The Political Economy of State-Level Social Cost of Carbon Policy

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Abstract

The use of the social cost of carbon in electricity regulation at the state-level has increased significantly during the past decade and is seen as a transition policy towards economy-wide carbon pricing, such as a national carbon tax. In this paper, I investigate the economic and political determinants that lead states to adopt the social cost of carbon (SCC) in state-level electricity policy. I use a Cox proportional hazards regression model to conduct an event history analysis of this policy trend, hypothesizing that electricity prices contribute to the differences in policy adoption among states. The model's results indicate that government ideology and electricity prices, specifically for the industrial sector, are significant predictors of state-level SCC policy adoption. High residential electricity prices reduce the positive effect of per capita income when accounting for the interaction between the two variables. I also use the Cox model to rank the remaining states that have not yet adopted the SCC in electricity regulation according to their relative conditional hazard to follow this adoption event. SCC policy proponents may wish to focus their advocacy efforts on the high ranking states within this paper's political economy model. Given the deregulated structure of the electricity markets in most of the high ranking states, resource compensation may be the more popular type of SCC policy in the short-run, as opposed to integrated resource planning.

Introduction

States are expanding their consideration of climate change impacts in electricity regulation. At the state level, some public utilities commissions (PUCs) and state legislatures have explicitly valued climate damages in various regulatory proceedings and policies. A widely-used framework for calculating this climate-induced monetary impact is the social cost of carbon. Measured on a dollars per ton of carbon dioxide equivalent basis, the social cost of carbon (SCC) places a value on the negative externality of climate change, in which society shares the external costs of a changing climate—sea level rise, droughts, wildfires, floods, etc.—while market participants bear only the private costs of their carbon-emitting activities. By accounting for the negative externality of climate change in the present, states hope to mitigate the impacts of such damages in the future. This section reviews the history and modelling behind the SCC, discusses how states are using the SCC in electricity regulation, and presents an overview of this paper's goal–to analyze the economic and political determinants that lead states to adopt such a policy and which states might be the next to follow.

Review of the Interagency Working Group's Social Cost of Carbon

The SCC values generated by the Interagency Working Group on the Social Cost of Greenhouse Gases (IWG) under the Obama administration, though widely debated, constitute the range of estimates used by state regulatory bodies in considering climate impacts. Through executive order, the Obama administration first created the IWG, a collection of federal agencies and other stakeholders. The original intention for the IWG's SCC values was to use the estimates for federal regulatory impact analysis (Kaufman, 2018), different than the context in which states are now using the IWG SCC. The IWG estimated their SCC values by using three integrated assessment models (IAMs), giving each one equal weight. The SCC estimation process involves calculations of future anthropogenic emissions and the resulting atmospheric greenhouse gas (GHG) concentrations, the impact of these accumulations on temperature change, and temperature change's relationship with economic damages.

To compute future lost consumption and a distribution of SCC values from each IAM, the IWG started by entering socioeconomic and emissions projections. This input resulted in yearly changes to global temperature and economic consumption. They then "shocked" the IAMs with a single ton of emitted carbon in a given year and recalculated the temperature and consumption changes in future years. To calculate yearly economic damages, the IWG took the difference in per capita consumption before and after the emissions shock to the model. Last, they computed the SCC as a present value by discounting the marginal damages back to the original year of emissions (Greenstone, Kopits and Wolverton, 2013).

An important parameter in any SCC calculation is the discount rate. The discount rate for the SCC is not only a scientific and economic issue, but an ethical issue as well. Philosophical concerns can be raised as to how society values intergenerational welfare. Government agencies typically use a discount rate between three percent and seven percent to estimate the benefits and costs of certain intragenerational regulations. For their SCC values, the IWG used discount rates to determine the present value of damages incurred that year for marginal changes in emissions. Today's investments in mitigating GHG emissions reduce future economic damages. Discount rates have a large influence on the SCC, especially when reflecting uncertainty, such as the lower bound 2.5% discount rate. Lower discount rates result in higher SCC values, and vice versa. For example, the IWG's range of SCC values for the year 2020 are $62 at a discount rate of 2.5%, $42 at 3%, and $12 at 5%, with a 95th percentile estimate of $123 at 3% to account for a low-probability, high catastrophe impact scenario, measured in 2007 dollars per metric ton of CO_2 (Interagency Working Group on Social Cost of Greenhouse Gases, 2016).

There exist various critiques of the IWG SCC. Some advocate for a SCC value that only reflects domestic damages, therefore decreasing its value. Others criticize certain parameters of the IWG's model as arbitrary and filled with uncertainty, such as the selection of discount rates and damage functions. Accounting for catastrophic scenarios is another concern (Pindyck, 2013). Due to the limitations of current climate and economic models, the IWG SCC does not fully account for all possible damages from climate change. This uncertainty in omitted impacts has led to calls for higher SCC values and more research on the subject (Howard, 2014).

With improvements in the climate and economic models used in the IAMs, the SCC values will update over time to reflect changes in estimates of the climate damages described above. Through executive power, however, the Trump administration has disbanded the IWG, and changed the SCC to only reflect domestic damages and higher discount rates, resulting in a much lower range of values (Plumer, 2018). Groups such as the University of Chicago's Climate Impact Lab are working to fill the SCC modeling vacuum left by the Trump administration and update the SCC values with a more robust range of estimates (Kim, 2018). Outside of this modelling work, states are moving forward with the SCC in the policy sphere, using climate damage estimates to inform the calculus of electricity regulation.

How Are States Valuing Climate Damages?

States lead the discussion on social cost of carbon policy in the absence of federal climate mitigation efforts, especially since the start of the Trump administration. Since 2015, ten states have enacted various forms of energy policy that explicitly use some version of the IWG SCC to place a monetary value on climate damages, continuing the trend of states as policy laboratories.

The New York University School of Law's Institute for Policy Integrity has identified three ways in which states use the social cost of carbon in policymaking: (1) integrated resource planning (IRP), (2) resource compensation or zero emission credits (ZEC), and (3) cost-benefit analysis (CBA). Through the IRP process, PUCs review a utility's proposal for meeting the future electricity demand of end-users through various power generation sources while balancing their economic viability in a given electricity market. A resource compensation program incentivizes the production of low-carbon electricity generators, utilizing the SCC to calculate the appropriate subsidy for the benefits of the avoided carbon emissions. This type of SCC policy, depending on the state, has included both nuclear generators through ZECs and distributed energy resources (DERs). In addition, states have used the SCC in cost-benefit analysis to approve the development of various DERs by utilities. States with vertically integrated or regulated electricity markets tend to choose IRPs as their form of SCC policy, while states with wholesale or deregulated electricity markets would utilize resource compensation mechanisms such as ZECs and properly valuing DERs (Grab, Paul and Fritz, 2019). Table 1 lists the ten states using the IWG SCC, by initial year of adoption and policy type.

Table 1: States Using the IWG SCC, by Year of Adoption and Policy Type

State	Year Adopted	Policy Type	SCC Values[1]
Maine	2015	Resource Compensation	IWG central estimate
New York	2016	Resource Compensation / Cost-Benefit Analysis	IWG estimates, accounting for emission allowance programs (ex. Regional Greenhouse Gas Initiative)

State	Year Adopted	Policy Type	SCC Values[1]
California	2017	Resource Planning / Cost-Benefit Analysis	IWG estimates and 95th percentile high-impact estimate ($123/ton CO_2e)
Colorado	2017	Resource Planning	IWG estimates - $43/ton CO_2e in 2022
Illinois	2017	Resource Compensation	$16.50/MWh ($23.33/ton CO_2e) – utilizing IWG estimates
Minnesota	2017	Resource Planning	IWG estimates, on a 100-year time horizon ($9.05 - $43.06 per short ton of CO_2e)
Maryland	2018	Cost-Benefit Analysis	IWG estimates, accounting for emission allowance programs (ex. Regional Greenhouse Gas Initiative)
Nevada	2018	Resource Planning	IWG estimates, specifically the 2016 3% estimate
New Jersey	2018	Resource Compensation	Less than IWG estimates, but benchmarked off of the IWG SCC
Washington	2018	Resource Planning	IWG central estimate
[1](Grab, Paul and Fritz, 2019)			

Some states modified different parameters of the IWG SCC, such as the model's time horizon. The Minnesota PUC, for example, adjusted the IWG's SCC model to only account for a shortened time horizon to the year 2200, as opposed to the standard 300-year time horizon in the IWG SCC (Minnesota Public Utilities Commission, 2016). Regulatory bodies also have chosen different discount rates for the SCC in their proceedings and policies, the most common a recommendation to use the IWG's central estimate, which is based on a three percent discount rate. The California PUC, in its proceedings on the value of distributed energy resources, used the 95th percentile estimate in conjunction with the three percent discount rate central estimate, to capture low probability, high damage catastrophe scenarios, in turn considering an increased SCC value of \$123/Mt CO_2e for 2020 emissions (California Public Utilities Commission, 2019). These modifications and discount rate selections have had direct impacts on the value of the SCC calculations that each state considers.

State SCC Policy Profiles

This section discusses how states utilize the IWG SCC in various ways through electricity regulation and policy, specifically via cost-benefit analysis, integrated resource planning, and resource compensation. Each type of SCC implementation is reviewed through three case studies: California for cost-benefit analysis, Colorado for integrated resource planning, and Illinois for resource compensation.

California – Cost-Benefit Analysis

California employed the IWG SCC in multiple instances, mostly related to cost-benefit analysis and integrated resource planning. As a progressive state with high risk to climate damages such as wildfires, they have used the SCC in an aggressive way, including the 95th percentile of the IWG's SCC estimates.

Assembly Bill No. 197, introduced by State Assembly member Eduardo Garcia and approved by Governor Jerry Brown in 2016, requires the State Air Resources Board "when adopting rules and regulations beyond the statewide greenhouse gas emissions limit…[to] consider the social costs of the emissions of greenhouse gases" (California AB 197, 2016).

The California Air Resources Board (CARB) has interpreted AB No. 197's definition of social costs to follow the IWG's SCC. In its 2017 Climate Change Scoping Plan, CARB uses the IWG SCC to estimate the benefits of avoided economic damages from their climate policies through 2030. The Scoping Plan outlines a set of policies, including cap-and-trade, that will help California achieve its climate targets of 40 percent below 1990 GHG emissions levels by 2030, and a 2050 goal of 80 percent below 1990 GHG emissions levels. Of tangential interest is CARB's decision to use a cap-and-trade program instead of a carbon tax. They cite the certainty of the emissions cap inherent in cap-and-trade as their motivating reason for selecting that market-based policy over a carbon tax. The cap-and-trade program, however, does not use the IWG SCC. As required by AB No. 197, CARB analyzes their proposed policies and their alternatives in monetary terms of avoided climate damages, using the IWG standardized range of discount rates, at 2.5, 3 and 5 percent. Using the three IWG discount rates, their range of avoided economic damages from the 2017 Climate Change Scoping Plan equals $1.92 to $11.23 billion, in 2015 U.S. dollars. The report states that CARB will follow and consider updates to the SCC based on "peer-reviewed modifications to estimates based on the latest available data and science" (California Air Resources Board, 2017).

Of tangential interest, Caltrans, the state's transportation authority, also produces life cycle and benefit-cost analyses for possible "federal interstate, state highway, and public transit projects," using the three percent discount rate estimate from the IWG SCC to monetize the benefits of GHG emissions reductions (California State Senate Office of Research, 2018).

In 2019, the California Public Utilities Commission (CPUC) ordered the use of the SCC when evaluating the societal value of distributed energy resources (DERs) through Rulemaking 14-10-003. The CPUC order mandates that utilities conduct a Societal Cost Test (SCT) when resource planning. The SCT uses two IWG SCC values, the 3% estimate and the 95th percentile high-impact estimate, which is valued at \$123/Mt CO_2e for 2020 emissions. The Commission Energy Division recommended considering the high-impact estimate as they believed the "other lower values to represent a lower bound for damage costs related to climate change...the high impact value is the more appropriate and defensible estimate." In this case, the utilities advocated that the CPUC should use the SCC and SCT "for informational purposes only" and that "the SCT should not be used for approving program budgets, procurement decision(s), or tariffs," due to the concern that this consideration would lead to over-procurement of DERs and under-procurement of more economical energy resources. This mandate is only an evaluation period through December 2020 for the use of the SCC in resource planning, and may lead to a more direct impact on resource planning in the future (California Public Utilities Commission, 2019).

Colorado – Integrated Resource Planning

Colorado state statutes grant their PUC the authority to evaluate the environmental costs of electricity generation. Under Colorado Revised Statute 40-2-123(1)(b), "The commission may give consideration to the likelihood of new environmental regulation and the risk of higher future costs associated with the emission of greenhouse gases such as carbon dioxide when it considers utility proposals to acquire resources" (Colo. Rev. Stat. § 40-2-123(1)(b)). Coupled with other statutory language that considers the benefits of "environmental protection" and "risk mitigation" in "generation acquisitions for electric utilities" (Colo. Rev. Stat. § 40-2-123(1)(a)), the Colorado PUC had reason to utilize the social cost of carbon in regulating electricity generation.

This legal basis for valuing the negative externality of carbon emissions led to a 2017 order for the Public Service Company of Colorado, Xcel Energy, to use the SCC in its Electric Resource Plan. The Colorado PUC found that "...the SCC serves as a modeling tool to incorporate the social benefits of reducing [carbon] emissions into cost-benefit analyses of regulatory actions that impact cumulative global emissions…" and directed Xcel Energy to run a third carbon price sensitivity using the SCC. These values start at $43 per ton in 2022 and increase to $69 per ton in 2050. They are based on the IWG SCC at the three percent central estimate (Colorado Public Utilities Commission, 2016).

In 2019, the Colorado State Legislature expanded on the 2017 PUC order and made the evaluation of the SCC a requirement in future resource planning. Senate Bill 19-236, passed during the 2019 Colorado legislative session to renew the Colorado PUC, added stipulations for the commission to undertake an increased focus on climate change with its regulatory powers. The Bill includes a directive for the Colorado PUC to evaluate the cost of carbon dioxide emissions in public utility proceedings and to have public utilities include the cost of carbon dioxide emissions when evaluating the procurement of various electric generation resources. In 2020, the base carbon price will be set at $46 per ton, with the authority to modify the rate of price escalation based on updates from a federal interagency working group (Colorado General Assembly, 2019).

Illinois – Resource Compensation

Illinois employed the SCC to properly value the benefits of carbon-free electricity generation, specifically nuclear power. With nuclear providing a substantial portion of the state's electricity, Illinois created a Zero Emissions Credit program to compensate nuclear generators for their avoided emissions at the value of the IWG SCC.

The Illinois Power Agency (IPA) enacted their Zero Emission Standard (ZES) in 2017, which establishes Zero Emission Credits (ZECs) that compensate electricity generators for the benefits of their avoided carbon emissions, using the IWG's SCC. The IPA did so partly in response to the fact that the State's Renewable Portfolio Standard (RPS) does not count nuclear power generating facilities as renewable energy and they are therefore ineligible for renewable energy credits (RECs). The ZES calls for the IPA "to procure ZECs in an amount approximately equal to 16% of the actual amount of electricity delivered by each electric utility to retail customers in the State during calendar year 2014." That 16% procurement mark is the average of the State of Illinois' RPS targets for 2017-2023. The value of the ZEC is the IWG SCC on a price per megawatt hour (MWh) basis, based on the three percent central estimate from 2016, which translates to $16.50/MWh. To ensure the cost effectiveness of the ZECs, the IPA will make adjustments to their value if the ZEC price rises above a predetermined level with respect to market indices (Illinois Power Agency, 2017).

After determining the ZEC value, procurement amount, cost cap and volume cap, the IPA opens up the program to bids from electricity generators. The IPA uses the ZECs under the Zero Emission Standard program to compensate power companies that can generate zero emissions electricity at the aforementioned procurement amount of 16% of the State's retail load in 2014. The IPA then requires utilities to sign 10-year contracts with these facilities and buy their ZECs.

For example, Exelon will receive $235 million in ZECs for its two nuclear power plants. The compensation provided helps Exelon keep these nuclear plants open for the next 10 years and allows them to continue providing zero emissions electricity to the State of Illinois (Martin, 2017).

Why Have Certain States Adopted the SCC in Energy Policy?

The question of which economic and political determinants motivate states to adopt the SCC in electricity regulation is the leading inquiry of this paper. The NYU Institute for Policy Integrity has identified three categories of statutory language authorizing state PUCs to value climate damages in electricity policy, using the SCC: "(1) statutes that specifically address environmental externalities; (2) statutes that incorporate consideration of public health, public welfare, or the public interest; and (3) statutes providing general regulatory discretion to the utilities commission…" most often through a "just and reasonable" standard, which 40 out of 50 states maintain (Grab, Paul and Fritz, 2019). While the first two categories grant explicit authority to regulators, the third can be interpreted more implicitly. The legal basis for valuing climate damages, therefore, has been established in many states with respect to their PUCs.

Understanding the motivating factors behind why certain states have considered the IWG SCC, as opposed to other states, will highlight the barriers that other states face in adopting SCC-based electricity regulations. Given that many states already have the explicit or implicit legal authority to consider the social cost of carbon, this paper will consider the economic and political differences between states that do and do not have SCC policies. By identifying a set of economic and political variables, I will set out to create a statistical model which will rank states according to their propensity to adopt a SCC policy. I hypothesize that differences in electricity prices among states and sectors are associated with the variation in states that have and have not adopted SCC policies. My political economy model posits that states with relatively high electricity prices, especially less wealthy states, will face a disincentive to follow this policy trend, so as to avoid putting themselves at a deeper comparative disadvantage in key industries such as manufacturing. I will also explore the aforementioned categorical differences in statutory authority to value climate damages with respect to state-level SCC policy adoption.

Methodology

Event History Analysis: Cox Proportional Hazards Regression Model

In this paper, I build a statistical model that analyzes which economic or political variables are significant in determining a state's propensity to adopt some form of a SCC policy, with the goal of ranking states according to their SCC policy adoption propensity. Past research on the adoption of various state-level policies has often utilized event history analysis (EHA) for this purpose, allowing for the modeling of duration-to-policy adoption data. Drawing on Berry and Berry's innovative policy adoption methodology (Berry and Berry, 1990), analysts have used EHA to look at various state-level energy policy adoption phenomena, such as renewable portfolio standards (Carley and Miller, 2012) and sustainable energy portfolio standards (Chandler, 2009).

Events are treated as discrete occurrences, with SCC policy adoption serving as the event in this model. The model considers the occurrence of an event as a binary dependent variable, with "1" indicating adoption of a SCC policy, and "0" indicating no adoption of a SCC policy in a given state-year. Although there exist different types of SCC policies, such as IRP and resource compensation, this model uses a binary dependent variable because these two types of policies are relatively exclusive to different market structures–IRP for regulated electricity markets, and resource compensation for deregulated electricity markets. Only 10 states have adopted a SCC policy up until this point, so there are only 10 "events" in this sample.

The EHA model chosen for this paper is a Cox proportional hazards regression model (Cox, 1972). This specific type of EHA is commonplace in the literature on state-level policy adoptions of various kinds, from building energy codes (Nelson, 2012) to education performance funding (Li, 2017). EHA models often analyze the hazard rate, *h(t),* or the instantaneous rate at which a state adopts a policy. Unlike logit-probit models, another popular EHA method, the Cox model does not assume that the baseline hazard is invariant or flat with respect to time (Buckley and Westerland, 2004). The baseline hazard represents the hazard function, or rate of policy adoption, for a state when the values of all predictor variables equal 0. Therefore, the Cox model does not require parameterization of the baseline hazard function, as opposed to logit-probit models (Jones and Branton, 2005). In addition, the assumption of the baseline hazard's time-independence may lead to the belief that a model's predictor variables and other considerations are completely and correctly specified, which is unlikely to be true given the complexity of this policy adoption issue (Buckley and Westerland, 2004). Furthermore, duration dependence in the data may not be fully assessed with the baseline hazard's relationship to time being invariant (Beck, Katz, and Tucker, 1998). By removing this assumption, the Cox model helps account for baseline differences not included by the predictor variables observed on the studied states. Without a specification of the baseline hazard function, however, the Cox model can only examine comparative, not absolute, statements about the hazard of event occurrence (Singer and Willett, 2003).

2010 is the first state-year in this model, as this was the year in which the IWG released their first range of estimates for the federal SCC. Policies using or closely following the IWG

SCC are the focus of this paper, as opposed to other SCC values, so states would not have had the opportunity to adopt such a SCC policy prior to that year. 2018 is the last state-year in the model, as it is the last year in which a state has adopted a SCC policy and for which much of the data on the selected variables are available. When a state adopts a SCC policy in a given state-year, the following years are omitted for that state. If a state never adopts a SCC policy, I include the data on the years 2010 through 2018. The model uses clustered standard errors within individual states to account for serial correlation in the error terms within states over time. This panel data set results in a total of 423 state-years across the states studied. This paper uses Efron's method of handling tied events within the Cox model (Efron, 1977).

The following is the standard Cox proportional hazards regression model:

$$H_i(t) = \mathrm{H}_0(t)*\exp(\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k) \qquad \text{(Equation 1)}$$

In which $H_i(t)$ is the cumulative hazard rate for the ith state, $\mathrm{H}_0(t)$ is the baseline hazard function, and $\beta_k x_k$ are the predictor variables and their associated regression coefficients. Of interest with respect to the political economy variables analyzed, the hazard ratio, $\exp(\beta_k)$, is the change in the event's hazard due to a one-unit difference of the given predictor variable. The event history analysis omits Alaska and Hawaii, only collecting data on the contiguous 48 states. This omission is due to the geography of energy infrastructure, with states often sharing resources across borders.

Selected Predictor Variables

Electricity Prices

By using SCC values to incorporate climate damages into the electricity generation decision making process, regulators hope this added cost for dirtier fuel sources will accelerate the transition to cleaner fuels, the adoption of energy efficiency measures, and an overall reduction in fossil fuel consumption. This method, through various types of SCC policy such as IRP or ZECs, will likely lead to increases in electricity prices for various sectors of the economy, depending on implementation. A study on the use of various SCC values—from the FUND model, a type of IAM—for a unilateral regional tax on production-based CO2 emissions from the electric sector found increases in electricity prices from such a policy. Not only do electricity prices increase in the short-term within the region implementing the SCC-based carbon tax, but there are even higher rate increases after an import constraint is used to mitigate carbon leakage from the region (Bistline and Rose, 2018). Although the SCC policies considered by this paper—integrated resource planning, resource compensation, cost-benefit-analysis—are not a direct power sector carbon tax like the one analyzed in the aforementioned study, increased electricity prices are plausible with these other forms of unilateral electricity regulation. States that already experience relatively high electricity prices may be less likely to adopt a SCC policy, given the assumption of increased costs from more stringent electricity regulation. Other studies have found significant, negative relationships between electricity prices and state-level adoption of various energy policies, such as commercial building energy codes (Nelson, 2012).

This predictor variable measures a state's average annual retail electricity price for the whole electric sector, in cents per kilowatt hour. Subsequent analysis of this variable differentiates electricity prices by the residential, commercial, and industrial sectors, more specifically. The residential sector includes private single and multi-family housing use of electricity, while the commercial sector covers private and public service-providing facilities and government institutions. The industrial sector constitutes facilities and equipment utilized for the manufacturing of goods. Data come from the U.S. Energy Information Administration, and track the annual retail price to ultimate customers of electricity consumption (U.S. Energy Information Administration, 2019).

Hypothesis 1: High electricity prices in a state will be associated with a decreased likelihood to adopt a SCC policy, as grid consumers are averse to perceived initial increases in retail rates from pricing in the social costs of carbon emissions stemming from electricity generation.

Carbon Intensity of the Economy

Similar to the issue raised by high electricity prices, states with high measures of carbon intensity may be less inclined to adopt a SCC policy. Carbon intensity is effectively a measure of how much a state's economy is based on fossil fuel consumption. The aforementioned study on a power sector SCC tax also found that regions with higher carbon intensities will experience larger electricity price increases (Bistline and Rose, 2018). Past studies on other climate and energy policies indicate a significant, negative relationship between a state's carbon intensity and its adoption of programs that support wind energy (Wiener and Koontz, 2012) and renewable portfolio standards (Matisoff, 2008).

Carbon intensity is measured as the annual metric tons of energy-related carbon dioxide per chained 2009 million dollars of GDP. The data, from the U.S. Energy Information Administration State Energy Data System (U.S. Energy Information Administration, 2019), only go through 2016, so an average of the last three years of a state's carbon intensity was used to estimate data points for 2017 and 2018.

Hypothesis 2: States with higher carbon intensities are less likely to adopt a SCC policy, as a state economy with greater dependence on fossil fuel consumption will experience greater costs in the face of regulatory measures that increase the price of carbon for activities such as the generation of electricity.

Income

With electricity demand generally price inelastic among residential electricity consumers in the short-term (Miller and Alberini, 2016; Espey and Espey, 2004), an increase in electricity rates from a SCC policy's incorporation of climate damages may affect a state's propensity to adopt such a policy. Personal disposable income will be a determinant of how much one will have to change their consumption pattern due to budget constraints. With more income, it is assumed that people in a SCC policy state will be better equipped to absorb any increases in electricity prices, and are therefore more open to the adoption of such a policy even with short-term electricity price inelasticity. From a governing perspective, states with lower average personal incomes may also have more pressing short-term policy issues they need to address, such as education, healthcare, and housing.

In the literature on other state-level climate and energy policy trends, personal income is found to have a positive and significant relationship with the adoption of sustainable energy portfolio standards (Chandler, 2009) and renewable portfolio standards (Yi and Feiock, 2012). Per capita personal income by state, measured in dollars on an annual basis, comes from the Federal Reserve Bank of St. Louis (Federal Reserve Bank of St. Louis, 2019).

Hypothesis 3a: States with higher per capita incomes are more likely to adopt a SCC policy, as regulators can more easily justify increasing overall retail and residential electricity rates and other energy costs for grid consumers when trying to account for the social costs of energy production and consumption.

Hypothesis 3b: High residential electricity prices reduce the ability of income to absorb any price increases from incorporating climate damages into electricity regulation. An interaction term between the two variables will be used to explore this relationship.

Government Ideology

When contrasted with their conservative counterparts, more liberal state governments tend to pass progressive climate and energy policies. This trend is evidenced by studies that found a significant, positive relationship between liberal state governments and the adoption of sustainable energy portfolio standards (Chandler, 2009) and renewable portfolio standards (Lyon and Yin, 2010; Huang et al., 2007). In addition, government ideology is a proxy indicator for the political climate surrounding a state's PUC, as the governor and state legislature often have some degree of control over PUC commissioner appointments, funding, or regulatory discretion, or a combination of one or more of these considerations.

The government ideology predictor variable comes from the Berry, Ringquist, Fording, & Hanson (BRFH) index on state-level political ideologies (Berry et al., 1998). The BRFH index is a common measure of government ideology used by studies on state-level policy adoption, specifically those focused on event history analysis. The model includes interest-group ratings of congressional representatives, estimated ideologies of electoral challengers, vote weights by district, and a nonlinear distribution of legislative partisanship. The resulting index is a scale from 0 to 100, with the degree of liberalism for a state increasing as it approaches 100. The data only go through 2017, so the model holds the 2017 BRFH index scores constant for 2018.

Hypothesis 4: States with higher measures of government liberalism are more likely to adopt a SCC policy, given previously established correlations between progressive governments and robust climate policies.

Table 2 includes summary statistics of the predictor variables used in this paper's political economy model. It provides the mean, median, standard deviation, minimum and maximum for each variable. Table 2 also presents a description of each variable's unit of measurement and the source of the variable's data.

Table 2: Summary Statistics of Predictor Variables

Variable	Description	Mean	Med.	Std. Dev.	Min.	Max.	Source
Carbon Intensity (CRB)	Metric tons of energy-related carbon dioxide per chained 2009 million dollars of GDP	470.20	370.23	334.80	127.87	1926.95	U.S. EIA
Government Ideology (GOV)	Ideology index, on a scale of 0-100 with 100 being most liberal	41.35	41.20	17.43	17.51	73.62	BRFH index
Income (INC)	Per capita income, measured in dollars	45511	44335	8003.70	30902	76456	Federal Reserve Bank of St. Louis
Retail Electricity Price (RET)	Cents per kilowatt hour, for the overall electricity sector	10.10	9.28	2.57	6.20	18.50	U.S. EIA
Residential Electricity Price (RES)	Cents per kilowatt hour	12.24	11.46	2.78	7.87	21.61	U.S. EIA
Commercial Electricity Price (COM)	Cents per kilowatt hour	10.10	9.57	2.26	6.41	17.17	U.S. EIA
Industrial Electricity Price (IND)	Cents per kilowatt hour	7.33	6.57	2.22	4.08	15.39	U.S. EIA

Results

The results in Table 3 show the coefficients, standard errors, and significance for the internal determinants included in the three separate Cox proportional hazards regression models (Equation 1). A positive coefficient indicates that the hazard ratio increases with an increasing covariate, demonstrating greater risk of a state adopting a SCC policy. A coefficient less than zero shows decreased risk of SCC policy adoption with an increase in the covariate's value.

Table 3: Cox Model Results

Variable	Model 1	Model 2	Model 3
CRB	-0.002784* (0.001562)	-0.002429 (0.001746)	-0.001227 (0.001198)
GOV	**0.04406** (0.01963)**	**0.0458** (0.02133)**	0.03887* (0.02206)
INC	0.00008263 (0.00005229)	0.00007541 (0.00005752)	**0.0005807**** (0.0001748)**
RET	**-0.2192** (0.1035)**	**---**	---
RES	**---**	0.2378 (0.3028)	**2.171 (0.6782)*** **
COM	**---**	-0.1229 (0.355)	-0.1744 (0.3556)
IND	**---**	**-0.4153*** (0.1552)**	**-0.3278*** (0.1215)**
INC*RES	**---**	**---**	**-0.00003249*** (0.00001147)**

Robust standard errors in parentheses

* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$ **** $p < 0.001$

Model Refinement and Variable Significance

Within the initial set of internal determinants, Model 1, retail electricity prices and government ideology are statistically significant with respect to SCC policy adoption. Although carbon intensity and per capita income are not statistically significant, the direction of their coefficients are consistent with the hypothesized relationships between these internal determinants and SCC policy adoption.

After determining that retail prices for the overall electricity sector were significant at the 5% level, I created Model 2 to analyze the main sectors of electricity consumption—residential, commercial, and industrial—with respect to price. Of these sectors, industrial electricity price is significant at the 1% level. Government ideology remains significant at the 5% level and positively associated with SCC policy adoption when adjusting for differences in sectoral electricity pricing, meaning more liberal state governments have a higher rate of implementing this type of policy. To examine the hypothesized negative interaction term between per capita income and residential electricity prices, I created Model 3. This iteration includes all of the variables from Model 2, only adding an interaction term for per capita income and residential electricity price. All three models maintain statistical significance, as the omnibus tests for each model's likelihood ratio have a p – value less than 0.01.

To test the proportional hazards assumption for the set of covariates in Model 3, a corresponding set of scaled Schoenfeld residuals with respect to time was created, allowing the examination of independence between residuals and time. Given that there are no statistically significant relationships between time and each of the covariates, as well as the model as a whole, the proportional hazards assumption holds according to this test.

Within Model 3, industrial electricity price is statistically significant at the 1% level. The hazard ratio of industrial electricity price is equal to 0.7205. Therefore, with each one unit increase in industrial electricity price, measured on a cent per kilowatt hour basis, the instantaneous rate of adopting a SCC policy is 27.95% lower, controlling for the other variables. The upper 95% bound of the industrial electricity price hazard ratio is equal to 0.9142, while the lower 95% bound is equal to 0.5679. States that experience high industrial electricity prices have a lower rate of SCC policy adoption in a given year *t,* if they have not already adopted by the year *t* - 1. Residential electricity prices and per capita income are now highly significant when adjusting for the relationship between the two variables. They have a negative interaction term as hypothesized, suggesting that a state with relatively higher residential electricity prices diminishes the positive effect of personal income on SCC policy adoption, as the ability to absorb price increases from more stringent electricity regulation is reduced.

Ranking the States

Given that the overall fit of Model 3, the interaction term model, is significant, I can use the model to rank states according to their relative conditional rate of SCC policy adoption. This measure of policy adoption propensity is the cumulative hazard generated by the Cox proportional hazards regression model, which demonstrates the covariate profiles that have the highest "hazard" of event occurrence, or SCC policy adoption. This cumulative hazard ranking uses the coefficients generated by the model for each predictor variable, as well as data on each predictor variable for the year 2018 as the input point estimates. With the derived coefficients, the model becomes:

$$H_i(t) = \exp(- 0.001227*CRB + 0.03887*GOV + 0.0005807*INC - 0.3278*IND - 0.1744*COM + 2.171*RES - 0.00003249*RES*INC)$$

(Equation 2)

In which "CRB" is carbon intensity, "GOV" is government ideology, "INC" is per capita income, "IND" is industrial electricity price, "COM" is commercial electricity price, "RES" is residential electricity price and "RES*INC" is the interaction term for residential electricity price and per capita income.

The states in Table 4 are ranked by their cumulative hazard, *H(t)* (largest to smallest). The 10 states that have already adopted SCC policies are omitted, as well as Alaska and Hawaii for reasons previously discussed, resulting in a total of 38 states listed in the table. States that have already enacted an environmental cost statute, considered a strong legal basis for enacting a SCC policy, are highlighted in green. It is important to note that Massachusetts and North Dakota are the only two states that currently limit or prohibit carbon pricing (Grab, Paul and Fritz, 2019). These two states are highlighted in red in the table. States that both rank relatively high in terms of their SCC policy adoption propensity and also currently maintain an environmental cost statute may provide fertile ground for SCC policy advocates. For example, Virginia, Vermont, and Delaware are strong candidates in this respect.

Table 4: Ranking of Cumulative Hazard to Adopt SCC Policy, by State

State	Cumulative Hazard ($x10^{12}$)	State	Cumulative Hazard ($x10^{12}$)
Pennsylvania	1814.578	New Mexico	72.784
Virginia	1339.786	Florida	72.072
Vermont	1203.673	Montana	63.741
Rhode Island	826.125	North Dakota	54.565
Oregon	654.224	Arizona	42.942
Delaware	646.056	Georgia	38.137
Michigan	427.148	South Carolina	34.153
Wisconsin	216.545	Missouri	33.718
New Hampshire	214.165	Indiana	33.507
Connecticut	138.408	Tennessee	28.101
Kansas	135.833	Oklahoma	25.071
Massachusetts	134.912	Louisiana	21.186
Iowa	115.591	Utah	21.073
Texas	110.522	Alabama	17.050
South Dakota	107.780	Idaho	11.268
Wyoming	104.827	Arkansas	8.416
Ohio	94.342	Kentucky	6.132

State	Cumulative Hazard ($x10^{12}$)	State	Cumulative Hazard ($x10^{12}$)
North Carolina	88.101	West Virginia	5.612
Nebraska	75.908	Mississippi	3.636

Using the cumulative hazard measures generated by Model 3, the maps below show the geography of state-level SCC policy's political economy. States with higher cumulative hazards trend towards dark red in color. States with lower cumulative hazards are lighter and more yellow in color. The 10 states that have already adopted some form of a SCC policy are blue.

Figure 1: Cumulative Hazard of SCC Policy Adoption, by State

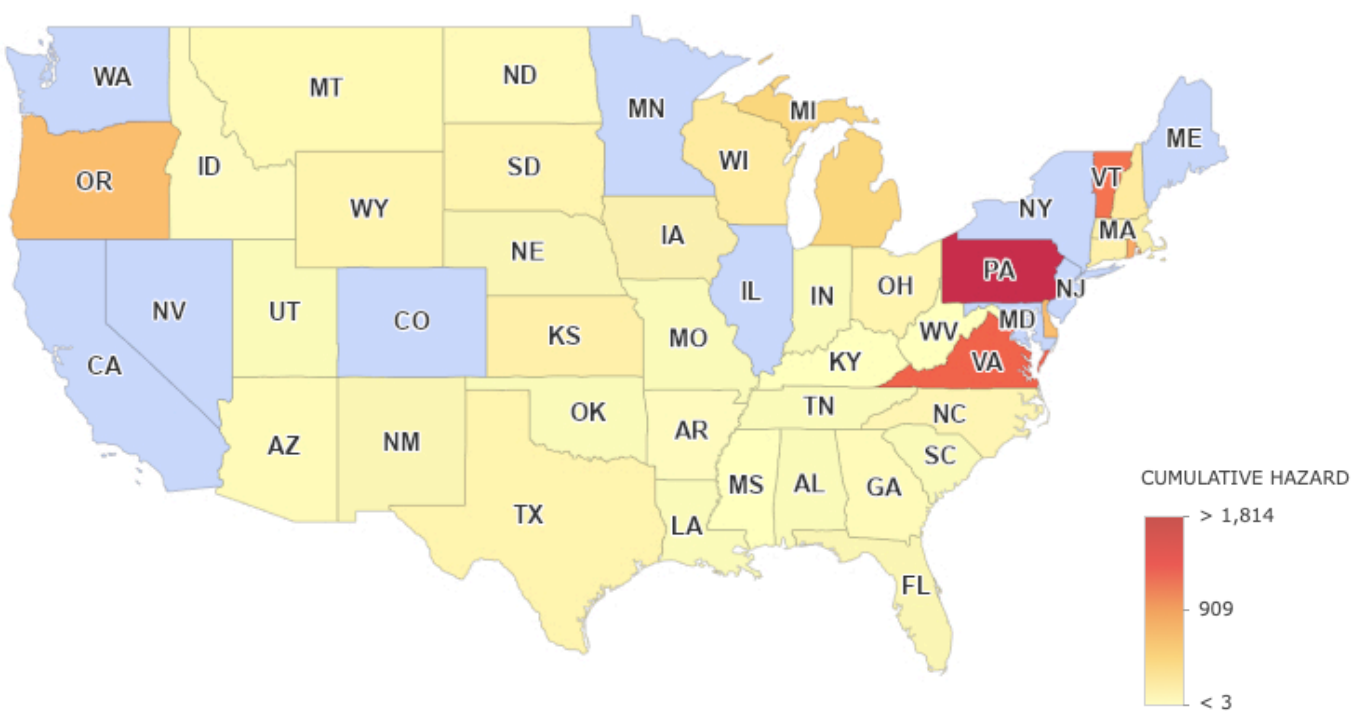
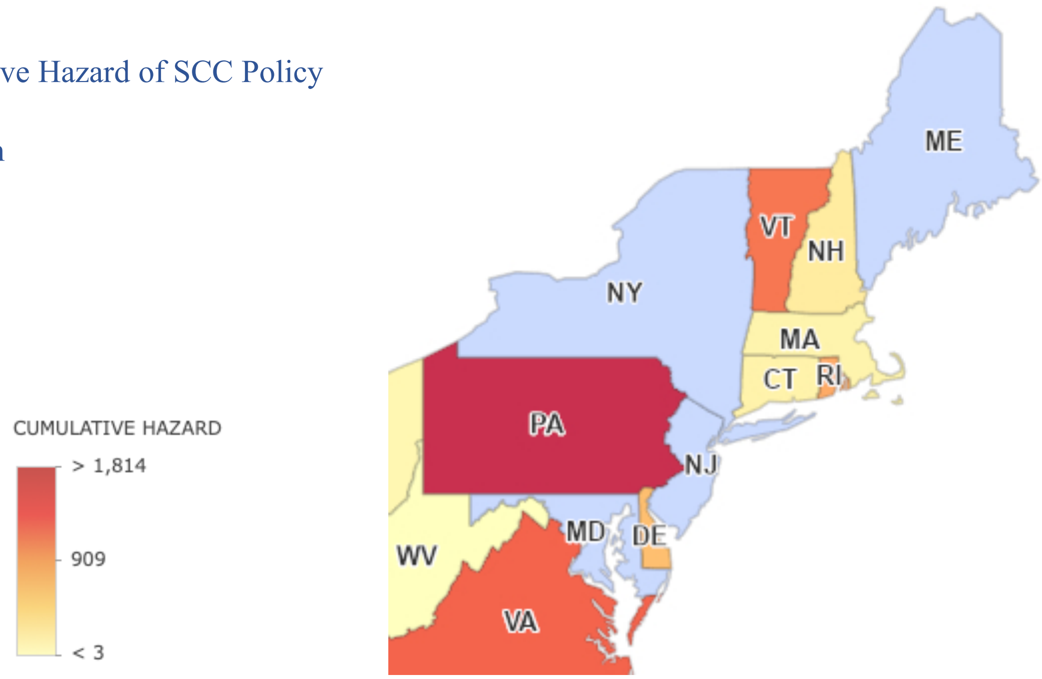


Figure 2: Cumulative Hazard of SCC Policy Adoption, by State
– Northeast Region



Discussion

Determinants of State SCC Policy Adoption

The significance of the industrial electricity price variable suggests that states with higher prices for the industrial sector are averse to imposing new sector-specific costs through SCC policies of various types. This relationship may originate in a few different processes, all of which merit further research. First, there may be a perception among both regulatory decision makers and industrial firms that the incorporation of climate damages into rate setting, resource planning, or resource compensation may increase industrial electricity prices in the short-run. Although the real effect of a given SCC policy on retail electricity prices is not the focus of this study, industrial firms may have reservations regarding SCC policy adoption due to concerns about profit reductions, stemming from perceived higher electricity prices in the short-run. The industrial sector is generally price inelastic in the short-run, with larger price elasticity in the long-run (Burke and Abayasekara, 2018). To avoid such perceived profit losses in the short-run due to inflexible capital stock, industrial firms may use their lobbying power with state regulatory bodies and legislatures in a form of rent-seeking behavior. Further, energy-intensive industries tend to locate in areas with comparatively low electricity prices to minimize costs (Kahn and Mansur, 2013). Therefore, for the decision makers in some public utilities commissions and other government agencies that regulate electricity generation, as well as state legislators, there may be a concern that industrial firms experiencing lower profits from such a SCC policy will flee the state in the long-run, thereby hurting the state's economy, specifically through decreased manufacturing employment.

In this way, the philosophical discourse at the center of the social cost of carbon and intergenerational welfare manifests. States that are implementing a SCC policy with respect to their electricity generation are making an explicit decision on how much they value present consumption and production—with lower industrial electricity prices as a proxy—versus the reduction of future damages from climate change. This tension includes the parameters of the IWG SCC model they might modify, such as the selection of discount rates. To further examine this relationship, subsequent studies could analyze the effects of industrial firm lobbying power and the industrial sector's share of a state's economy on SCC policy adoption.

Overall, wealthier states are positively correlated with this electricity regulation trend, highlighting the relationship between economic equity and the ability to enact robust climate policy. In addition, high residential electricity prices diminish the positive effect of per capita income when accounting for the interaction between the two variables. Government ideology is also significant and positively correlated with SCC policy adoption. Therefore, conservative states with relatively high industrial electricity prices, and high residential electricity prices measured against personal income, are more averse to SCC policy adoption, and vice versa.

State SCC Rankings

When examining the entire political economy model I posit in this paper, there are clear relative differences in SCC policy adoption propensity among the 38 continental states that have not yet implemented this energy regulation. One exercise that is helpful in distinguishing between these relative differences is to categorize the states into tiers, grouping states together using the previously discussed cumulative hazard measures. The top six states can be separated into three tiers:

- Tier 1 – Pennsylvania (cumulative hazard = 1814.578)
- Tier 2 – Virginia (1339.786) and Vermont (1203.673)
- Tier 3 – Rhode Island (826.125), Oregon (654.224) and Delaware (646.056)

Of the six states in the top three tiers, four are RGGI-affiliated. RGGI is the abbreviation for the Regional Greenhouse Gas Initiative, a greenhouse gas emissions cap-and-trade scheme among northeastern states that is a form of regional carbon pricing. Delaware, Rhode Island, and Vermont are current members of RGGI. Virginia recently passed legislation to join the cap-and-trade-program (St. John, 2020). Another state, Pennsylvania, has had their gubernatorial branch indicate interest in joining RGGI contingent on state legislature approval (Lavelle, 2019). Similarly, four of the ten states that have already implemented a SCC policy are RGGI members—Maine, Maryland, New Jersey, and New York. This trend, coupled with the existence of California's cap-and-trade program, suggests that there may be a relationship between the adoption of SCC policies and existing use of other carbon pricing mechanisms. Initial observations on the spatial distribution of the cumulative hazards also indicate that a relatively large portion of western and northeastern states have either already adopted or are trending towards adoption of SCC policies, given their internal determinants. Although spatial diffusion was not the focus of this paper, this trend may become statistically significant as more states adopt SCC policies, and could be a focus of future research on the implementation of this type of electricity regulation.

As mentioned previously, there are three main types of SCC policy with respect to electricity regulation: integrated resource planning (IRP), resource compensation or zero emissions credits (ZEC), and cost-benefit analysis (CBA). Which type of policy each of these states will adopt is dependent on the regulatory structure of their electricity market. In states such as Colorado or Minnesota that have vertically integrated utilities, PUCs can incorporate the IWG SCC values into the IRP process. In states with deregulated electricity markets such as Illinois or New York, ZECs or other forms of resource compensation can be used to account for the benefits of cleaner sources of electricity generation (Grab, Paul, and Fritz, 2019). Since many of the high ranking states–Pennsylvania, Virginia, Rhode Island, Oregon and Delaware–are relatively deregulated electricity markets, it may make sense for them to adopt a resource compensation program as a type of SCC policy. This trend suggests that resource compensation, as opposed to integrated resource planning, may be a more popular SCC policy in the short-term if these states are the next ones to adopt. For a RGGI member state like Delaware or Rhode Island, they should adjust their SCC value with respect to the existing carbon price under RGGI.

Since the creation of this paper's model, one of the high ranking states with respect to the relative cumulative hazard measure, Virginia, has implemented the SCC in energy policy. In March 2020, Virginia's legislature passed the Clean Economy Act, with Governor Ralph Northam signing it the next month (Roberts, 2020). The bill aims to make the state's electricity sector 100% carbon-free by 2045. Included in the bill is a mandate for the State Corporation Commission, Virginia's PUC, to use the SCC when reviewing the integrated resource plans of utilities, similar to existing SCC states such as Colorado and Minnesota (St. John, 2020). The adoption of SCC policy by Virginia, therefore, validates the predictive power of this paper's political economy model.

Unilateral State Policies and Optimal Regulatory Scale

As the trend of state-level SCC policy adoption continues, it is important to note the phenomenon's tension with climate policies at a larger scale, be they national or international. States, through the SCC policies discussed in this paper and energy mandates such as renewable portfolio standards, have created a patchwork of incongruent regulations. Piecemeal welfare policies, however, may not increase social welfare if they lead to differences in sectoral competitiveness (Sattinger, 1970). For some state governments, therefore, especially those with relatively high industrial and residential electricity prices measured against income, unilateral SCC electricity policies may generate concerns about short-term economic disadvantages resulting from regulation addressing the negative externality of carbon emissions, which occurs at a level much greater than the jurisdictional scale of a state. These perceived economic disadvantages may include the aforementioned relationship between high industrial electricity prices and manufacturing employment leakage to non-regulated, neighboring areas.

An optimal welfare policy is one that matches the scale of the externality. There are clearly different scales of optimal policy with respect to the global negative externality of climate change. A first-best policy is a global carbon pricing system, either through cap-and-trade or a carbon tax. Such an international climate agreement could incentivize greater participation by creating a "climate club," whereby non-member countries face a modest border carbon tax

(Nordhaus, 2015). This border adjustment for the carbon content of traded goods is similar to the electricity import constraints states might consider when enacting their own unilateral carbon pricing schemes, so as to avoid carbon leakage into neighboring states. A second-best policy is national in scale and scope. The United States could use a similar border adjustment mechanism if it enacted a national-level carbon tax. A third-best policy would be regional, covering the emissions of multiple states, such as RGGI's cap-and-trade scheme.

After a regional multi-state policy, state policies, such as those using the SCC in resource compensation, resource planning, and most efficiently, an economy-wide carbon tax, are the next best option for addressing this negative externality. Currently, the United States only maintains third-best and fourth-best electricity policies that confront the negative externality of climate change, with less than a dozen states utilizing the SCC in electricity regulation. As evidenced by the relationship between relatively high electricity prices, low income, and SCC policy adoption, not all states can afford to adopt the third-best or fourth-best policies. Therefore, in the absence of a global or national carbon pricing scheme, there are natural leaders at the state-level with respect to climate policy, those states with relatively low electricity prices and high per capita incomes.

Although a second-best policy, such as a national carbon tax, may not necessitate that states already administrate their own unilateral or multilateral carbon pricing schemes, the SCC policy adoption phenomenon, in combination with other carbon pricing programs such as RGGI, may shift the national conversation towards a policy that is more appropriate for the scale of the externality. It is clear that the adoption of the SCC in electricity regulation has already motivated other states to follow the trend and implement their own SCC policies such as resource compensation or resource planning. These policies are less direct than a carbon tax, which may make them more politically palatable. Washington state, for example, uses the SCC in resource planning but failed to pass a carbon price ballot initiative, twice (Roberts, 2018).

Unfortunately, the slow, disjointed nature of politics often constrains the rapid, collective action needed to avoid serious economic harm from climate change, the very damages made explicit by the SCC. What might be an optimal policy from a purely economic perspective does not always translate to the complex, paradoxical realities of the American political economy. In this way, states currently using the SCC to inform energy regulation are but one pioneering phase of the United States economy's transformation towards a better accounting of the social costs of climate change and the inevitable clean energy transition.

Model Limitations and Future Research

The use of the social cost of carbon in electricity regulation is a relatively new phenomenon, with only 10 states having adopted some form of SCC policy since 2015. Given this regulatory tool's emergent status, this initial study has some limitations which merit more research on this policy adoption topic. Future studies, especially once more states adopt SCC policies, could look at a variety of variables that have been shown to be significant in the innovation of other state-level energy and climate policies, such as renewable portfolio standards.

A few specific political and economic determinants may be significant in future research, given this study's examination of the role of electricity prices in SCC policy adoption, specifically the rates experienced by the industrial sector. Industrial influence on the legislative and regulatory processes, possibly analyzed by some measure of lobbying power, may have an effect on state-level SCC policy adoption, due to the desire to avoid increased electricity prices from the incorporation of climate damages. Similarly, states that maintain high industrial productivity relative to their overall economy may be less inclined to adopt this type of electricity regulation. Environmental and other public interest advocacy groups may be a counteractive factor with respect to the industrial lobby. Another force in this sphere which merits future study is the effect of legislative or regulatory professionalism, measured by each institution's available resources, due to the technical aspect of this policy. With more technical expertise available, states may be better equipped to initially implement and later administrate SCC policies. Creating a SCC policy stringency index, perhaps distinguishing rigor by the combination of different regulatory methods such as resource compensation, resource planning, and cost-benefit analysis, may also make for insightful analysis on this adoption phenomenon with respect to the economic and political determinants discussed above.

Outside of future research on the internal determinants regarding SCC policy adoption, exogenous factors are also an important consideration as more states adopt SCC policies. Past state-level policy innovation research has utilized external diffusion models, looking at the effect of national, regional, and neighboring state adoption on other states' propensity to adopt various policies. This factor was not examined in this study due to the relatively small number of states, only 10 of the continental 48, that have adopted a SCC policy of some kind so far. National-level event shocks with respect to climate policy, on both the progressive and conservative extremes, may also provide an interesting indicator of the speed with which states adopt electricity regulations such as a SCC policy. Examples of these external events include the Trump administration's recent devaluation of the federal SCC and dissolution of the IWG, or a national-level carbon tax, which is more likely to occur with a different administration.

Conclusion

The use of the social cost of carbon in electricity regulation is an emerging policy trend. Utilizing a Cox proportional hazards regression model to conduct an event history analysis, this paper looked at internal determinants, both economic and political, in the adoption of such policies. Retail electricity prices, specifically industrial electricity prices, were found to be statistically significant and negatively associated with driving this policy adoption trend. This relationship supports previous research on the industrial sector's short-run price inelastic electricity demand and its tendency to locate in areas with relatively lower electricity prices. Liberal governments are also positively associated with SCC policy adoption. In addition, high residential electricity prices diminish the positive effect of per capita income, and vice versa, when accounting for the interaction between the two variables.

The Cox model was used to rank the remaining 38 continental states that have not yet adopted some form of SCC policy based on their cumulative hazards. The resulting ranking indicates that Pennsylvania, Virginia, and Vermont have the highest estimated relative rates of SCC policy adoption, based on the model's economic and political predictor variables. States that maintain environmental cost statutes are highlighted, a statutory precedent that provides strong legal basis for incorporating the IWG SCC in regulation to account for climate damages. SCC advocates may want to prioritize their efforts in states that both have this statutory authority and rank highly in their propensity to adopt. RGGI-affiliated states also constitute a significant portion of existing SCC states and those that have relatively high adoption hazard estimates, suggesting that previous experience with carbon pricing is an indicator of state-level SCC policy implementation. In addition, resource compensation may be a more popular form of SCC policy in the short-term, as opposed to integrated resource planning, due to the relatively deregulated nature of electricity markets in the model's high ranking states.

Given this study's findings, as well as the limitations of its political economy model, there are many opportunities for future research on this subject. Future studies could analyze other internal determinants, such as regulatory resources or the industrial sector's economic and political leverage. External factors, such as spatial or ideological peer diffusion and exogenous events, are another area of interest. As more states adopt SCC policies, better data will be available to further examine this electricity policy adoption phenomenon aiming to better account for the social costs of climate change.

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