different scenarios of competition can explain strategic interaction in environmental stringency, but previous literature has been unable to disentangle these effects. Tax competition predicts that states act strategically when deciding environmental policy in order to attract industry to the state, as in the so-called “race to the bottom.” Spillover competition is based on spillover effects, and reflects the desire of states to respond to the emissions of their neighbors, which may transcend jurisdictional borders. We use ideal weighting matrices for each type of competition to analyze the differing effects of the selection of neighbors. My results show that the tax competition weighting matrix reveals a higher level of competition than the spillover competition weighting matrix, although the estimates are not statistically different from each other. This implies that tax competition may be the stronger force overall.

Chapter 4 also uses the within-state marginal damages from Chapters 2 and 3 to explain the effects of marginal damages on competitive behavior. We find evidence that states with higher marginal damages limit competitive behavior. This effect is asymmetric, with marginal damages limiting downward competition while having no effect on upward competition.

While the analysis of Chapter 4 has many important contributions and implications, it is necessary to note that these results come with some minor caveats. Additional regressions using a nonsense weighting matrix show significant results, which implies that there is some source of persistent spatial correlation among states that the model does not capture. However, further testing confirmed that overidentification was the source of the problem with the estimates based on the nonsense weighting matrix.

While this dissertation has contributed to the literature on environmental policy and answered some important questions, it has also posed a number of new questions. The analysis of environmental federalism in Chapter 2 analyzes sulfur dioxide and nitrogen oxide in a partial equilibrium framework, with each pollutant addressed individually. In order to inform policy in a more applicable way, these pollutants should be addressed simultaneously in a general equilibrium framework. If there are substantial interactions between sulfur dioxide emissions and nitrogen oxide emissions (if they are substitutes or complements in production), then the partial equilibrium analysis will not be sufficient. Future work will search for the optimal policies given the interactions between the two pollutants.

Additionally, the analysis in Chapter 2-3 assumed that the transmission of pollution from state to state is fixed, while in the real world it is subject to change. By strategically locating polluting firms on the borders of the state, state governments can partially control how much of the pollution damages are suffered within state and how much is “exported” to other states. Future research will calculate this mix of within-state damages and out of state damages to test whether plants in border locations systematically pollute more than non-border plants.

The constituent interest variables used in Chapter 3 would be widely applicable in a number of political economy studies of environmental regulation. They are valuable not only as a measure of constituent interest, but also as the raw marginal damages each state experiences.

The future of Chapter 4 will more completely examine what factors influence strategic competition among the states. We also intend to examine the case of strategic interaction among states in the funding of renewable energy programs and renewable energy standards.

This dissertation has contributed to the environmental economics literature with its analyses of environmental federalism, constituent interest, and strategic interaction. Like all worthwhile research projects, these studies have answered some questions while posing more. The work contained in this dissertation is only the beginning of a much longer research agenda.

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VITA

Benjamin A. Chupp was born in Rome, Georgia. He graduated from Guntersville High School in Guntersville, Alabama in 2001. He then went to Berry College, graduating in 2005 with a double major in economics and mathematics. While at Berry, he completed his honor's thesis under the direction of Dr. E. Frank Stephenson. He was also married in 2005 to his wife, Meredith Godwin Chupp.

That same year, he began his graduate studies in the department of economics at Georgia State University, having been awarded the Andrew Young Fellowship. While in the program, Benjamin worked as a graduate research assistant for Dr. Felix Rioja, Dr. Jim Alm, and Dr. Spencer Banzhaf. He also worked as a graduate teaching assistant for Dr. Shelby Frost, culminating in teaching his own section of principles of macroeconomics. His teaching in this class earned him the Andrew Young School Excellence in Teaching Economics Award for 2009.

Benjamin's research interests are in the fields of environmental and public economics, with additional interests in energy economics and experimental economics. Benjamin has received external grants to present at several academic conferences, including the Association of Private Enterprise Education Annual Conference 2006, the Southern Economic Association Conference 2007, and Camp Resources 2008. Benjamin's published work has appeared in the *International Journal of Sport Finance*. Benjamin received a Master of Arts in economics from Georgia State University in May 2008, and defended his Ph.D. dissertation in July 2009. He has accepted an appointment as assistant professor of economics at Illinois State University.