The Influence of Political Ideology on Carbon Emissions

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Abstract

Liberal states emit less carbon than conservative ones on average, but the causal mechanisms behind this are unclear. While there is a substantial body of work that focuses on economic motivators, there is a growing literature that highlights the surprisingly significant role of politics. I expand on this literature by analyzing two domains of climate policy and environmental outcomes: carbon intensity and energy intensity. I find compelling evidence that liberal states are far more aggressive than their conservative counterparts in terms of policy adoption, strong evidence that ideology influences energy intensity outcomes, but weak evidence that ideology influences carbon intensity outcomes. Liberal states face profound difficulties implementing renewable energy policy, so to overcome this, I recommend that legislators bundle polarizing renewable energy policy with more broadly popular incentives and efficiency standards.

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1 Introduction

Climate change is the most pressing issue of the twenty-first century.[1] More Americans than ever before perceive climate change as both a personal and national security risk (Ballew et al. 2019), and see a greater role for government in addressing this issue (Tyson, Funk, and Kennedy 2023). Politicians also understand the need to act: in 2020, Joe Biden ran his successful presidential campaign on the most aggressive climate change platform out of any major party nominee in history, and since then, has committed the United States to cutting carbon emissions to 50-52% of 2005 levels by 2030 (Lashof 2024).

Despite this growing awareness, climate change is still one of the most politically difficult policy domains. Belief in the scientific consensus that climate change is man-made still falls largely along partisan lines (McCright, Dunlap, and Marquart-Pyatt 2016; Chan and Faria 2022), and one of two major political parties maintains its skepticism on whether the problem exists at all (Mildenberger 2020). Politically sustainable climate action is threatened by the abstract and scientific nature of climate change, whose elite-driven messaging alienates conservatives (Tesler 2018). Political viability is further threatened by the need for policy solutions that often incur short-term costs for the long-term, indeterminate benefits of reducing carbon emissions. Even once passed, policy must survive opposition from entrenched fossil fuel interests,[2] and politicians must risk suffering electoral consequences for forwarding a low-carbon transition.[3] These challenges have led scholars to place a great deal of importance on the political determinants of deep decarbonization.

Numerous works have identified the struggle that politicians face in translating emission reduction as a legislative priority into meaningful results. Past studies highlight cases where governments fail to adopt much-needed climate policy (Fransen et al. 2023), and perhaps more unfortunate, cases where governments adopt policy yet fail to reach their desired outcomes (Bättig and Bernauer 2009). Even politicians designated as *Climate Champions* by the United Nations fail to meaningfully adjust fossil fuel taxes and subsidies (Martinez-Alvarez et al. 2022). Despite these challenges, left governments still generally perform better on environmental outcomes than their right-wing counterparts (Wang et al. 2022). Reconciling this with the understanding that there are numerous areas where politicians fail to induce long-term change through policy requires a deeper analysis. I propose that there are areas of climate policy where ideology has immediate and significant influence, and areas where ideology is trampled by other, more pressing economic or geographic interests.

I seek to find the extent to which political ideology influences carbon emissions. I approach this problem by estimating the effect of political ideology on

[1]Replication files can be found at https://github.com/eigenstuffs. Please contact brandenb@ucla.edu if there are any issues.

[2]Eisenack et al. (2021) outline how fossil fuel interests hamper policy implementation, and argue the importance of evaluating foregone fossil fuel profits.

[3]Stokes (2016) finds evidence that a wine turbine project resulted in a 4-10% electoral loss for the local incumbent party. Copland (2020) highlight how Australian conservative actors leveraged the Clean Energy Act to topple the Gillard government in 2013.

state climate policy and environmental outcomes, focusing on two domains: carbon intensity and energy intensity.[4] Carbon intensity is defined as the amount of carbon emissions per unit of energy, whereas energy intensity is defined as the amount of energy consumed per unit of GDP.

I choose this framework as the leaders in American renewable energy production are a relatively diverse mix of red and blue states (Kirk 2023), whereas energy efficiency outcomes are consistently higher among Democratic states (Berg et al. 2020), suggesting a potential discrepancy in the effect of political ideology. This discrepancy makes sense, as these domains differ vastly in incentive structures: today's fossil fuel consumption burdens future generations, whereas energy efficiency leads to immediate savings. Punishing carbon emissions burdens the fossil fuel industry with explicit costs, whereas energy efficiency is a cost-saving mechanism of emission-intensive industries. These distributional conflicts are likely to manifest in how ideology interacts with carbon and energy intensity. The literature justifies an interest in this framework: left governments tend to prioritize environmental quality (Wen et al. 2016) and improve energy efficiency standards (Chang, Lee, and Berdiev 2015), but scholars disagree over how ideology influences renewable energy adoption.[5][6] Modeling outcomes side-by-side with measures of policy aggressiveness provides the opportunity to identify any gaps in implementation or enforcement that explain why ambitious policy sometimes fails to make a meaningful impact.

My results suggest three key takeaways that are of interest to the study of political ideology and environmental outcomes. First, states with a more liberal legislature ideology experience significant energy intensity improvements over conservative legislatures. I argue that this may be a function of individual political attitudes, as consumers have greater power to act on environmentalist beliefs when purchasing energy efficient products, vehicles, and utilities. I also note that energy efficiency incentives for both business and households are less immediately threatening to fossil fuel interests and voters concerned over electricity costs, which allows for more sustainable policy. In applying my results to case study evidence, I find that the fossil fuel industry is highly receptive to energy efficiency incentives, especially as an alternative to renewable energy mandates. In sum, liberal states do not face significant challenges translating energy efficiency policies into outcomes.

Second, liberal states fail to see immediate improvements in carbon intensity outcomes relative to conservative states. I interpret this result cautiously, as liberal states do perform better than conservative states in the long-term. The failure to see significantly different outcomes from conservative states year-

[4]These are components of the Kaya identity, which also includes GDP per capita and population. Carbon emissions are a function of these four features.

[5]Trachtman (2020) finds that energy efficiency policy has more bipartisan appeal than renewable energy policy.

[6]Thonig et al. (2021) find that governments across the spectrum have similar renewable energy targets; Clulow et al. (2021) find that left voters support renewable technologies more than right ones; Arslan, Koyuncu, and Yilmaz (2023) find that left and centrist governments are associated with greater renewables consumption. It is not clear how these findings translate to the United States, where climate change is uniquely polarized.

over-year can be partially attributed to intentionally incremental policy design.[7] I initially argue that the falling cost of renewable energies[8] would be appealing to conservatives in pursuit of "energy independence," but find evidence suggesting the opposite, in that carbon intensity partisanship actually rises over time. Finally, I propose that the cost of implementation (both in terms of explicit cost and in terms of political backlash) is higher for certain carbon intensity policies, like performance standards[9] and cap-and-trade,[10] which may be underestimated by legislators. These policies are likely to face years-long implementation difficulties, and are thus more vulnerable to shifts in partisanship and lobbying. I find evidence in favor of this, in that fossil fuel interests are exceptionally agile and effective in broadly opposing climate policy, but that their most pressing concerns are rejecting the preferential treatment of renewable energy. Liberal states face significant difficulties translating carbon intensity reduction from a legislative aspiration to tangible outcomes.

Third, liberal states tend to adopt policies targeting both carbon intensity and energy intensity at a rate significantly higher than conservative states. This suggests an evolution in how states adopt climate policy: the calculus has become more complex than whether localized climate policy co-benefits outweigh the explicit and tacit costs of implementation; instead, it has followed the trends of polarization seen in almost all other policy domains. My findings suggest that liberal legislatures struggle immensely to translate their carbon intensity policy regimes into tangible outcomes. The political contentiousness of both carbon intensity and energy intensity policy suggests that more immediately meaningful policies in both domains (namely performance standards, distributed generation, and decoupling incentives) should be bundled with sustainable policies like the solar tax credit, voluntary efficiency incentives, and weak but mandatory renewable portfolio standards, which have broader bipartisan appeal.

I contribute to the literature by extending the study of political ideology and carbon emissions to carbon intensity and energy intensity, in wake of the nuanced relationship between ideology and climate policy adoption. Modeling policy adoption with environmental outcomes also allows for an interesting side-by-side analysis, yet to be applied to the question of ideology and climate policy.

I begin by reviewing the literature on how scholars understand political ideology to relate to environmental outcomes and climate policy. I then derive my hypotheses from theoretical arguments and preliminary evidence. I then discuss why and how I acquire my data, and justify my choice of methodology. I present my empirical results and expand upon them with exploratory data and qualitative analyses. The final section concludes.

[7] California's Renewables Portfolio Standard, for example, sets minimum renewable energy thresholds for electricity providers. Ambitious goals are established over many years, even decades, with smaller goals enforced intermittently.

[8] Two-thirds of renewable power added in 2020 had lower costs than the cheapest coal options in G20 countries (*Renewable Power Remains Cost-Competitive amid Fossil Fuel Crisis* 2022).

[9] Performance standards limit the amount of CO_2 per unit of energy

[10] Cap-and-trade is a method of carbon pricing which creates a market for producers to buy and sell carbon allowances.

2 Literature Review

2.1 Ideology and Emissions

Scholars are confident in the ideological divide between liberals and conservatives on climate change (McCright, Dunlap, and Marquart-Pyatt 2016), with conservatives less in favor of investment in energy-efficient technology (Gromet, Kunreuther, and Larrick 2013), conservation campaigns, funding for renewable energy research (Wolters, Steel, and Warner 2020), and climate-conscious behavioral changes (Chan and Faria 2022). Governments tend to reflect this, with left-wing governance being associated with fewer emissions among the least polluted countries (Chang, Wen, et al. 2018), left-wing parties preferring environmental quality over economic performance – unless under pressure for said performance (Wen et al. 2016) – and American states with more liberal citizen ideology emitting less carbon dioxide (Gokkir and Barkin 2019). The understanding of political ideology and emissions is further nuanced by disassembling climate policy: left-wing parties are associated with energy efficiency improvements (Chang, Lee, and Berdiev 2015) and increased secondary education spending (Wang et al. 2022), two investments that decrease emissions long-term. On the other hand, scholars have found left-wing governance to have a small effect on decarbonization and renewable energy targets (Thonig et al. 2021), no significant effect on the net price of fossil fuels (Martinez-Alvarez et al. 2022), and, contrary to conventional wisdom, carry less stringent environmental policy than their partisan counterparts (Tawiah 2022), suggesting that left-wing governments have not successfully harmonized environmentalist worldviews with meaningful outcomes in all areas. Due to the seemingly inconsistent effect of political ideology on certain climate policies and outcomes, which fluctuates throughout countries of different pollution levels and stages of development (Wang et al. 2022), it is imperative to delve deeper into the effect on specific emission components.

2.2 Decomposition and the Kaya Identity

Due to the wide array of political, social, and economic consequences brought about by different paths of decarbonization (Bigerna and Polinori 2021), it is useful to separate emissions into easily understood components. Decomposition analysis – that is, the analysis of specific emission contributors – is integral in assessing the most important drivers of carbon emissions and uncovering potential policy levers (Ma and D. I. Stern 2008). Various frameworks exist for decomposing emissions, but the Kaya identity is commonly used in the literature, simplifying emissions into a function of energy intensity, carbon intensity, affluence, and population (Kaya 1990). Criticisms arise given the simplistic nature of the Kaya identity and its applications to large-scale economic transformations (Kemp-Benedict 2012), but because state decarbonization efforts are gradual and stable transitions, and the sub-national literature using the Kaya identity is growing, precedent is strong for this identity to be used. Sub-national applications of the Kaya identity yield important findings around the world – for example, Eastern European countries face barriers to decarbonization due to lower disposable incomes (Bigerna and Polinori 2021), Ireland's renewable energy penetration has a minor yet increasing mediating effect on economic drivers (Mahony 2013), and the United Kingdom's universities failed to reach decarbonization targets, despite lower overall emissions, because of reduced renewable usage (Eskander and Nitschke 2021)). The logic for pursuing a similar lens of analysis for American states is similar: state A and state B may have similar emissions per capita, but state A may have achieved this by dramatically improving its energy efficiency, while state B may have achieved this by leveraging its natural potential for wind energy; overall emissions are not indicative of the decarbonization pathways of each state, and fail to reveal their relevant social, economic, and political implications. Additionally, similar to (Bigerna and Polinori 2021), this kind of analysis can reveal how certain states may be financially or politically restricted from decarbonizing, or increasingly capable of it through technology and policy transfer. Finally, the consistency of political structure among American states allows for a more generalized understanding of the interaction between ideology and emissions. Knowing how political ideology impacts energy intensity versus carbon intensity allows us to direct policy towards areas where action is politically feasible and effective, allowing states to specialize in specific contexts where they may excel due to their geographic, economic, or political attributes.

2.3 Support for Climate Policy

Liberal political ideologies are associated with greater concern over climate change, and thus willingness to act. The acceptance of climate policy is one facet of environmental activism (P. C. Stern 2000), and is characterized by a willingness to incur financial costs, in the form of higher prices or taxes, and behavioral costs, like effort or inconvenience (Drews and Van Den Bergh 2016). The immediate costs of many climate policies and the perception of indeterminate benefit further threatens their political viability. Indeed, this effect may be more problematic than uncertainty about climate change itself (Weber 2015).

One of the most contentious climate policies is the carbon tax (Carattini, Carvalho, and Fankhauser 2018). A strong explanatory factor is the growing distrust of 'political elites' among voters, which conseravtive interests can leverage to present climate policy in a *liberal elite* versus *working class* paradigm: such a strategy was highly influential in the opposition to the Gillard Government's *Clean Energy Act* in Australia, the Trump Administration's withdrawal from the Paris Climate Agreement, and the Yellow Vests Protests in France (Copland 2020). This *anti-politics* sentiment (Mete 2010) is difficult to navigate, especially in cases liike the carbon tax, where support for the policy grows after implementation (Murray and Rivers 2015). In America, both conservatives' skepticism of and liberals' belief in climate change are functions of political interest, and Republicans would be more receptive to climate policy if more Republican political leaders expressed belief (Tesler 2018), indicating a problem where the people who understand the most about climate change (climate scientists) cannot argue for mitigation without alienating conservatives.

Climate policies can be divided into two main categories: policies that "push" measurements in the form of punishment to fossil fuels or electricity consumption, and policies that "pull" and incentivize behaviors favorable to decarbonization (Drews and Van Den Bergh 2016). "Push" policies are those like the carbon tax and cap-and-trade, which tend to receive high levels of citizen opposition (Rhodes, Axsen, and Jaccard 2017), while "pull" policies are those like subsidies and R&D investment, which tend to be highly popular (Tobler, Visschers, and Siegrist 2012; Lam 2015). The public opinion of regulatory policy is more nuanced: polling shows it to be highly popular, but support drops off when a clear price signal is attached (Lachapelle, Borick, and Rabe 2014), indicating that policy support among both Democrats and Republicans declines when costs are made explicit (Bergquist, Mildenberger, and Stokes 2020). Even among voters who would otherwise be receptive to climate policy, the specific design (whether it be regulation, mandates, incentives, strategies) is highly important and could be a mechanism by which political ideology affects emission components differently.

2.4 Closing Remarks

The literature is consistent that left-wing governance is associated with reduced carbon emissions. The mechanisms behind this are unclear, but scholars understand that left-wing governments push for higher energy efficiency standards, struggle to substantially reform fossil fuel taxes or subsidies, and risk adopting less stringent policies than their multiparty counterparts. The effect of left-wing governance is most present across developed and less-polluting countries, so looking at the United States as the unit of analysis is most interesting for my research question. The interaction between political ideology and policy support is nuanced, but generally has similar takeaways: liberals support climate policy more than conservatives, and political viability tends to be threatened by elite-driven polarization and explicit costs.

I identify a notable gap in the literature, in that there is preliminary evidence supporting a disparate effect of ideology on carbon intensity and energy intensity, yet no work on the subject. Scholarship on the political economy of climate change is increasingly complex, and if the effect indeed is disparate, this methodological choice may allow future scholars to fine-tune our understanding of political obstacles to a low-carbon future. Policymakers can also leverage these findings to identify cases where meaningful climate action has been achieved, even in spite of the state's political lean.

3 Argument

Before conducting my analysis, I leverage preliminary data on environmental outcomes across American states and the existing literature on political ideology and carbon emissions. I cover two strands of thought on how states decide to act on climate change, and extrapolate from this to argue why legislative ideology may or may not influence a state's carbon and energy intensities.

3.1 States and Climate Policy

State legislatures specialize in the delivery of localized benefits (Bagashka and Clark 2016), so the incentives to tackle geographically-dense problems like air pollution fail to carry over to the global public good[11] of decarbonization. Despite this, American climate policy has shifted to a state-centric approach[12] in the wake of national inaction. I aim to justify their surprising ambition.

States are not subject to the same decarbonization incentives as countries. Countries like the United States may be such prominent emitters that nationwide action can lead to globally notable outcomes, but most states are relatively small economic actors that would fail to make such an impact.[13] They are also not subject to the top-down influence of comparable sub-national governments, as there is no federal policy on carbon emissions, and until 2015, the EPA lacked the authority to directly regulate carbon emissions under the Clean Air Act.

Two dominant theories exist on how states decide to adopt climate policy. The *climate federalism*[14] view suggests that decarbonization becomes a legislative priority when the localized benefits of climate policy – air quality, job potential – outweigh costs – literal costs like taxes or job loss, and the opportunity cost of fossil fuel investment. The second is *polarized federalism*,[15] whereby partisan factors increasingly dominate economic ones in determining climate policy adoption and intensity (Trachtman 2020). This view suggests that liberal states will outperform conservative ones on policy, prioritizing political will over climate policy co-benefits.

These co-benefits are vast; I outline two that I find especially relevant to the climate federalism framework. First, legislators can benefit politically from relatively weak climate commitments. Rabe (2008) highlights policies like the renewable portfolio standard, which carry less immediate efficacy but greater localized co-benefits, as being especially desirable to state legislators. Other scholars argue that legislators can benefit from gaps between climate policy rhetoric and observable outcomes due to voters' climate demands and incomplete information on outcomes (Bättig and Bernauer 2009). Voters are acutely

[11] A good that is non-excludeable and non-rival, requiring strong commitment from all countries (Bättig and Bernauer 2009).

[12] Rabe (2008)

[13] Engel (2006)

[14] Much of Barry Rabe's work argues the importance of these co-benefits; see Rabe (2008) for an introduction.

[15] Originally coined by Grumbach (2018)

aware of explicit costs attached to policies like the carbon tax,[16] so these "soft" policies may benefit from being weaker by design: indeed, voters favor subsidies and other pull[17] policies over policies configured as mandates (Hess, Mai, and Brown 2016). These policies also avoid placing the economic losses directly onto the fossil fuel industry: legislators may face less organized resistance from the industry and policy may be more sustainable.

Second, legislators are motivated by economic factors: they can exploit climate change to diversify the energy grid of their state and supply new jobs to their districts (Engel 2006). The green transition brings significant job-growth potential: all non-fossil fuel technologies create more jobs per unit-of-energy than coal and natural gas (Wei, Patadia, and Kammen 2010), although the minimal geographic overlap between where fossil fuel jobs are lost and where clean energy jobs are created serves as a potential caveat (Gazmararian and Tingley 2023). Conservative support for the somewhat vague notion of "energy independence" is perhaps greater than ever, especially in response to President Joe Biden's rejection of Russian oil imports in response to the country's 2022 invasion of Ukraine, giving renewable energy the politically desirable co-benefit of energy diversification.

Much of the recent empirical work and preliminary evidence suggests some kind of polarized federalism. Democratic states still broadly outperform Republican ones in terms of energy efficiency, renewable energy consumption, and overall emissions (Berg et al. 2020; EIA 2023; Gokkir and Barkin 2019). Trachtman (2020) finds compelling evidence that political factors are increasingly more powerful than economic factors in determining policy adoption. The general divergence between Democratic and Republican state policy since 2000 suggests that this may be a more recent phenomenon (Grumbach 2018), although with the caveat that state chambers are still generally less polarized than the national Congress (Shor and McCarty 2011).

One motivator in-line with the polarized federalism framework is the potential for politicians to position themselves against entrenched interests. Whereas the sentiment on the populist right is greatly hostile to the green transition,[18] those on the populist left may gauge a candidate on their hostility towards the fossil fuel industry. Another (perhaps more broad) motivator is that climate action is becoming more popular, especially among liberals. In otherwise liberal districts, climate policy is simply an act of being a responsible politician.[19]

To summarize, there are two main arguments on what motivates a state to decarbonize. Legislators either gauge support for climate policy based on the localized co-benefits against the costs (both economic and political), or adopt policy in-line with growing partisanship of state legislature policy. More recent

[16] Drews and Van Den Bergh (2016) attach this to the perception of climate policy, a significant determinant of public support.

[17] Policy that "pulls" people and companies towards more favorable behavior.

[18] Copland (2020) applies this paradigm to case studies on the 2013 Australian federal elections, the Trump Administration's withdrawal from the Paris Accords, and the French Yellow Vest Protests.

[19] Engel (2006))

work has suggested a shift towards the latter framework, with political factors increasingly taking preference over economic ones.

3.2 Carbon Intensity

States reduce their carbon intensities through two main strategies: pulling states towards renewable energy, and pushing states away from fossil fuels. States may punish excess carbon emissions via taxing them, or by creating a market for the purchase and sale of finite carbon permits. They may set enforceable limits on the amount of carbon dioxide emitted per unit of energy generated, or reimburse companies who operate more carbon-efficiently than others. To encourage renewable energy, states subsidize technological advancements that lead to lower lifetime costs, and reimburse residents who purchase or generate it on-site. They also set thresholds for electricity providers to reach minimum renewable energy standards.

Numerous factors explain why liberal states could perform better on carbon intensity than conservative states. Left-wing and centrist governments around the world promote greater renewable energy consumption than right-wing counterparts (Arslan, Koyuncu, and Yilmaz 2023), and left voters are far more supportive of renewable energy technology than right-wing voters (Clulow et al. 2021). It is expected by polarized federalist view that liberal legislatures will adopt renewable energy earlier than conservative ones: Democrats support renewable energy for environmental reasons above economic ones (Gustafson et al. 2020), suggesting they may be eager to become early adopters.

The first caveat is that left-leaning states could struggle to reduce carbon intensity due to political resistance. Electorally, voters are hostile to green energy projects due to concerns over noise or visual pollution.[20] The fossil fuel industry, too, organizes in mass to resist measures that either punish carbon emissions directly or position renewable energy as a viable threat to their incumbency, oftentimes before states can divert from their "carbon lock-in." This is more immediately a concern for concentrated, punitive measures – pricing carbon makes an explicit loser of the fossil fuel industry, whereas the costs of subsidies are more broadly distributed. Grumbach (2018) outlines why concentrated and well-resourced interest groups, like the fossil fuel industry, excel in lower levels of government: groups are agile, and can redirect efforts to exploit more favorable state legislators with greater informational and resource constraints. This is remarkably easy for fossil fuel interests, who are tasked with only upholding the status quo and provide significant funding to conservative political movements (Kirk 2020).

The second caveat is that the falling cost of renewable energy could appeal to conservative legislators. This naively assumes that these actors are rationally promoting fuel sources based off of complete information about lifetime cost and geographic opportunity, but is nonetheless worth discussing. Two-thirds of energy added in 2020 from renewable sources was cheaper than the

[20]Renewable projects perceived as too disruptive can turn voters away from the incumbent party (Stokes 2016).

most affordable coal option (*Renewable Power Remains Cost-Competitive amid Fossil Fuel Crisis* 2022), making clean energy lucrative to all legislators. Stokes (2020) suggests that, while falling costs make wind and solar cost competitive with natural gas and coal plants, policymakers must contest with the cheaper maintenance costs of existing plants and the emergence of greater resistance efforts from a threatened fossil fuel industry. Nonetheless, renewable energy generation has increased in states both with and without a renewable portfolio standard (Upton and Snyder 2017), so there is preliminary evidence suggesting that falling production costs are reflecting in greater supply.

Carbon intensity reductions are a deeply complex clash of incentives. Liberal states undoubtedly have greater political will for renewable energy consumption and the immediate and aggressive reduction of carbon emissions, but they face significant resistance from voters and fossil fuel interests. Conservative legislators receive significant funding from these interests and serve electorates more culturally or economically tied to fossil fuels, but they also may see potential in energy diversification, job potential, and falling costs.

I hesitate to make any frivolous claims of causality, as the mechanisms are simply beyond the scope of this thesis, but I am confident that the reduction of carbon intensity is politically difficult, which may burden liberal states. I also expect the localized co-benefits to manifest in environmental outcomes, such that conservative states pursue renewable energy as the costs fall and economic opportunity arises. Based on this, I do not expect state legislature ideology to be a significant predictor of carbon intensity.

3.3 Energy Intensity

Energy efficiency is the primary means by which states reduce their energy intensity: promoting efficient products and utilities, educating the population to be more environmentally conscious, and subsidizing public transportation are three mechanisms by which governments can accomplish this. Other contributors are industrial structure and population agglomeration, long-run changes that are more exogenous to political ideology than efficiency standards.

One argument in favor of liberal states experiencing lower energy intensity is the relative importance of individual decision-making. Liberals are far more open to climate-friendly behavior changes and are more willing to incur costs to be more energy efficient (Chan and Faria 2022; Gromet, Kunreuther, and Larrick 2013). We can then expect liberals to live their environmentalist values by using energy efficient utilities, products, and modes of transportation, like electric vehicles and public transportation. Similar opportunities to reduce one's carbon footprint through renewable energy are limited, and often limited to homeowners (solar tax credits, net metering, mandatory renewable energy option, etc.), a voter block that leans majority conservative (Hadziabdic and Kohl 2022).

Liberal states appear to perform better on other important determinants of energy intensity as well. Politicians are likely to reflect their constituency's political views regarding transit services (Connolly and Mason 2016), suggesting that the quality of public transportation is higher in liberal cities and states.

Demand for public transit is elastic to service quality (Litman 2004), so I expect this to manifest in greater ridership and, consequentially, fewer transportation emissions. Democratic-majority chambers also raise educational spending across the board (Saeki 2005), whereas right-wing parties generally concentrate spending on universities and limit their spending in times of economic downturn (Manzano 2013). This can negatively influence energy efficiency in the long-term: energy awareness (Hassan et al. 2009) and targeted energy education programs (Zografakis, Menegaki, and Tsagarakis 2008; Keller et al. 2022), are both linked to more desirable energy consumption behavior.

One notable caveat is that energy efficiency is a cost-saving mechanism as much as it is a means to reducing emissions. While conservatives fail to incur costs to make their consumption more energy efficient (Gromet, Kunreuther, and Larrick 2013), they may be receptive to voluntary programs if they lead to significant savings on electricity. For customers of publicly-owned utilities, efficiency programs saved electricity at an average cost of 2.4 cents per kilowatt from 2012 to 2017 (Friedrich and Eldridge 2009). This appears to be a mutually-beneficial relationship: by 2025, savings from customer-funded efficiency programs are expected to offset most of the load growth (Barbose et al. 2013). We could feasibly expect conservative states to pursue energy efficiency as a means to save on electricity.

Industry is receptive as well: in improving energy intensity, incentives are largely aligned between environmentalists and fossil fuel stakeholders. Indeed, government often promotes voluntary programs like the EPA's Energy Star cooperate with industry to incorporate energy efficiency both as an environmental strategy and as a means to reduce production costs. These efforts manifest in energy efficiency being "by far" the least costly energy resource option for utility resource portfolios (Friedrich and Eldridge 2009). State policies like electricity and gas decoupling also reimburse companies for less product sold, rewarding companies for favorable behavior rather than punishing them. This should minimize opposition from the conservative-aligned fossil fuel industry, and suggests state legislature ideology may not be a significant predictor of energy intensity.

There are convincing reasons that state legislature ideology could either play a significant or insignificant role in energy intensity. I am swayed by the preliminary Berg et al. (2020) data which lauds Democratic performance on energy efficiency, rebuking my caveat about these standards having broad bipartisan appeal. From this, I expect state legislature ideology to be a significant predictor of energy intensity.

3.4 Model of State Climate Policy

There are compelling reasons to believe that ideology could have anywhere from a marginal to a deeply influential effect on both carbon intensity and energy intensity. Relating this back to the prior discussion on what motivates state climate policy, I argue that, since belief in climate change falls largely along a partisan divide, climate policy is intrinsically partisan. My caveat is that when the localized co-benefits of renewable energy grow and costs fall, conservative states will be drawn to carbon intensity policy. This will be reinforced by conservative states being geographically suitable for renewable energy generation. I do not expect a similar trend for energy intensity, as efficiency standards should be equally attractive to all states at any given time. For these reasons, political ideology will be a significant predictor of energy intensity, but not carbon intensity. I expect policy to follow this trend as well, and believe I will see broad declines in carbon intensity between liberal and conservative states.

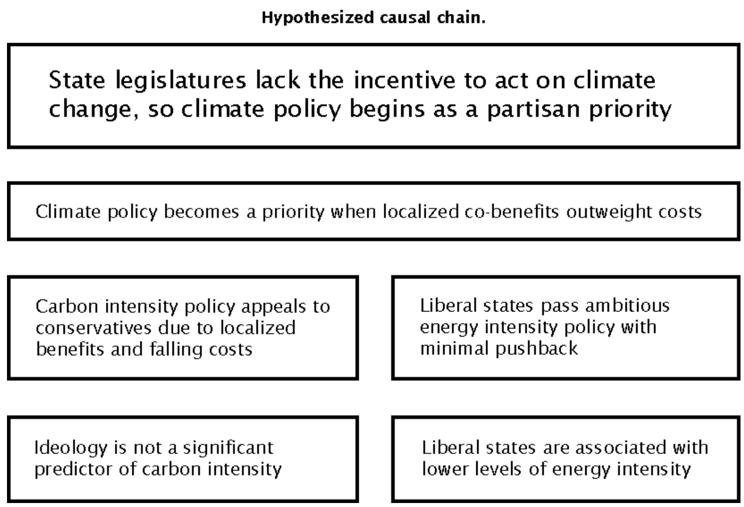

Figure 1: Hypothesized causal chain.

3.5 Hypotheses

I formally state my hypotheses as follows:

- H_1: The more liberal (conservative) the state legislature ideology, the lower (higher) the state's energy intensity.
- H_2: State legislature ideology is not a significant predictor of a state's carbon intensity.

Two additional exploratory hypotheses are nominated to analyze policy regime and environmental outcomes side-by-side. These were developed after the initial analysis, so in an effort to be consistent, they were derived from the same arguments presented above:

- H_1: The more liberal (conservative) the state legislature ideology, the more (less) energy intensity policies the state has enacted.
- H_2: State legislature ideology is not a significant predictor of a state's carbon intensity policy regime.

I reject or accept these hypotheses based on my permutation inference results at the 95% significance level.

4 Data

The units of analysis for this study are American states from 1998 to 2020. To create my panel data set, I first acquire estimates of population and GDP per capita from the U.S. Bureau of Economic Affairs, and estimates of energy and carbon intensities from the U.S. Energy Information Administration.

I collect a number of supplementary variables that influence either intensity but are exogenous to state legislature ideology. Industrial structure is a strong predictor of energy intensity, so I collect data from the U.S. Bureau of Economic Affairs on the proportion of people employed both in farms and the manufacturing sector to the total labor force in a state. Population agglomeration is also a useful variable of interest, as more sparse regions demand greater transportation and trade emissions. As a proxy, I obtain data on the urbanization rates of states from the Iowa Community Indicators Program.[21]

Additionally, I leverage data on each state's average global horizontal irradiance and average wind speeds at 120 meters, as to estimate their geographic suitability for renewable energy generation.[22] This data originates from the National Renewable Energy Laboratory (NREL)'s 2020 Reference Access collection, which conservatively accounts for land use exclusions and is used in NREL capacity expansion modeling (Sengupta et al. 2018). I perform a spatial join[23] to categorize each site by state, before computing the averages.

As proxies for political ideology, previous works have used metrics such as environmental group membership (Dietz et al. 2015), binary left/right categorizations of national government ideology (Wang et al. 2022), or measures of citizen ideology (Gokkir and Barkin 2019). The state legislature ideology index created by Shor and McCarty (2011) – and updated by Shor and McCarty (2022) – provides a unique opportunity to have a continuous measure of legislature ideology.[24] This has reason to part from citizen ideology: the influence of interest groups, their fellow party members, or pressure from fossil fuel-dependent (through direct employment or otherwise) voters could influence their climate policy priorities or stances in ways that individuals would not experience. I create a variable to represent the expected value of each state's legislative chambers.

I collect data on state climate policy from Bergquist and Warshaw (2023), who leverage government sources, NGOs, academia, and domain expertise to provide categorical and continuous measures of comparable climate polices between states over time. Certain categorical variables have multiple levels,[25] so

[21]Data originally stems from the U.S. Census Bureau's Decennial Census.

[22]I initially collected data on fossil fuel reserves and consumption, but these are likely endogenous to political ideology. Also, it is difficult to determine whether a state's reserves are low due to over-consumption or minimal resources to begin with.

[23]I use the built-in `states.x77` R data to identify all sites within each state's borders.

[24]Comparability between states is established via surveying state and national candidates on key issues.

[25]For example, renewable portfolio standards can either not exist, be voluntary or mandatory at less than 1%, be mandatory and between 1 and 100%, and be mandatory at 100%. These are coded as 0/1/2/3 and are treated as factors.

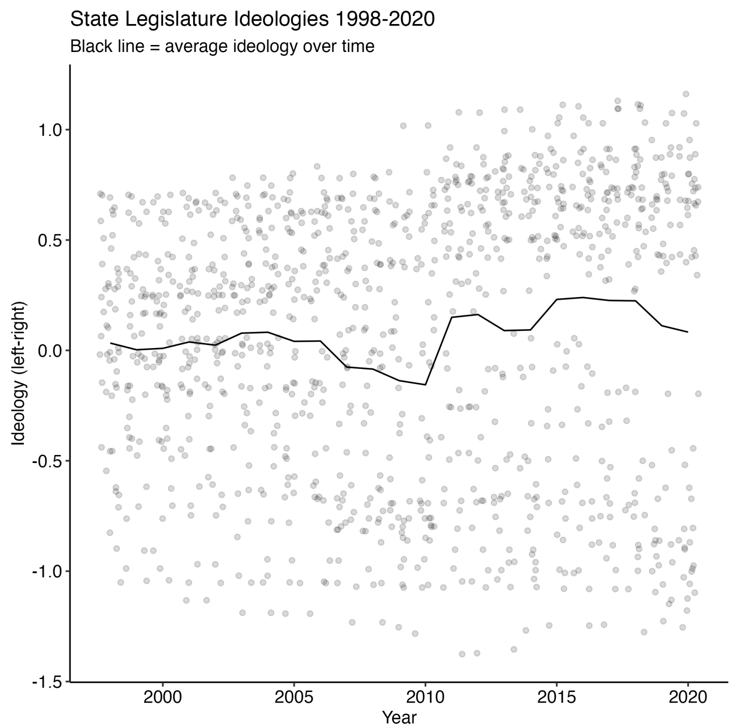

Figure 2: Average state legislature ideology over time.

in computing each state's policy score for each year, I award one point per layer of stringency.[26]

I code each policy as targeting either carbon intensity, energy intensity, or both/neither, before horizontally summing the values for each state/year combination, producing tallies (or scores) of overall climate policy, energy intensity policy, and carbon intensity policies. In the Appendix, I present each policy covered in the data, alongside its description, levels, and categorization. Some policies are more loosely connected to an intensity metric than others, so these counts should be scrutinized and improved upon in future works. Below, I present a brief summary of the categorizations.

Some variables used in the exploratory multiple linear regression models require imputation or have missing data. I address my approaches to handling these cases in the Appendix. I also propose a log transformation for all variables, but only apply it to carbon intensity, energy intensity, GDP per capita, and population. I also discuss this further in the Appendix.

After acquiring all necessary data, I transform it into state-year panel format,

[26] Another approach was to award partial points, but this seemed too conservative, as wide-reaching policies with multiple layers of stringency are greater determinants of climate policy regime than less-controversial policies like climate action plans or solar tax credits.

Table 1: Policies from Bergquist and Warshaw (2023) by Category

Carbon	**Energy**	**Both**
• Community solar (0/1) • Cap on greenhouse gas emissions for utilities (0/1) • Natural gas hookup bans are prohibited (0/1) • Mandatory fuel disclosures (0/1) • Performance standards (0/1) • Net metering (0/1/2) • Residential solar tax credit (0/1/2) • Power plant emission reporting (0/1/2) • Renewable sources offered (0/1/2) • Renewable portfolio standard (0/1/2/3)	• Public building standard (0/1/2) • Complete streets (0/1/2) • Energy efficiency targets (0/1/2) • Low-income energy efficiency programs (0/1/2) • Electricity decoupling incentives (0/1/2/3) • Gas decoupling incentives (0/1/2/3)	• Climate Action Plan (0/1) • Public benefit funds (0/1) • PACE (0/1) • State equivalent to NEPA (0/1/2) • Emission reduction targets (0/1/2) • Car emission standards at or above the level of CA (0/1)

where each observation is a unique state-year combination. This results in a new panel data set of 1,150 observations, of 50 states over a 23 year period.

5 Methodology

To model the extent to which state legislature ideology impacts carbon and energy intensity, I apply fixed effects OLS models and permutation inference. I accompany this with exploratory multiple linear regression models.

5.1 Econometric Models

I propose the following log-linear fixed effects OLS models:

$$\begin{aligned} \log(CarbonIntensity_{it}) = \beta_0 + \beta_1 \cdot Ideology_{it} + \beta_2 \cdot \log(Population_{it}) \\ + \beta_3 \cdot \log(GDPPerCapita_{it}) + \alpha_i + \gamma_t + \varepsilon_{it} \end{aligned} \quad (1)$$

$$\begin{aligned} \log(EnergyIntensity_{it}) = \beta_0 + \beta_1 \cdot Ideology_{it} + \beta_2 \cdot \log(Population_{it}) \\ + \beta_3 \cdot \log(GDPPerCapita_{it}) + \alpha_i + \gamma_t + \varepsilon_{it} \end{aligned} \quad (2)$$

I include state-year fixed effects aim to hold constant variation attributable to time (e.g. the falling lifetime cost of renewable energy, technological innovations, awareness about climate change) and location (e.g. weather, geography, natural resources). I include the logged `GDPPerCapita` and `Population` as controls as they are components in the Kaya identity and relatively time-variant, meaning that their changes will not be sufficiently captured by state-year fixed effects. The income of a population also is positively correlated with more climate-friendly consumption choices, making it an ideal control.

To explore the importance of potential economic and geographic determinants of carbon emissions, I propose an additional set of multiple linear regression models:[27]

$$\begin{aligned} \log(CarbonIntensity) = \beta_0 + \beta_1 \cdot Ideology + \beta_2 \cdot \log(GDPPerCapita) \\ + \beta_3 \cdot \log(Population) + \beta_4 \cdot PercentManuEmpl \\ + \beta_5 \cdot PercentFarmEmpl + \beta_6 \cdot GHI \\ + \beta_7 \cdot Speed120m + \beta_8 \cdot PercentUrban + \epsilon \end{aligned} \quad (3)$$

$$\begin{aligned} \log(EnergyIntensity) = \beta_0 + \beta_1 \cdot Ideology + \beta_2 \cdot \log(GDPPerCapita) \\ + \beta_3 \cdot \log(Population) + \beta_4 \cdot PercentManuEmpl \\ + \beta_5 \cdot PercentFarmEmpl + \beta_6 \cdot GHI \\ + \beta_7 \cdot Speed120m + \beta_8 \cdot PercentUrban + \epsilon \end{aligned} \quad (4)$$

[27] `PercentManuEmpl` and `PercentFarmEmpl` are the proportion of part-time and full-time employees employed in the manufacturing and farming industries. `GHI` is the average solar exposure of all sites in a state, and `Speed120m` is the average wind speed at 120 meters of all sites in a state. `PercentUrban` is the ratio of the urban population to the total population.

I do not include state-year fixed effects as many of my independent variables are time-invariant. Including both risks "confusing" the model and attributing inconsistent significance to certain predictors.

These multiple linear regression models are problematic. I observe many non-normal variables, utilize imputation methods that risk incorrect estimations, and exclude Hawaii and Alaska due to the NREL estimates covering only the contiguous United States. The OLS models have better diagnostic plots and include the complete 50 states, so I use them to validate my hypotheses.

I extend the OLS model to analyze policy regimes, proposing three models that use running tallies of policy score, carbon intensity policy score, and energy intensity policy score as dependent variables:

$$\begin{aligned} PolicyScore_{it} = {} & \beta_0 + \beta_1 \cdot Ideology_{it} + \beta_2 \cdot \log(Population_{it}) \\ & + \beta_3 \cdot \log(GDPPerCapita_{it}) + \alpha_i + \gamma_t + \varepsilon_{it} \end{aligned} \tag{5}$$

$$\begin{aligned} CarbonScore_{it} = {} & \beta_0 + \beta_1 \cdot Ideology_{it} + \beta_2 \cdot \log(Population_{it}) \\ & + \beta_3 \cdot \log(GDPPerCapita_{it}) + \alpha_i + \gamma_t + \varepsilon_{it} \end{aligned} \tag{6}$$

$$\begin{aligned} EnergyScore_{it} = {} & \beta_0 + \beta_1 \cdot Ideology_{it} + \beta_2 \cdot \log(Population_{it}) \\ & + \beta_3 \cdot \log(GDPPerCapita_{it}) + \alpha_i + \gamma_t + \varepsilon_{it} \end{aligned} \tag{7}$$

I include the same independent variables as the previous OLS models as to establish direct comparability for the effect size of `Ideology`.[28]

5.2 Outliers

States that under- or outperform their political ideology are an integral part of understanding the politics of decarbonization, but they also distort the model's applicability to new data. I propose variations of each model with influential values removed – a point is *influential* if it has a Cook's Distance of over $\frac{4}{n}$, where n is the sample size of the data – an approach supported by the diagnostic plots before and after. The robustness of my findings will be supported if the signs, significance, and approximate magnitude are similar between the models with and without outliers.

5.3 Permutation Inference

To obtain more robust results amidst questions of model fit (see Appendix), I apply permutation inference. Permutation inference is a non-parametric method

[28] I take the natural log of the environmental outcome variables, but not the policy scores, which affects interpretation. See Appendix for further explanation.

that concerns itself not with the distributions of the data, but the comparison between test statistics. My approach involves storing my statistic of interest (the effect size of `Ideology`) and running one thousand null models where the variable of interest is permuted. I determine the significance of the *true* effect based on whether it is greater than 95% of the *fake* effects.

I permute `Ideology` by performing a circular shift on the state legislature ideologies of each state, such that they maintain the same order, but the order begins in different years. Maintaining order is a conservative approach that intends to reduce bias induced by artificial variability and between-group variation. Still observing significance in the shuffled `Ideology` predictor would indicate that the effect is not significantly different from chance and I would fail to reject the null hypothesis.

This approach has potential vulnerability to states whose legislature ideology has remained constant over two decades analyzed. Shuffling the ideologies of a state of this kind has very little meaning if all values are similar, and the result is likely to not be of much interest and bias the resulting distribution. I am confident that, since state legislators are up for election frequently, legislatures generally have been becoming more partisan, and ideology has shifted dramatically in many states (see Appendix), this risk is minimized. Further work could better accommodate this potential shortcoming.

6 Results

I begin by exploring the correlational relationships between political ideology and my dependent variables of interest.

I find a weak linear relationship between political ideology and carbon intensity. There is a moderately strong linear relationship between ideology and energy intensity.

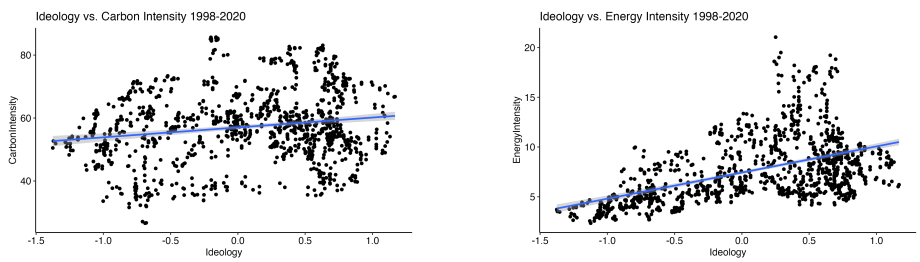

Figure 3: Ideology and Environmental Outcomes

I plot political ideology and policy scores. Both relationships are considerably strong. The slope for carbon intensity policy is steeper, indicating a stronger relationship.

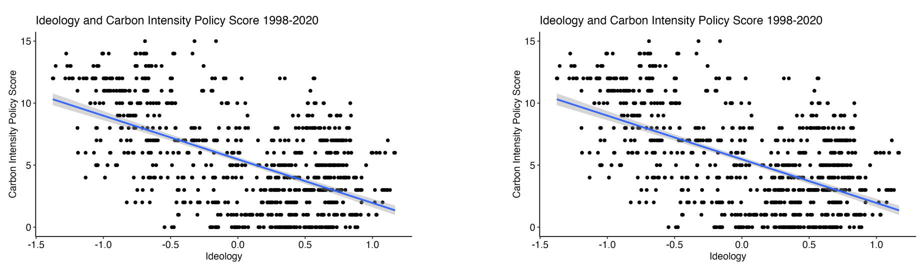

Figure 4: Ideology and Policy Scores

I then seek to test whether my environmental outcomes of interest are related to their respective policy score. I find that the relationships are about equally as strong between carbon intensity and energy intensity policy. There is a moderately strong, negative linear relationship between more policies and improved outcomes.

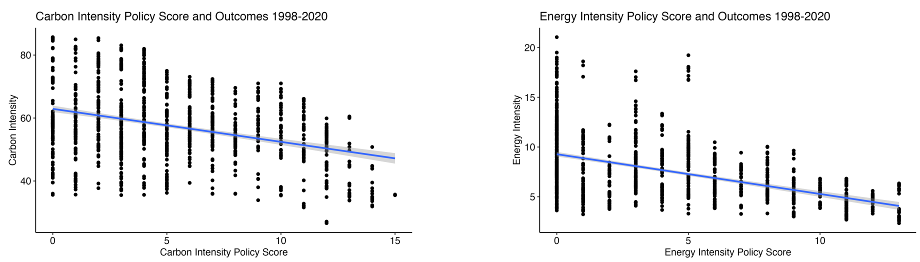

Figure 5: Policy Scores and Environmental Outcomes

I first present my regression tables and Wald tests, before testing my hypotheses with permutation inference and performing exploratory analysis to detect potential lagged effects between ideology and environmental outcomes.

6.1 Regression Tables

According to the fixed effects OLS models, a one-unit shift in state legislature ideology towards the right is associated with an insignificant 0.36% increase in carbon intensity, and a significant 2.36% increase in energy intensity. The p-values are 0.655 and 0.007 respectively. The multiple linear regression models estimate that a one-unit shift in state legislature ideology towards the right is associated with a 5.98% increase in logged carbon intensity, and a 16.87% increase in logged energy intensity. Both p-values are effectively zero.

Dependent Variables:	log(CarbonIntensity)	log(EnergyIntensity)
Model:	(1)	(2)
Variables		
Ideology	0.0036	0.0236***
	(0.0080)	(0.0080)
log(Population)	0.0731*	-0.3352***
	(0.0410)	(0.0350)
log(GDPPerCapita)	-0.0732***	-0.2882***
	(0.0223)	(0.0605)
Fixed-effects		
State	Yes	Yes
Year	Yes	Yes
Fit statistics		
Observations	1,134	1,134
R^2	0.96210	0.98338
Within R^2	0.01720	0.13189

Driscoll-Kraay (L=2) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notably, the predictive accuracy in the models with energy intensity as the dependent variable are significantly higher, both for the fixed effects OLS models and the multiple linear regressions. The within R^2 statistics for the fixed effects models[29] are 13.189% for the energy intensity model, and 0.0172% for the carbon intensity models.

The general R^2 statistics are remarkably similar, indicating that state-year fixed effects explain significant variation in carbon intensity.

The adjusted R^2 statistics for the multiple linear regression models are 70.54% for energy intensity, and 26.06% for carbon intensity. Interestingly, across both models, the difference in variance explained brought about by excluding influential points is greater for the models predicting carbon intensity. This suggests a stronger influence of outliers in carbon intensity models. When removing influential points, the effect size of ideology increases for carbon intensity by 0.0007, and falls for energy intensity by 0.0039.

[29]Within R^2 represents the proportion of variance explained within each state and year.

Dependent Variables:	log(CarbonIntensity)	log(EnergyIntensity)
Model:	(1)	(2)
Variables		
Constant	3.683***	2.973***
	(0.2171)	(0.1592)
Ideology	0.0598***	0.1687***
	(0.0054)	(0.0088)
log(GDPPerCapita)	-0.2714***	-0.4342***
	(0.0335)	(0.0402)
log(Population)	-0.0118***	0.0013
	(0.0028)	(0.0087)
GHI	0.0903***	0.1691***
	(0.0156)	(0.0070)
Speed120m	0.1156***	0.0418***
	(0.0067)	(0.0075)
PercentUrban	0.0044***	-0.0082***
	(0.0006)	(0.0006)
PropManuEmployment	-0.5862***	-0.0176
	(0.1369)	(0.1160)
PropFarmEmployment	-0.4497**	7.155***
	(0.1830)	(0.7837)
Fit statistics		
Observations	1,088	1,088
R^2	0.26600	0.70757
Adjusted R^2	0.26056	0.70541

Driscoll-Kraay (L=2) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

I find that the majority of variance explained comes from state fixed effects.[30] Whereas the state-year carbon intensity model explains 95.94% of variance, a model with only state fixed effects explains 93.72% of variance. Removing state fixed effects and including time fixed effects results in a poor model that explains only 12.22% of variance. A similar (but less extreme) phenomenon exists for energy intensity: the state-year fixed effects model explains 98.22% of variance, a state fixed effects model explains 98.07%, while a year fixed effects model explains only 57.02%.

[30]See Appendix for full models.

Dependent Variables:	CI_Score	EI_Score
Model:	(1)	(2)
Variables		
Ideology	-2.102***	-1.280***
	(0.3476)	(0.2734)
log(Population)	-4.053***	-6.391***
	(1.105)	(0.8820)
log(GDPPerCapita)	-3.814**	-6.069***
	(1.355)	(1.384)
Fixed-effects		
State	Yes	Yes
Year	Yes	Yes
Fit statistics		
Observations	1,134	1,134
R^2	0.89162	0.83711
Within R^2	0.18276	0.09139

Driscoll-Kraay (L=2) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Further fixed effects OLS modeling suggests that a one-unit shift rightwards in ideology is associated with a -2.1 unit decrease in the amount of carbon intensity policies, and a -1.28 unit decrease in the amount of energy intensity policies. The within R^2 is higher for carbon intensity policy, suggesting that the dependent variables are better predictors.

6.2 Wald Tests

Model	Dependent Variable	stat	p	df1	df2	vcov
OLS	log(CarbonIntensity)	0.20	0.65	1	1059.00	D-K (L=2)
	- No influential	0.56	0.45	1	1006.00	D-K (L=2)
OLS	log(EnergyIntensity)	8.75	0.00	1	1059.00	D-K (L=2)
	- No influential	6.45	0.01	1	986.00	D-K (L=2)
MLR	log(CarbonIntensity)	124.10	0.00	1	1079.00	D-K (L=2)
	- No influential	368.08	0.00	1	1079.00	D-K (L=2)
MLR	log(EnergyIntensity)	61.33	0.00	1	1035.00	D-K (L=2)
	- No influential	285.23	0.00	1	1030.00	D-K (L=2)

Wald tests estimate the individual significance of the political ideology predictor, under the assumption that the sampling distribution of the estimator is normal. The exploratory models suggest that political ideology is a significant predictor of both, but the test statistics vary significantly, showing that the effect size for the logged energy intensity is up to 2 times that of carbon intensity.

In the fixed effects OLS models, political ideology is a significant predictor of energy intensity, but not carbon intensity. The Wald statistics suggest that, in these models, ideology is over 40 times as strong a predictor for energy intensity than it is for carbon intensity.

6.3 Permutation Inference

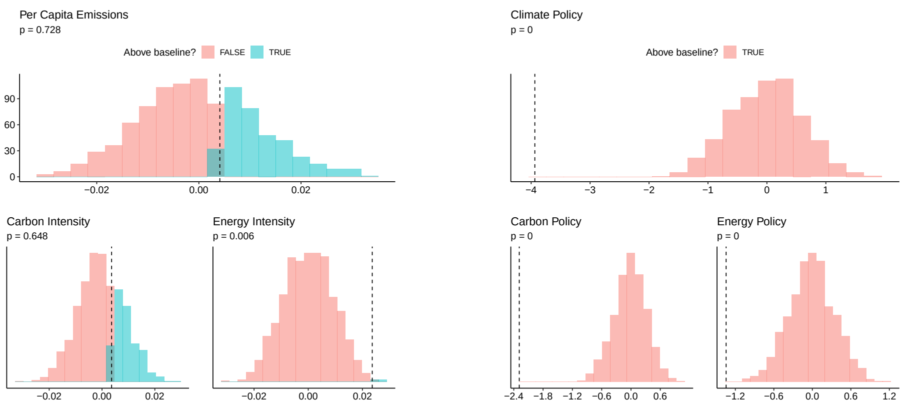

Figure 6: Permutation inference results for the effect of ideology on various dependent variables.

I employ permutation inference to test the effect size of state legislature ideology against the null hypothesis that the effect is insignificant from zero. I present the distribution of the "fake" effect sizes, generated by shuffling `Ideology`, and calculate the proportion of those greater than or equal to the true effect size (denoted by the dashed black line) to obtain the p-value. If $p < 0.05$, I verify the hypothesis that the dependent variable in question is statistically significant.

According to the permutation tests, ideology is only a significant predictor of energy intensity, not carbon intensity or per capita carbon emissions: less than 5% of the fabricated effect sizes are equal to or greater than the true effect size. The effect of ideology is significant for all metrics of climate policy; no fabricated test statistics are greater than the true effect size.

6.4 Exploring Lagged Effects

Given that I observe a correlational relationship but no formal significance, I attempt to expand upon my carbon intensity modeling by asking whether ideology has a lagged effect. Renewable energy policy can take years to pass through legislatures, and can face resistance from the fossil fuel industry at any time in its lifespan. It would be reasonable, then, to expect that observable changes in carbon intensity attributable to political ideology will not immediately.

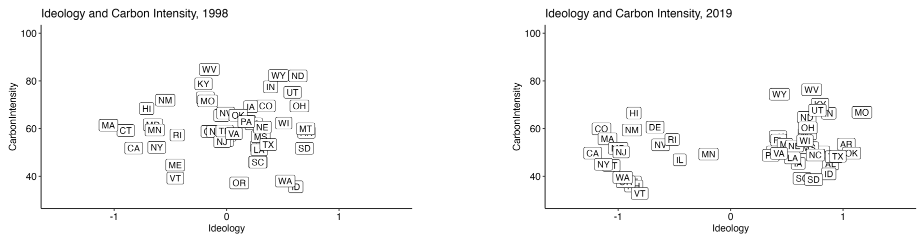

Figure 7: Ideology and Carbon Intensity, 1998 and 2019

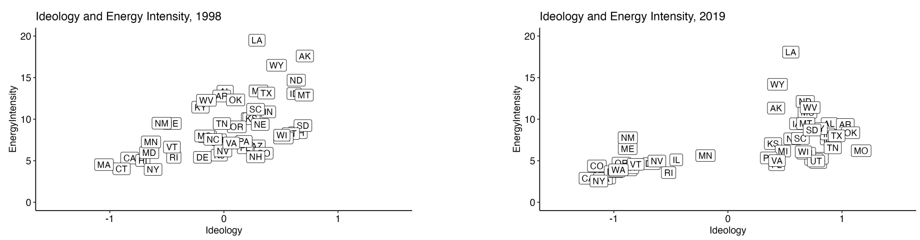

Figure 8: Ideology and Energy Intensity, 1998 and 2019

To answer this question informally, I plot the relationship between state legislature ideology and environmental outcomes in 1998 and in 2019, to observe within-state variation (excluding 2020 for pandemic-related reasons).

The relationship between political ideology and carbon intensity appears greater over time. In 1998, there is essentially zero effect, whereas in 2019, there is a slight positive effect. For energy intensity, outcomes are highly polarized in 1998, and although the slope has become less extreme, are still highly polarized in 2019.

I conduct a brief formal test on whether the effect of political ideology is lagged: I iterate five models,[31] lagging state legislature ideology by one additional year each iteration, and compare both the coefficient effect sizes of ideology and the root mean square error (RMSE) of the model.

I find weak evidence that the effect of political ideology is larger with lags applied - indeed, the models' coefficients become smaller in magnitude after the third lag at about the same rate. Interestingly, the p-values for the ideology coefficients become smaller between first and fifth lag. Ideology remains an insignificant predictor of carbon intensity throughout, but reaches a p-value of 0.66 by the fifth lag. The within R^2 statistics for both intensities also increases over time: the carbon intensity model with no lag explains only 1.72% of variance within units, whereas the five year-lag model explains 2.01%. Without a lag, the energy intensity model explains 13.19% of within unit variance, whereas

[31] I choose five years as the Shor and McCarty (2022) index currently spans 1993-2020.

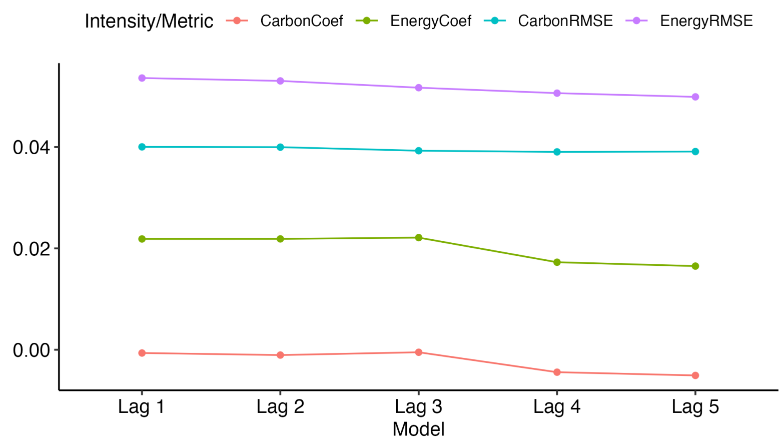

Figure 9: Metrics of lagged models

the five year-lag model explains 17.81%. This can also be partially attributed to potential lagged effects of per capita GDP, as this predictor also becomes slightly more significant over time, although by changes in magnitude less extreme than ideology. This could be interpreted to suggest that the true effect of ideology is small but significant over long periods of time, but I lack the data to formally test such claims. Future work should examine lagged effects with greater rigor.

I expand on the implications of my results below. The Appendix also includes omitted models without outliers, and a discussion of the fixed effects.

7 Discussion

I find compelling evidence that state legislature ideology is a significant predictor of energy intensity. The regression coefficients, Wald tests, and permutation inference all verify this. These findings are of the same signs, significance, and approximate magnitude when outliers are excluded. I accept my hypothesis that political ideology is a significant, positive predictor of energy intensity.

I find weak evidence that political ideology is a significant predictor of carbon intensity. The permutation inference results and Wald tests show nearly zero effect, whereas my exploratory modeling and visualizations show at least some long-term correlation. I cautiously accept my hypothesis that political ideology is not a significant predictor of carbon intensity.

I find strong evidence that political ideology is a significant determinant of carbon intensity and energy intensity policy adoption. The effect is slightly larger for carbon intensity policy. I reject my hypothesis that political ideology is not a significant predictor of carbon intensity policy, and accept my hypothesis which stated the opposite for energy intensity policy.

My hypothesized causal chain was deeply flawed: energy intensity policy actually possesses more bipartisan appeal than carbon intensity policy, and distributional conflict plays a greater role in carbon intensity than previously anticipated. I explore potential mechanisms below using exploratory analysis and brief case studies, before presenting a revised causal chain.

7.1 Case Study Applications

By focusing on states that outperform or under-perform relative to their ideological allies, I apply my findings to explain unlikely successes in otherwise hostile political environments. I explore South Carolina and Delaware for their efforts towards reducing carbon intensity, and Massachusetts and Arizona for for their efforts towards reducing energy intensity.

South Carolina: The Palmetto State has no renewable portfolio standard and, in 2021, generated less than 10% of its energy from renewable sources (EIA 2023). Nonetheless, it has the fifth best baseline level of carbon intensity, outperforming every conservative state except Iowa.

South Carolina has no in-state extraction of its second and third-most utilized electricity sources, coal and natural gas (EIA 2023). Its renewable generation is similarly challenged: despite being ranked 14th nationwide for installed solar capacity, solar generation has only marginally improved in recent years and composes less than 10% of total consumption (CNEE 2022). The state does, however, have four operating nuclear power plants, which are responsible for over half of the state's electricity generation.

Over its life-cycle, nuclear emits about the same amount of carbon per unit of energy as wind, and about one third as much as solar (WNA n.d.). Given the political hostility towards nuclear energy, it is far from a universal solution, but South Carolina shows its potential to serve as a stopgap on the path to a renewable energy grid: from 2008 to 2021, the proportion of electricity generated by coal decreased from 41% to 15.1% (CNEE 2022). Advocating the construction of new nuclear plants is insufficient due to their long construction time and high costs (Bowen, Ochu, and Glynn 2010), but the continued operation of them contributes significantly to a low-carbon future.

The most valuable insight lies in how incumbent interests react to renewable energy expansion. South Carolina's electric power companies share in the opposition to renewable energy, despite their reliance on the low-carbon source of nuclear. Duke Energy, which runs six nuclear plants between the Carolinas, recommended to the state legislature in 2010 that South Carolina implement tax credits for investment and returns on the achievement of clean energy goals (House 2023). It also encouraged the use of the phrase "clean energy" rather than "renewable energy" to include nuclear and energy efficiency. Progress Energy Carolina (which eventually merged with Duke) explicitly condemned the favoring of renewable energy, instead preferring the use of softer incentives.

This case study illustrates that even clean energy actors ally with fossil fuel coalitions to reject giving preferential treatment to renewable energy. They are, however, open to renewable energy incentives and energy efficiency measures. The legal use of the phrase "clean energy" could assist in leveraging the broad political appeal of energy efficiency while still directing resources towards renewable energy. Climate change is an issue that demands immediate action – policymakers should leverage policies that are attractive to powerful incumbents. The use of a "good fit" paradigm[32] for diagnosing climate policy solutions would be especially useful in balancing the political economy of climate policy with utility maximization.

Delaware: The First State lags behind many of its liberal peers in terms of carbon intensity. Despite having the 12th highest binding renewable portfolio standard target, over 85% of Delaware's electricity consumption comes from natural gas (EIA 2023). Surprisingly, this isn't the result of significant reserves: the state has no oil or natural gas activity (CNEE 2017).

Delaware's limited success is not without promise; the solar industry has shown promising developments in response to state policy. 2010 legislation extended a carve-out for solar energy in the state's renewable portfolio standard: by 2025, 3.5% of sales must come from solar photovoltics. Legislation also included solar renewable energy certificates (SREC), whereby companies could "trade-in" their solar generation for direct compensation. Between 2011 and 2021, utility-scale solar generation grew from 7 to 61 GWh (EIA 2023).

The SREC became hugely popular. In 2017, an "excess of bids were submitted to the auction due to oversupply of solar in the market" (Heeter et al. 2018). Subsequent results have shown promise. In the early years of Delaware's renewable portfolio standard, the state fell slightly short of its goal. In 2014, 2015, and 2016, Delmarva Power – the primary company mandated with meeting the state's RPS target – achieved full compliance without resorting to alternative payments. Several thousand new solar developments were eligible to benefit

[32]The recommendation of policies based on what is likely to succeed in the political environment, rather than what is optimal for utility maximization.

from these incentives (Heeter et al. 2018).

Delaware's experience relates to South Carolina. South Carolina's status quo coalition rejects renewable energy mandates in favor of incentives, and Delaware has successfully leveraged incentives to foster a solar industry. Independent of the solar carve-out and the state's RPS (two important policies in their own right), Delaware's SREC has succeeded in guaranteeing long-term contracts and stimulating the distributed generation of solar. Given that distributed generation is highly provocative towards the monopoly power of fossil fuels (Stokes 2020), this success, albeit small, is especially appealing. Delaware is a special case, as the sole buyer of certificates is Delmarva Power, but it nonetheless shows potential for a state with a relatively weak appetite for renewable energy to stimulate clean energy growth. Such lessons can be applied to states vulnerable to big fossil fuel interests.

Massachusetts: In 2020, the state with the highest energy efficiency resource standard[33] (EERS) target was Massachusetts. Much of their progress can be traced to the 2008 Green Communities Act, which required electric and gas utilities to secure efficiency resources that are cost-effective or less expensive than supply as a first recourse. It also required the adoption of the International Energy Conservation Code (IECC) and mandated updates within one year of each revision.[34] The Bay State is an undeniable leader in the realm of energy efficiency, scoring second on the nationwide Berg et al. (2020) scorecard.

The landmark 2008 legislation also included many renewable energy initiatives: it implemented the cross-state auction of Regional Greenhouse Gas Initiative pollution permits, with 80% of the revenue going to utility efficiency programs. This was paired with net metering and modest increases to the renewable portfolio standard (a target of 15% by 2020). It also authorized municipalities to install renewable energy generating facilities (up to 10 MW) and sell any electricity and products (such as renewable energy certificates) from such facilities (Gold 2008). This is a clear example of a Democratic trifecta forwarding aggressive carbon intensity reduction alongside efficiency standards.

Why then, in spite of its ambition, is Massachusetts is a leader in energy efficiency, and a relative under-performer in carbon intensity? One mechanism behind this is lobbying – four coalitions routinely oppose climate and clean energy bills: (1) utilities, (2) fossil and chemical companies, (3) real estate companies, and (4) fossil fuel power generation companies (Hall, J. Culhane, and J. Roberts 2021). Utilities have a long-understood opposition to policies that encourage distributed generation – unsurprisingly, National Grid, one of two large utilities in the state, has repeatedly lobbied against bills to expand decentralized solar generation (Vardi 2020). Fossil fuel, generation, and chemical companies have a clear vested interest in preserving fossil fuel incumbency. Real estate is the only industry out of the four with a clear mandate against energy efficiency, on the basis that it places an undue burden on homeowners.

[33]Energy efficiency resource standards (EERS) mandate that a specific amount of natural gas and electricity be procured with energy efficient measures.

[34]The IECC establishes minimum requirements for building systems using prescriptive and performance-related provisions (Council 2021).

The logic of reconciling this distributional conflict with promising efficiency outcomes is clear: fossil fuel and chemical companies can stand to benefit from energy efficiency as an environmental strategy and cost-saving mechanism (Friedrich and Eldridge 2009). On the other hand, any policy that positions renewable energy as a viable alternative threatens the incumbency of the fossil fuel industry, and attracts opposition.

This is was reflected clearly between 2008 and 2013, when no major climate action passed in Massachusetts, despite a Democratic trifecta. As expected, the utilities coalition supported some energy efficiency and large-scale wind and hydro project legislation, while opposing solar energy (Hall, J. Culhane, and J. Roberts 2021). They saw the greatest return on their efforts out of any coalition discussed, not by outspending, but by convincing legislators that the coalition's stance on legislation would be politically favorable (Hall, J. Culhane, and J. Roberts 2021). This, again, suggests a more abstract yet highly meaningful relationship between ideology and carbon intensity.

Relative to these powerful coalitions, pro-climate interests in Massachusetts are fragmented. Studies from the state conclude that, opposite to the broad support for climate policy exhibited by environmentalists, renewable energy firms fail to testify for legislation that does not direct economic benefits towards their industry (Basseches et al. 2022). Much of their effort is instead spent on narrow issues like RPS carve-outs (T. Culhane, Hall, and J. T. Roberts 2021). Other scholars note that Massachusetts' more concentrated renewable energy industries are more effective in lobbying (Si and Stephens 2021). The fossil fuel industry is highly agile and effective at lower levels of government – this disadvantages ambitious climate policy. Clean energy interests are too resource-limited to spread their efforts beyond what immediately benefits them.

The lessons drawn from Massachusetts pair well with that of the previous two cases: the politics of renewable energy and energy efficiency differ massively. Fossil fuel stakeholders are able to rapidly organize broadly against solar and wind expansion, and pro-climate interests are stretched too thin to compete. In Massachusetts, they are outspent more than 3.5 to 1 (Hall, J. Culhane, and J. Roberts 2021). Energy efficiency, relative to renewable energy expansion, sees minimal opposition, and is occasionally even supported by these powerful coalitions. Even when there is a strong political will for both renewable energy and energy efficiency, and when legislation passes that targets both, distributional conflict can explain why liberal states still observe underwhelming outcomes.

Arizona: In 2020, the conservative state of Arizona had the third highest EERS standard nationwide, ranking just behind the liberal states of Rhode Island and Massachusetts. The Grand Canyon State performs better than almost all conservative states in terms of energy intensity, making it a promising case study for the political viability of energy efficiency.

In 2010, the Arizona Corporation Commission (ACC) adopted mandatory standards for certain electric and gas utilities. By 2020, these investor-owned utilities would have to achieve cumulative electricity savings of at least 22% of 2019's retail electric sales through efficiency programs. The policy survived until its expiration in 2020, and has yet to be renewed. One year prior, the ideologically diverse Commission established net metering, which allows homes and businesses to sell their excess solar energy back to the grid. Net metering performed exceptionally well, which attracted intense opposition efforts that drained the solar industry of its growing cost-competitiveness (Stokes 2020).

The Arizona Corporation Commission is a separate elected body from the state legislature. Some even consider it the "fourth branch" of Arizona state government.[35] This theoretical independence does not play out in reality: as Stokes (2020) outlines, the ACC was vulnerable to significant regulatory capture by fossil fuel interests who relentlessly chipped away at net metering. Three years after the implementation of net metering (and two years after EERS enactment) the 2012 election saw Republicans sweep all five positions on the ACC. A subsequent 2013 ad campaign promoted by the Arizona Public Services Company (APS) rallied support for increasing costs on solar customers, viewing them as a threat to their monopoly power (Kotch 2016). This sudden shift away from climate ambition is well-illustrated in succeeding election cycles. The 2016 Republican primary debate for the Commission saw two out of three eventual general election winners raise skepticism about whether climate change was real, and the other questioning humanity's involvement. Neither of the first two left the Commission until forced out by term limits in 2021, and the remaining skeptic was appointed to state government in 2019.

While the EERS eventually expired in 2020, it survived a deeply well-funded and organized pushback against clean energy policy. From 2010-2019, energy efficiency investments cut the state's greenhouse gas emissions by more than 17 million metric tons, saved ratepayers more than $1.4 billion, and accrued nearly $4 in total benefits for every $1 spent (Climate XChange 2023). Net metering met a more disappointing fate. The Commission installed a $5 a month change on new solar customers, seen as a partial victory for solar advocates given the APS-proposed fee of between $50 and $100 (Smith 2019). Once these fees were imposed, installations by the affected companies fell abruptly, to the tune of over 75% quarter-over-quarter (Stokes 2020). In the years following, even amidst campaign finance scandals relating to APS, the Commission reduced the amount it was willing to pay for solar, and installations plummeted even further (Stokes 2020).

Much like we see in the previous three examples, policies that directly threaten the monopoly power of utilities, like net metering, are greater targets of fossil fuel coalitions. Even supposedly independent institutions are subject to the vast political challenges of promoting renewable energy. While not a substitute for renewable energy consumption, advocates should not neglect the significant environmental benefits of efficiency programs. Legislators should leverage energy efficiency in polarizing environments, as much like the Arizona EERS, these policies may be robust to partisan shifts and opposition efforts. The bundling of policies from both domains could assist their political viability.

Motivated by the apparent disparate political viabilities of certain policies, I turn my analysis to how ideology influences policy regimes.

[35] Stokes (2020)

7.2 Policy Regimes

Liberal states, in both categories, began with higher policy scores. Between 1998 and 2020, the partisan policy adoption gap widened significantly for renewable energy policy, and slightly widened for energy efficiency policy. I extend to this understanding by finding that broader bipartisan appeal for policy has not translated into bipartisan outcomes – the opposite is true.

In an effort to understand which policies are the most contentious, I run a series of generalized linear models with each policy's status as the dependent variable (each layer of stringency is one-hot encoded so that 1 = yes, 0 = no). I use political ideology as the sole dependent variable.

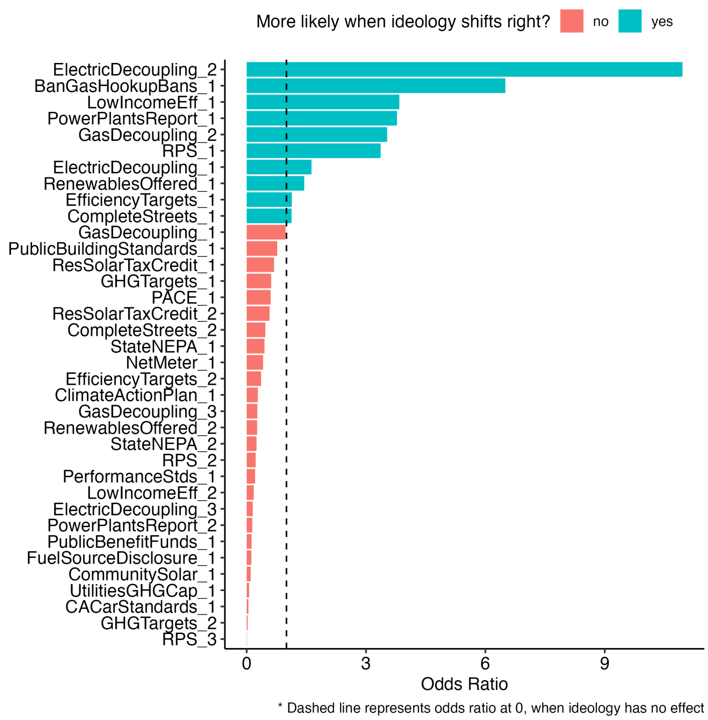

Figure 10: Odds ratios of policy adoption.

I sort my results by how much a rightwards shift in ideology influences the chance of a state having a policy adopted. A state having greenhouse gas targets through statutory or public utility commission order was the policy best predicted by ideology – with an odds ratio near zero.[36] Whether a state adopts car emission standards at or above the level of California, mandatory

[36]The odds ratio tells us the multiplicative relationship between the odds of the DV being 1 and one-unit increase in the IV. Less than 1 indicates a negative relationship, and more than 1 indicates a positive relationship.

RPS standards at 100%, or a greenhouse gas cap on the utilities sector are all predicted well by ideology, with an odds ratio of less than 0.1. Conservative states are more likely than liberal states to adopt non-decoupling incentives for utilities to sell less electricity, prohibit natural gas hookup bans, and offer low-income energy efficiency programs that spend less than $6.50 per resident. The least polarizing policies were performance-based compensation for utilities that sell less gas, complete streets planning guides, voluntary efficiency targets, green building requirements, voluntary renewable energy offerings, and state-approved local solar tax credits – all of these policies had less than 0.01% of their variance explained by ideology.

These models support the theory that policies configured as mandates are much less politically feasible than voluntary policies or incentives. Action plans, state equivalents to NEPA, and non-binding RPS policies are also considerably bipartisan, which is harmonic with the notion of politically rewarding yet less tangible climate policy. Mandatory efficiency standards, gas decoupling incentives, state-mandated solar tax credits, and net metering are all policies that are slightly more controversial yet maintain some bipartisan appeal.[37] The results reinforce that climate policy must be designed with the political environment of the state in mind – a weak/non-binding policy that passes is preferable to a mandate that fails.

A potential mechanism that I covered in my argument was that conservative states have intrinsic advantages in renewable energy potential, in that they are bigger, less dense, and experience more favorable weather conditions. Under the climate federalism view, this should incentivize conservative states to prioritize carbon intensity policy to the same degree that liberal states do.

An operationalized hypothesis is that a state's mandatory renewable portfolio standard will be weaker in states with greater renewable energy potential. Testing this model, I find that ideology alone explains 19.62% of variance, whereas the interaction term explains 18% of variance.[38] The results suggest that right-wing political ideology, more solar exposure, and more urbanization are associated with lower RPS targets. The interaction term is positive, suggesting that when urbanization increases, solar exposure becomes less of a negative predictor.

The influence of ideology on binding RPS targets is not tied to a state's renewable energy potential. They are two distinct effects – liberal states will pursue higher RPS targets than conservative ones even when controlling for natural resource potential.

I observe mixed evidence that conservative states have an intrinsic advantage in carbon intensity. Among observations with approximately two or less carbon intensity policies, conservative states have a slightly lower baseline carbon intensity than liberal states. The same is true for states with approximately eight or more carbon intensity policies – conservative states have a lower baseline. This is potentially a product of the resource potential of conservative states, but

[37]Less than 10% of variation can be explained by ideology.
[38]A model with both explains 31.08% of variance in binding RPS target.

limitations on high quality data restrict me from drawing robust conclusions.

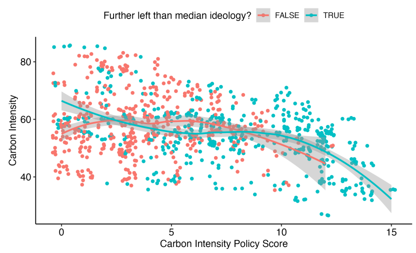

Figure 11: Carbon Intensity Policy Scores vs. Outcomes

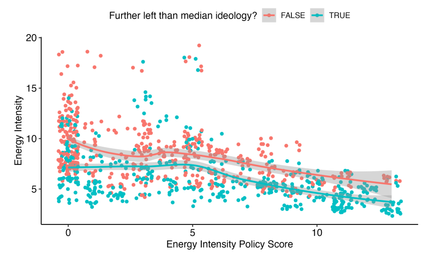

Figure 12: Energy Intensity Policy Scores vs. Outcomes

Conservative states do, however, experience baseline levels of energy intensity consistently higher than liberal states. This could be explained by conservative states being less population dense, hence transportation emissions being greater. Conservative states also have stronger manufacturing and agricultural bases, which are more energy intensive than most other industries. Energy intensity policies appear to have similar impacts on liberal and conservative states.

7.3 Closing Thoughts

I aim to situate my findings within the broader climate politics literature. First, on energy intensity. The understanding that energy efficiency policy has more bipartisan appeal than renewable energy policy is not new — Trachtman (2020) finds a similar phenomenon, and similarly argues that energy efficiency is less immediately threatening to the fossil fuel industry. My original contribution is the analysis of outcomes. Energy intensity outcomes vary significantly along partisan lines, and this is robust to controlling for industrial structure, affluence, geography, and more. This reaffirms the findings of earlier works that relate energy intensity to public education, public transportation, and individual ideology. It is also harmonic with the Berg et al. (2020) scorecard, where Democratic strongholds perform consistently well year-over-year.

Second, on carbon intensity. There is an increasingly strong understanding that political factors are competitive with if not more influential than economic factors (Trachtman 2020). I find that the influence of ideology is about as significant in determining RPS targets as renewable energy potential and population agglomeration. Despite this ambition, I fail to find strong evidence that political ideology is a strong determinant of carbon intensity. The subsequent discussion shows at least some correlation, which merits future research. The failure to translate policy ambition into improved outcomes reinforces our understanding of the distributional conflict and implementation barriers that plague renewable energy expansion.

There is one clear temporal limitation of my study. For political ideology to be a significant predictor of any model, the effect must manifest that same year. This is a potential oversight: policies can take years to make it through legislatures, and even successful policies can take years to manifest into outcomes. They also might face years-long pushback efforts from opposing coalitions. While I briefly explore the potential of lagged effects, this warrants deeper analysis.

Other limitations are also notable. First, my use of the Shor and McCarty (2022) index relies on environmental outcomes responding to slight, continuous changes in state legislature ideology. My contribution to the literature is unique in that it uses this continuous measure, but it could be that a broader, categorical distinction between ideologies is better suited. Second, I fail to formalize the relationship between ideology and carbon intensity. My exploratory visualizations show there to be a correlational relationship, but I fail to find a reliable model that attributes any significant amount of this variation to ideology. Future work should utilize more flexible models as the relationship may be non-linear, and case study work would be deeply valuable in isolating this effect. Third, my measure of climate policy is naive in assuming that all layers of stringency should be weighted equally. More complex Bayesian methods are likely better suited to assign relative value to each policy, but were outside the feasibility of this project. Future work should use higher quality data to support or oppose the robustness of my findings.

To conclude the discussion of my results, I develop a revised causal chain. Given that I use observational data and stray from bold claims of causality, the main purpose is to rebuke my prior model and instead develop a plausible causal chain in-line with what my quantitative findings showed.

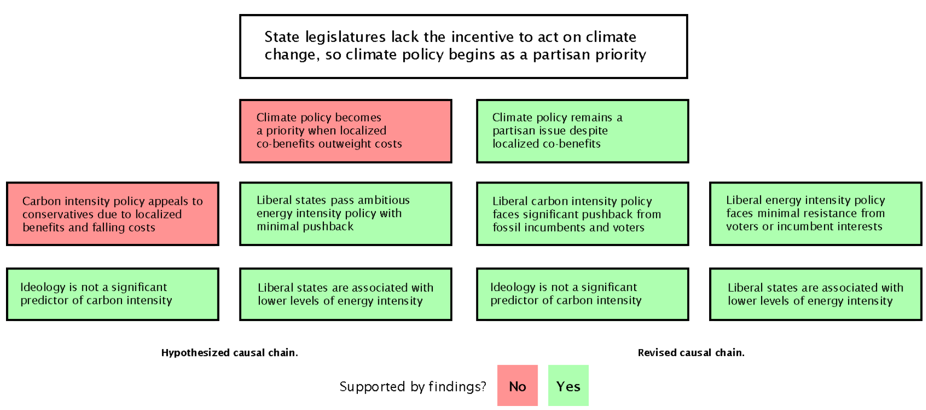

Figure 13: Revised causal chain (with hypothesized causal chain for comparison)

I close by relating this back to the prior discussion of climate federalism and polarized federalism. Under climate federalism, I expected that conservative states would be drawn to renewable energy policy due to falling costs and greater localized co-benefits. My findings suggest that this isn't the case, and that polarized federalism is the framework by which states are motivated to pursue climate policy. The calculus of carbon intensity policy may include consideration of natural resources, but the difference is not enough to pursue policy regimes comparable to liberal states. From this, I conclude that a more compelling explanation is the distributional conflict brought about by climate intensity policy that threatens to displace the fossil fuel incumbency.

8 Conclusion

Politicians face incredible difficulties in passing sustainable and effective climate policy. I provide evidence that liberal legislatures pass more aggressive carbon intensity and energy intensity policies, but only see significantly improved results in energy intensity. The effect of legislature ideology on carbon intensity was statistically insignificant and weak, but I observe correlation in the long-term, and explore potential mechanisms through case studies.

My most significant contribution to the literature is my comparison of policy adoption and environmental outcomes. The current understanding is that energy efficiency has broader bipartisan appeal – I find this to be true in terms of policy adoption, but false in terms of environmental outcomes. Energy efficiency outcomes are highly responsive to changes in political ideology, even when controlling for industrial structure, population density, gross product, and state-year fixed effects, despite the policies being less controversial than carbon intensity policy. My findings on carbon intensity are the opposite: policy adoption occurs along partisan divides, but outcomes are not immediately responsive to changes in ideology. This reaffirms the value of examining the implementation gap in climate policy, and extends this understanding to individual carbon emission contributors.

There are numerous practical applications that can help promote politically feasible decarbonization. Legislators should bundle controversial renewable energy measures that attract opposition from fossil fuel stakeholders with energy efficiency incentives that appeal to them. States should also value legally binding targets, even if they must sacrifice ambition, for the sake of achieving tangible results. Finally, states can afford to be overly ambitious when setting efficiency targets, as they are resistant to shocks in partisanship and are occasionally even endorsed by the fossil fuel industry. Politicians can leverage the aligned incentives associated with energy efficiency to forward decarbonization in areas of the country where the appetite for renewable energy is weak.

Climate policy is incredibly difficult, and the global community simply cannot afford to wait for the solution to spontaneously appear. Incremental improvements that are tailored to the political environment of states can and have added up in the long-term. I close with a more positive interpretation: despite not having a clear incentive to do so, states are undeniable leaders in decarbonization. My results suggest that when the will is strong, voters can demand climate policy in even the most hostile of political environments. There is optimism to be felt with every additional state that leads on climate action, and with an issue as pressing as climate change, any step in the right direction is a step worth appreciating.

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9 Appendix

9.1 Policy classifications

Table 2: Policies from Bergquist and Warshaw (2023)

Code	Description	Levels	Category
ClimateActionPlan	Does the state have a plan that details steps it will take to address climate change?	0/1	Both
CommunitySolar	Does the state have a community solar program?	0/1	Both
CACarStandards	Does the state adopt California's car emissions standards (which are more stringent than the federal level)?	0/1	Both
UtilitiesGHGCap	Does the state have a binding cap on greenhouse gas emissions in the utility sector (e.g. RGGI, WCI)?	0/1	Carbon
BanGasHookupBans	Does the state prohibit local bans on gas hook-ups in buildings?	0/1	Carbon
PublicBenefitFunds	Does the state have a public benefit fund for renewable energy and energy efficiency?	0/1	Both
FuelSourceDisclosure	Does the state require electricity providers to disclose their fuel sources?	0/1	Carbon
PerformanceStds	Does the state have performance standards designed to reduce CO2 emissions?	0/1	Carbon
NetMeter	Does the state have net metering (which credits solar owners for electricity added)?	0/1	Carbon
PACE	Has the state authorized Property Assessed Clean Energy programs?	0/1	Both
PubBuildingStandards	Does the state have energy efficiency and other green building requirements for public buildings?	0/1/2	Energy

Continued on next page

Table 2 continued from previous page

Code	Description	Levels	Category
CompleteStreets	Does the state have complete streets policies?	0/1/2	Energy
EfficiencyTargets	Does the state have energy efficiency targets?	0/1/2	Energy
ResSolarTaxCredit	Does the state have a tax credit for residential solar installations?	0/1	Carbon
StateNEPA	Does the state have its own version of the federal National Environmental Policy Act?	0/1/2	Both
PowerPlantsReport	Does the state require all power plants to register and record their emissions?	0/1/2	Carbon
GHGTargets	Does the state have a goal for emission reduction levels by a certain time period?	0/1	Both
LowIncomeEff	Does the state have energy efficiency programs for low-income individuals?	0/1/2	Energy
RenewablesOffered	Does the state require utilities to offer customers electricity generated from renewable sources?	0/1	Carbon
ElectricDecoupling	Does the state compensate utilities for selling less electricity?	0/1/2/3	Energy
RPS	Does the state have renewable portfolio standards?	0/1/2/3	Carbon
GasDecoupling	Does the state compensate utilities for selling less gas?	0/1/2/3	Energy

9.2 Log transformations

I propose a log transformation for every variable collected for this analysis. I apply the transformation if the natural log of a variable is more normally distributed than the original variable, which ends up being true for per capita emissions, carbon intensity, energy intensity, GDP per capita, and population.

Log transformations on either side of the regression model affect interpretation. If the dependent variable is logged, and the independent variable isn't, then the effect of x on y is that a one-unit increase in x is associated with a $1 - \exp(\beta_1)$ percent increase in y. If the independent variable is logged, and the dependent variable isn't, then a 1% increase in x is associated with a $\frac{\beta_1}{100}$ unit increase in y. If both variables are logged, then the relationship measures elasticity, and a 1% increase in x is associated with a β_1% in y.

Here, I present the distributions of all variables with and without the log transformation. Graphs in green indicate that the transformed variable was selected.

9.3 Missing Data

The NREL solar exposure and wind speed estimates I use do not include Hawaii and Alaska, and I only acquire estimates for 2020. I simply impute previous years with the 2020 estimates as I do not assume weather trends to be very time-variant. Since I do not evaluate my hypotheses with the multiple linear regression models, I consider this approach acceptable.

The urbanization data is also limited to estimates from 2010 and 2020. I utilize a "next-observation-carried-backwards" imputation approach, such that all years between 2011 and 2020 use the 2020 estimates, and all years prior use the 2010 estimates. These variables are similarly slow to change and are only used in the multiple linear regression model.

9.4 Addressing Model Fit

To check for non-constant variance, I run Breusch-Pagan tests for each model, finding highly significant results for all. This indicates significant heteroskedasticity among all models.

Dependent Variable	BP	df	p-value
log(EmissionsPerCapita)	414.01	74	$< 2.2 \times 10^{-16}$
log(CarbonIntensity)	356.54	74	$< 2.2 \times 10^{-16}$
log(EnergyIntensity)	496.09	74	$< 2.2 \times 10^{-16}$
Score	518.16	72	$< 2.2 \times 10^{-16}$
CarbonScore	444.98	72	$< 2.2 \times 10^{-16}$
EnergyScore	471	72	$< 2.2 \times 10^{-16}$

Table 3: Studentized Breusch-Pagan Tests for Heteroskedasticity

Because I suspect violations of the linear regression assumptions, including cross-dependence across units and serial auto-correlation over time, and I provide evidence for heteroskedasticity above, I employ Driscoll-Kraay standard errors.

9.5 Full Regression Tables (with and without influential points)

Dependent Variable:	log(CarbonIntensity)	
	Outliers	No Outliers
Model:	(1)	(2)
Variables		
Ideology	0.0036	0.0043
	(0.0080)	(0.0058)
log(Population)	0.0731*	0.0351
	(0.0410)	(0.0391)
log(GDPPerCapita)	-0.0732***	-0.0474**
	(0.0223)	(0.0189)
Fixed-effects		
State	Yes	Yes
Year	Yes	Yes
Fit statistics		
Observations	1,134	1,081
R^2	0.96210	0.96507
Within R^2	0.01720	0.00771

Driscoll-Kraay (L=2) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Dependent Variable:	log(EnergyIntensity)	
	Outliers	No Outliers
Model:	(1)	(2)
Variables		
Ideology	0.0236***	0.0197**
	(0.0080)	(0.0078)
log(Population)	-0.3352***	-0.3157***
	(0.0350)	(0.0382)
log(GDPPerCapita)	-0.2882***	-0.2869***
	(0.0605)	(0.0751)
Fixed-effects		
State	Yes	Yes
Year	Yes	Yes
Fit statistics		
Observations	1,134	1,061
R^2	0.98338	0.98486
Within R^2	0.13189	0.13295

Driscoll-Kraay (L=2) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Dependent Variable:	log(CarbonIntensity)	
	Outliers	No Outliers
Model:	(1)	(2)
Variables		
Constant	3.683***	3.904***
	(0.2171)	(0.2172)
Ideology	0.0598***	0.0431***
	(0.0054)	(0.0055)
log(GDPPerCapita)	-0.2714***	-0.2525***
	(0.0335)	(0.0355)
log(Population)	-0.0118***	-0.0121***
	(0.0028)	(0.0043)
GHI	0.0903***	0.0720***
	(0.0156)	(0.0163)
Speed120m	0.1156***	0.1006***
	(0.0067)	(0.0068)
PercentUrban	0.0044***	0.0033***
	(0.0006)	(0.0005)
PropManuEmployment	-0.5862***	-0.8669***
	(0.1369)	(0.0789)
PropFarmEmployment	-0.4497**	-0.3462
	(0.1830)	(0.2351)
Fit statistics		
Observations	1,088	1,044
R^2	0.26600	0.21027
Adjusted R^2	0.26056	0.20417

Driscoll-Kraay (L=2) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Dependent Variable:	log(EnergyIntensity)	
	Outliers	No Outliers
Model:	(1)	(2)
Variables		
Constant	2.973***	2.978***
	(0.1592)	(0.1536)
Ideology	0.1687***	0.1641***
	(0.0088)	(0.0097)
log(GDPPerCapita)	-0.4342***	-0.4534***
	(0.0402)	(0.0408)
log(Population)	0.0013	0.0006
	(0.0087)	(0.0081)
GHI	0.1691***	0.1769***
	(0.0070)	(0.0082)
Speed120m	0.0418***	0.0479***
	(0.0075)	(0.0086)
PercentUrban	-0.0082***	-0.0081***
	(0.0006)	(0.0005)
PropManuEmployment	-0.0176	-0.1235
	(0.1160)	(0.1501)
PropFarmEmployment	7.155***	7.209***
	(0.7837)	(0.7997)
Fit statistics		
Observations	1,088	1,039
R^2	0.70757	0.70270
Adjusted R^2	0.70541	0.70039

Driscoll-Kraay (L=2) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Dependent Variable:	log(CarbonIntensity)		
Model:	(1)	(2)	(3)
Variables			
Ideology	0.0036	-0.0118	0.0839***
	(0.0080)	(0.0111)	(0.0075)
log(Population)	0.0731*	-0.1303*	-0.0066**
	(0.0410)	(0.0745)	(0.0030)
log(GDPPerCapita)	-0.0732***	-0.2123***	0.1179***
	(0.0223)	(0.0355)	(0.0334)
Fixed-effects			
State	Yes	Yes	
Year	Yes		Yes
Fit statistics			
Observations	1,134	1,134	1,134
R^2	0.96210	0.94004	0.14154
Within R^2	0.01720	0.51273	0.05816

Driscoll-Kraay (L=2) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Dependent Variable:	log(EnergyIntensity)		
Model:	(1)	(2)	(3)
Variables			
Ideology	0.0236***	0.0161	0.3405***
	(0.0080)	(0.0096)	(0.0057)
log(Population)	-0.3352***	-0.4614***	-0.1068***
	(0.0350)	(0.0315)	(0.0115)
log(GDPPerCapita)	-0.2882***	-0.3975***	-0.5211***
	(0.0605)	(0.0173)	(0.1045)
Fixed-effects			
State	Yes	Yes	
Year	Yes		Yes
Fit statistics			
Observations	1,134	1,134	1,134
R^2	0.98338	0.98163	0.57967
Within R^2	0.13189	0.78293	0.54872

Driscoll-Kraay (L=2) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

9.6 Exploration of Fixed Effects

Controlling for state-year fixed effects means that each state and year is assigned its own coefficient. While fixed effects usually are not of substantive interest to researchers, they can provide unique value to this study, as I take great interest in comparing political determinants of carbon emissions to other economic or geographic contributors. I plot and discuss them below.[39]

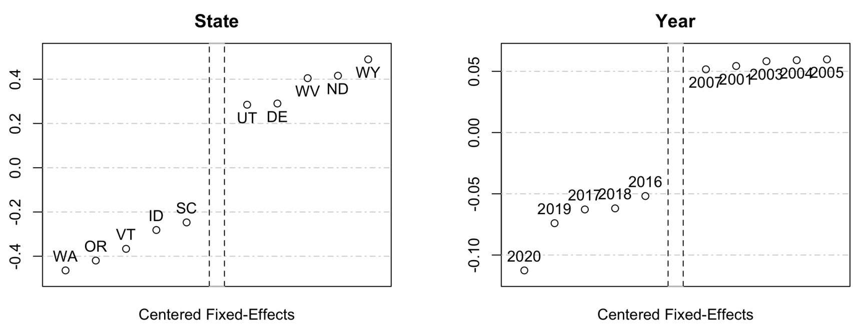

Figure 14: Carbon Intensity Fixed Effects

Washington, Oregon, Vermont, Idaho, and South Carolina are the five best-performing states in terms of carbon intensity (in that order), all else equal. Wyoming, North Dakota, West Virginia, Delaware, and Utah are the five worst performing states. California, New York, New Jersey, Texas, and Massachusetts perform the best in carbon intensity policy adoption, all else equal, while Wyoming, Arkansas, Idaho, South Dakota, and North Dakota have the weakest carbon intensity policy regimes.

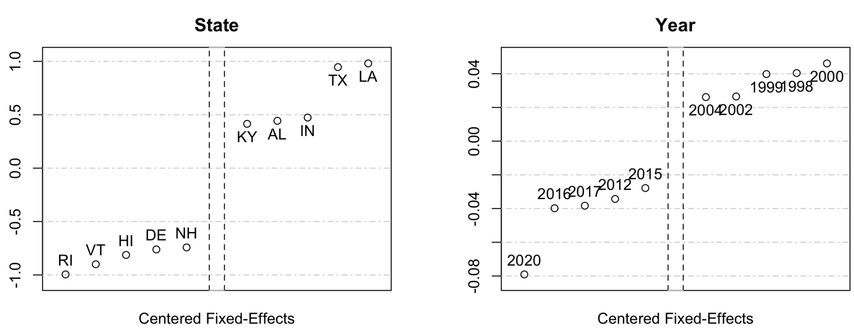

Figure 15: Energy Intensity Fixed Effects

[39]For readability, I refer to individual fixed effects as being "best" or "worst" performing. The formal interpretation is that each coefficient represents the difference in the dependent variable for that fixed effect relative to the omitted (reference) fixed effect, holding GDP per capita, population, and the other effect (state or year) constant.

Rhode Island, Vermont, Hawaii, Delaware, and New Hampshire are the five best performing states in terms of energy intensity, all else equal. Louisiana, Texas, Indiana, Alabama, Kentucky are the five worst performing states. California, New York, Texas, Illinois, and Florida appear to be leaders in energy intensity policy, whereas North Dakota, Wyoming, Arkansas, Montana, and South Dakota appear to under-perform. Since energy intensity is determined by countless factors both stronger than ideology and exogenous to political ideology, these fixed effects are less valuable. North Dakota, Wyoming, Arkansas, Montana, and South Dakota have the weakest policy regimes, whereas Florida, Illionis, Texas, New York, and California lead the country in terms of energy intensity policy.

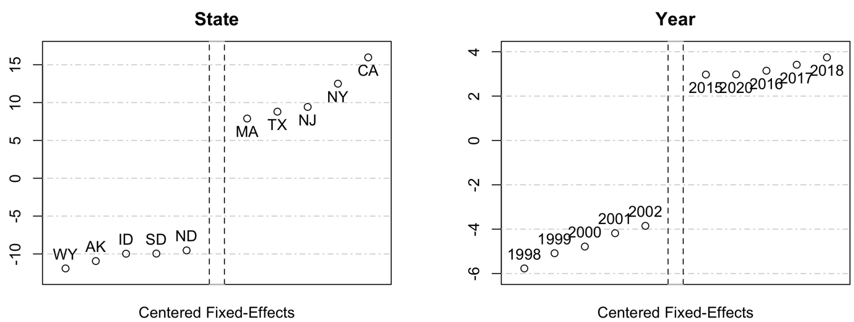

Figure 16: Carbon Intensity Policy Fixed Effects

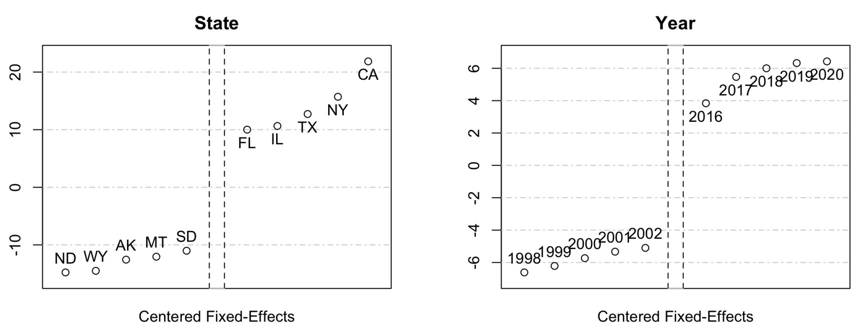

Figure 17: Energy Intensity Policy Fixed Effects

9.7 Exploration of Polynomials

Political ideology could have a non-linear relationship with policy adoption and environmental outcomes. I test this by repeating my fixed effects OLS model structure ten times, each with a polynomial degree added to ideology. My dependent variable of interest are carbon intensity, energy intensity, binding RPS target, and binding EERS target.

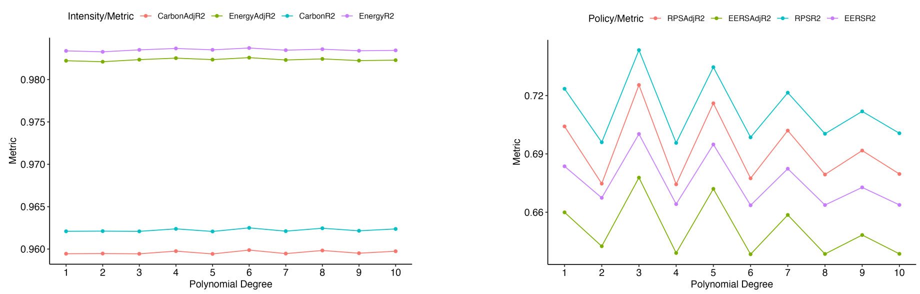

Figure 18: Performance by Polynomial Degree

There is no significant difference in performance in the environmental outcome models. There is however, significant variation when modeling RPS and EERS targets as a function of ideology. The third degree polynomial is most effective in terms of adjusted R^2 and overall R^2.