Explaining National Variation in Unilateral Climate Change Mitigation

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Abstract:
In this paper, I argue that much of the observed variation in national climate change mitigation levels can be explained by a combination of national interests and the strategic constraints of the collective action problem. Specifically, the interactions between state costs and benefits and state size, a proxy for invulnerability to free-riding, strongly predict observed variation in national yearly emissions. I derive this hypothesis and connect it to extant literature with a theoretical framework that interrelates state climate change mitigation interests, preferences, behaviors, and outcomes. I test the hypothesis by predicting the difference between real emissions changes and a novel estimate for counterfactual emissions changes. The theoretical framework and the counterfactual estimation methodology developed in this paper will facilitate future work on climate mitigation politics, from both international and domestic politics approaches.

1 Introduction

The politics of global anthropogenic climate change are commonly understood as a dilemma of cooperation amidst international anarchy. Unmitigated climate change threatens to restructure global geography, yet effective mitigation requires fundamentally restructuring the global economy. Thus, both climate change and efforts to mitigate it incur immense and varied costs, with dramatic implications for relative power and prosperity. States, as self-interested actors not bound by any authoritative or enforcement-capable global government, will pursue climate policy in line with their own national interests. But there is little consensus in social scientific research about the determinants of climate national interest or about its relationship to actual mitigation levels. Establishing theoretical expectations for mitigation levels as a function of states' interests, preferences, and policies is crucial for exploring promising new directions in climate politics research at the interstate, state, and sub-state levels.

I argue that much of the observed interstate variation in climate change mitigation can be explained by a simple schema of national costs and benefits, moderated by state size. Larger states will feel a greater share of the externalities of their actions and thus should be relatively less vulnerable to free riding and more responsive to their national interest for mitigation. I develop this simple and testable hypothesis from a parsimonious theoretical framework that can be modified in future research to incorporate national institutions, state capacity, or other pertinent variables. Therefore, my approach consolidates and connects diverse extant literature on climate change mitigation, allowing direct comparison of past research and the generation of further hypotheses at multiple levels of analysis.

Unlike most empirical studies of climate change mitigation politics, I test my hypotheses by predicting actual emissions changes rather than by predicting ambiguous policies or intangible preferences. In order to isolate the signal of climate policy against the noisy environment of national yearly emissions, I estimate a novel counterfactual emissions projection (i.e. a "business-as-usual" (BAU) pathway) using an empirical model. For each state-year, I predict counterfactual emissions' growth as a weighted sum of counterfactual industry-state-year economic growth and carbon intensity growth, each flexibly predicted by global growth in the relevant industry-year. This method accounts for fluctuations in emissions due to economic and technological developments in the global economy. The resultant difference between real emissions growth and predicted emissions growth represents the policy-induced change in emissions, and is well predicted by the political variables specified in my theoretical framework: costs, benefits, and size.

The results of this paper confirm that states are pursuing their national interests through climate change mitigation policy, but are constrained by collective action dynamics. The implications of this paper are theoretical, methodological, and practical. First, this paper's findings validate classical theoretical approaches to climate change politics. Significant explanatory power from state-level variables indicates the usefulness of an international relations approach. At the same time, the robustness of free-riding constraints demonstrates the soundness of the collective action framework, rebutting recent criticisms of its empirical support. But rather than proposing collective action or any other model as a singular explanation, my theoretical framework facilitates integration of interstate-, state-, and substate-level theories of climate change mitigation politics. Second, this paper develops a new empirical method for estimating BAU counterfactual emissions levels, thereby allowing the use of emissions themselves as an outcome of interest in future studies. New state-level theories of climate change mitigation, for example, can be validated by explaining deviations from the counterfactual. In addition, the empirical results from this paper's predictions for states as rational and unitary actors can serve as a baseline for future work at the inter-state, state, and sub-state levels of analysis. Domestic politics research, for example, adds explanatory power through comparison to these simplistic state-level predictions. Third, the BAU method developed here has wide applicability as a tool for program evaluation or policy analysis.

The remainder of this paper is organized as follows. In Section 2, I discuss the relationship between state interests, preferences, behavior, and outcomes. In doing so, I hypothesize that climate change mitigation patterns can be largely explained by national costs and benefits mediated by state size. In Section 3, I operationalize and describe the key variables in my analysis. In Section 4, I test for the consistency of the model and operationalizations with observed state-level climate change mitigation outcomes, after adjusting for BAU emissions changes. In Section 5, I evaluate the implications of my theoretical and empirical frameworks, as well as the necessity of well-defined state-level predictions for baseline comparisons. I conclude with suggestions for future research utilizing these tools.

2 Theory

I argue that observed variation in climate change mitigation is largely explained by national costs and benefits, mediated by the collective action problem for which larger actors face lower constraints. Before I discuss these variables and their interactions in detail, I explain how this theory of mitigation relates to adaptation and to alternative explanations for mitigation in the existing climate change politics literature.

This paper explains mitigation as a distinct outcome from adaptation to climate change. Adaptation is a strategic substitute to mitigation for state actors, and should be studied in tandem with mitigation in future work. I discuss mitigation as an independent theoretical concept and control for ability to adapt (GDP per capita) in my main analysis. In Section 5.1 I also describe how future work can incorporate adaptation.

Recent attempts to explain the politics of climate change mitigation have varied by choice of independent and dependent variables, without agreement on a clear framework relating these different levels of analysis and outcomes. As an independent variable, scholars have alternated between studying the effects of raw costs and benefits (Gazmararian and Milner, 2022; Gaikwad, Genovese and Tingley, 2022; Colgan, Green and Hale, 2021), of domestic institutions (Gaikwad, Gonzalez and Wilkinson, 2023; Bättig and Bernauer, 2009), and of strategic considerations or international institutions (Aklin and Mildenberger, 2020; Gaikwad, Genovese and Tingley, 2023). As a dependent variable, scholars have alternated between studying the causes of public opinion (Gaikwad, Genovese and Tingley, 2023; Gaikwad, Gonzalez and Wilkinson, 2023; Gaikwad, Genovese and Tingley, 2022; Aklin and Mildenberger, 2020), of state policy (Gazmararian and Milner, 2022), and occasionally of emissions changes themselves (Bättig and Bernauer, 2009). But comparing or integrating these studies requires a framework, usually left implicit, relating alternative independent and dependent variables to each other.

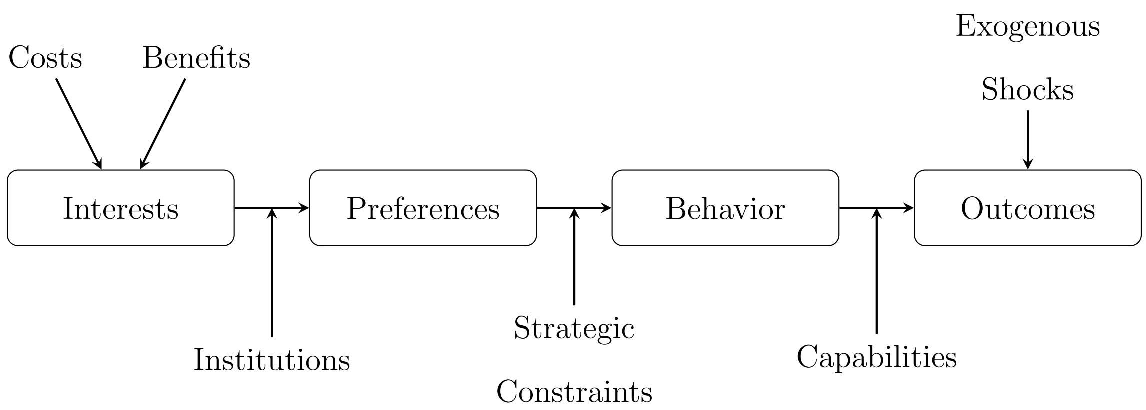
Moreover, scholars disagree about the usefulness of centering discussions of global climate outcomes around states as purposive actors, as in the collective action framework. While global collective action, which assumes as-if rational and as-if unitary state actors as units, has long been the primary lens for research on climate change (Barrett, 2005), some scholars have recently questioned whether states really respond to the strategic incentives of their environment in the form of the free-rider problem (Aklin and Mildenberger, 2020).

In this section, I outline a new framework for integrating research across the discipline of international climate politics. My approach borrows from the Open Economy Politics (OEP) research tradition (Lake, 2009) while maintaining states as central actors, thereby allowing a valid test of collective action theory. After developing this framework, I generate the simple hypothesis that much of the variation in mitigation is explained by national costs and benefits, mediated by state size. I operationalize and test this hypothesis in subsequent sections.

2.1 Interests, Preferences, Behavior, and Outcomes

An OEP framework explains international relations outcomes through domestic interests and institutions, combined with international dynamics such as bargaining. Applying a similar approach to climate change mitigation allows integration of the diverse sets of variables in the extant research described above, as well as the generation of new hypotheses. Below, I have diagrammed a simple and highly stylized model of international relations outcomes derived from national interests, state preferences, and state behavior. Arrows pointing directly to a box represent additive effects, while arrows pointing to an arrow represent interactive effects.

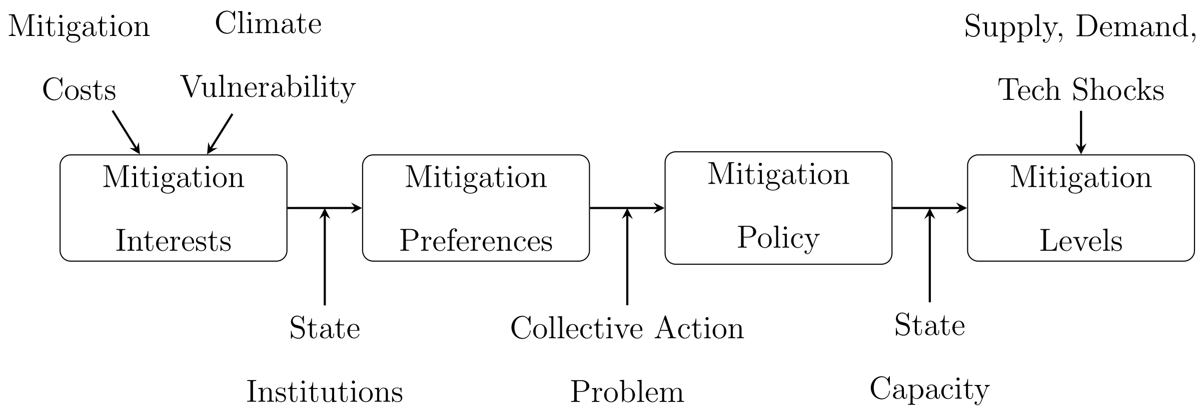
Figure 1: An OEP Model of International Relations Outcomes



States can be thought of as having raw interests derived from the objective costs and benefits defining a particular issue. These raw national interests are translated into state preferences through a process determined by national political institutions. For example, democracies may value public good benefits more than autocracies (Deacon, 2009), while states that are relatively more permeable to interest groups may consider concentrated costs more than states with more majoritarian institutions. Next, state behavior is based on state preferences, but states are strategic actors and their behavior will thus be mediated by the strategic constraints of their environments. Finally, because states are the most decisive actors in international politics, international outcomes are shaped by state behavior. But differing state capabilities will determine how effectively state action shapes outcomes (Evans, Rueschemeyer and Skocpol, 1985). For example, states vary significantly in their ability to extract wealth from their societies and direct those resources to autonomously-defined purposes. International outcomes are also driven by shocks exogenous to any given state acting in the international arena.

This general conceptualization of international relations can be specifically applied to climate change mitigation, as shown below.

Figure 2: An OEP Model of Climate Change Mitigation



A state's interests in mitigation are a product of the costs and benefits of mitigation. Specifically, mitigation requires economic transformation that incurs either direct costs (i.e. capital substitution costs) or indirect costs (i.e. opportunity costs of investing in mitigation over productivity growth). These costs are weighed against the benefits of mitigation, namely the reduction of harms from climate change. States vary both in the potential costliness of decarbonizing their economies and in their vulnerability to the potential harms of climate change. These costs and benefits are discussed at greater length in Section 2.2 and operationalized in Section 3.1.

Those raw interests in climate change mitigation determine state preferences after mediation by national political institutions. Mitigation costs are likely to be concentrated in particular sectors or in the rents of particular endowments. Climate vulnerability will also vary sub-nationally by geography or asset ownership (Colgan, Green and Hale, 2021).[1] Further research is needed to predict the precise relationship between state climate change mitigation preferences and government institutions.

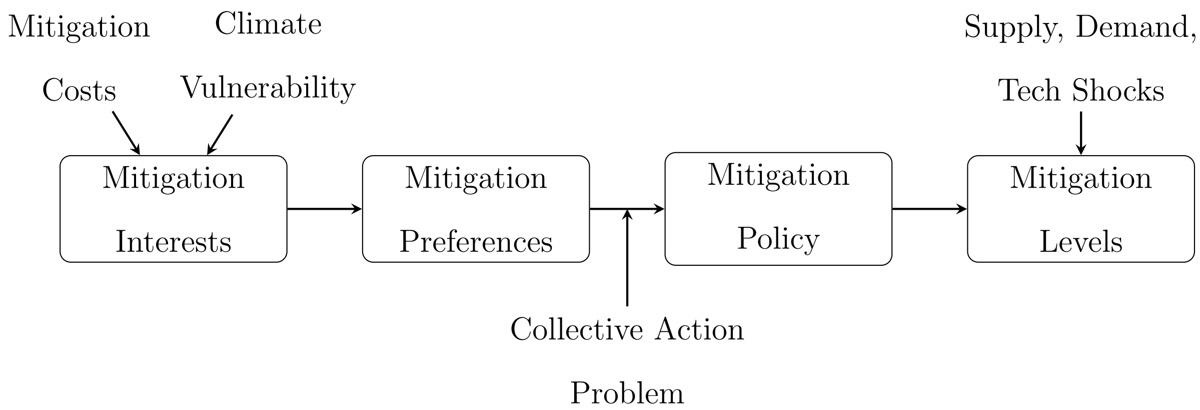
Whatever a state's preferences for climate mitigation, its mitigation policy will be limited in its effectiveness by the international collective action problem. States will only experience a small portion of the benefit of their mitigation action, but can enjoy the benefits of others' mitigation without cost. This dynamic encourages free-riding and lowers overall mitigation levels. States will likely consider this strategic environment when crafting policy from their preferences. The collective action problem will be further explained in Section 2.2 and operationalized in Section 3.2.

Finally, how well a state's mitigation policy actually mitigates emissions will be a function of state capacity. Highly corrupt states, for example, may fail to effectively shape environmental outcomes (Povitkina, 2018). The determinants of mitigation policy efficacy provide fertile ground for future research. But even a highly effective state does not directly control its entire economy, which will experience emissions fluctuations independent of state policy. Specifically, emission levels may vary due to economic fluctuation from supply or demand shocks or due to fluctuations in the carbon intensity of the economy from technological shocks. The conceptualization and measurement of these shocks will be further developed in Section 3.4.

[1] This step could be complicated further by considering sub-state mediators such as psychology, organizational politics, or bureaucratic politics.

The diagram described above makes dramatic simplifications to the reality of climate change mitigation politics, yet remains too complicated for parsimonious analysis. Mitigation costs and climate vulnerability each affect actual mitigation levels only through a four way interaction: with state institutions, collective action constraints, and state capacity. Although each of these topics deserves research attention, this study makes a rational unitary actor assumption, thus simplifying climate change mitigation politics further in order to maintain tractability.

Figure 3: An OEP Model of Climate Change Mitigation (with unitary, rational states)



I amend the theoretical diagram above with this simplifying assumption, assuming that state preferences rationally aggregate state interests into unitary preferences and that state capacity does not get in the way of state policy. If so, then after accounting for supply, demand, and technology shocks, climate change mitigation levels will be predicted by the interaction of the collective action constraint with mitigation costs and climate vulnerability.

2.2 Climate Change Mitigation by Rational States

Above, I argue that unitary rational states will mitigate climate change in accordance with their national interest, moderated by a collective action constraint. Rather than treating national interests for climate change mitigation as a single dimension (i.e. "green-ness"), I decompose interests into costs and benefits. States face varying costs of mitigation through economic differences. They also enjoy varying benefits of mitigation due to their differing geographical and economic vulnerabilities to climate change. This decomposition allows nuanced predictions about state-level mitigation interest, as demonstrated in the two-by-two costs and benefits table below.[2]

Table 1: Costs and Benefits of Climate Change Mitigation

		Climate Change Vulnerability: Low	Climate Change Vulnerability: High
Mitigation Cost	High	low mitigation interest	intermediate
	Low	intermediate	high mitigation interest

State responsiveness to these interests will be mediated by strategic constraints, namely collective action. The collective action problem occurs when actors would be best off if all cooperated to provide a good, but each finds it individually rational to defect and free-ride on others' provision (Olson, 1965). This scenario is also known as a public goods game, and occurs when a broadly-desired good is both non-rivalrous, meaning that one's consumption does not reduce another's, and non-excludable, meaning that none can be stopped from consuming (Samuelson, 1954, 1955). Public goods, like the non-excludable but rivalrous category of commons goods (Hardin, 1968), can be modeled as an n-player prisoners' dilemma. Absent external enforcement or incentives, actors will voluntarily contribute less than the optimal amount to the collective good in all equilibria.

[2]This table's reduction of international environmental problems to the costs and benefits of particular states is similar to the approach taken by Sprinz and Vaahtoranta (1994) in their discussion of state preferences for acid rain and ozone treaties. But because their outcome variable is preferences about treaty content rather than independent action outside of a binding treaty, the strategic constraint of free-riding is not considered in their analysis.

But provision will not necessarily be uniform or equal to zero. Variation in actor preferences (costs and benefits) and size (vulnerability to free-riding) can lead actors to pursue different strategies in equilibrium, including relatively high (though still suboptimal) levels of contribution (Kennard and Schnakenberg, 2023). Recent studies purporting to invalidate climate collective action theory which have demonstrated that abatement behavior is not uniform and not composed only of extreme behavior (full abatement or full defection) (Aklin and Mildenberger, 2020) are therefore not valid tests of the theory.

An accurate test of the collective action model would probe its core theoretical prediction: that actor preferences and behavior will be mediated by size (Olson and Zeckhauser, 1966). Larger actors will internalize a greater share of the consequences of their actions or will yield greater returns for the same amount of effort (depending on how the provision function is modeled), weakening the appeal of free-riding. While all actors in a collective action game will contribute to the collective good at a sub-optimal level, this shortfall will be proportionally greater for smaller actors than for larger actors. Olson (1965) notes the crucial distinction between a "privileged group," in which one actor is relatively large enough to find it worthwhile to provide the collective good alone, and a "latent group," in which no actor is large enough to rationally contribute in the absence of externally provided coercion or inducements. The later concept of a "k-group" extends the logic of privileged groups to cases where a small number (i.e. k) of large actors can find some level of joint contribution worthwhile even without contributions by every other actor (Schelling, 1978; Hardin, 1982).

The international system may have been a privileged group or contained a very small k-group when dealing with the ozone depletion crisis due to the significant concentration of problematic chemical production in a few key industries in a few key states (Benedick, 1998). Countries attempting local environmental protection, on the other hand, are generally latent groups of citizens who would each be irrational if acting alone. Taxes and regulation must rely on government enforcement rather than individual voluntary contributions. The climate crisis may be a latent group problem at the sub-state level but a k-group problem at the interstate level. If so, state size should strongly predict the degree to which states act on their costs and benefits from climate mitigation.[3]

The idea of small actors effectively taking advantage of large actors by free riding on public good provision has been explored extensively in the international relations literature. Hegemonic stability theory (Kindleberger, 1973; Krasner, 1976), for example, can be thought of as a simple collective action game that can be solved if a privileged group exists: one large actor (the hegemon) may find it worthwhile to provide public goods, and small actors (all other states) free-ride. Other scholars have extended the hegemonic stability model to k-groups (Snidal, 1985).

Rather than modeling a normal global climate as a public good and emissions reduction as a contribution to the provision of that good, some scholars instead model the global climate as a common pool resource degraded by (privately rewarding) emissions (Sandler and Arce M., 2003). Climate change is similar to the commons problem of resource over-exploitation, in that actors must refrain from doing something negative rather than contribute something positive as in the classical subscription model of a public good. This is an important distinction because commons good problems may generate opposite predictions about actor size to those discussed above (Sandler and Arce M., 2003). But emissions reductions can also be framed as a positive action, especially if they occur through spending on technology substitution rather than through restraining consumption. More importantly, climate change cannot be accurately classified as a commons good problem because pollution is a non-rivalrous activity; although one state's emissions impose costs on another state, it does not reduce the ability of the other state to emit and will affect them whether they also want to emit or not. The Nash Equilibrium of a commons good game has an upper bound defined by the decreasing marginal return of selfish action. This does not apply to the scenario of climate change, in which the private benefits of greenhouse gas emissions will not decline as the world becomes warmer. The Nash Equilibrium of the public goods game is instead defined by country-specific capacity

[3] Alternatively, the international politics of climate change may resemble the related Olsonian concept of an "intermediate group," or a situation in which actors are not large enough to supply the good on their own but are large enough to meaningfully affect one another (Olson, 1965). This concept overlaps with that of a k-group, but makes clear that interaction between agents may drive unpredictable patterns of contribution and cooperation. For this reason, future research on the systems effects mentioned in Section 5.1 is crucial.

for emissions, or the total possible amount that a particular economy could emit if it maximized consumption with no consideration of the environmental effects. This maximum capacity is analogous to state size because actors with greater emissions potential have relatively greater ability to contribute to the good provision with proportional emissions cuts.

The application of collective action theory to the international politics of climate change should not be seen as an all-or-nothing alternative to domestic (or other) approaches to climate politics. Climate change is a complicated phenomenon affecting and interacting with human behavior at almost any level of analysis. Instead of replacing other levels of analysis, this paper makes an argument for an international collective action approach as necessary and useful to other levels of analysis. Because climate change is a global public good, the international collective action dilemma cannot be ignored without sacrificing the validity of rationalist theorizing. For example, Colgan, Green and Hale (2021) emphasize the climate effects of domestic policy on domestic actors, but overlook the fact that domestic policy only has a fractional effect on domestic climate outcomes, which are tied to global climate outcomes. Rather than theorizing around the free-rider dilemma, this exclusive focus on domestic politics actually ignores collective action's centrality to the argument's mechanism. Although non-rationalist domestic politics mechanisms for climate preferences could conceivably ignore international collective action and may be valid means of predicting behavior, any rationalist domestic politics mechanism where the (sub-state) actor is motivated by climate effects rather than by the co-benefits of abatement must account for international collective action.

In Section 3 I lay out simple and robust operationalizations of mitigation levels, costs, vulnerability, and shocks.

3 Conceptualization and Measurement

In the theoretical discussion above, I have outlined a framework for integrating discussion of national interests, preferences, behavior, and outcomes with respect to climate change mitigation. I have also used this framework to generate a simple, first cut hypothesis explaining national variation in climate change mitigation. Under the rational unitary actor assumption, state costs and benefits, mediated by state size, predict emissions. This relationship should be visible once emissions changes are adjusted for exogenous supply, demand, and technology shocks. In this section, I dig deeper into each relevant variable, operationalizing costs, benefits, size, mitigation outcomes, and exogenous shocks. In Section 4 below, I use these operationalizations to test my theoretical hypothesis.

3.1 Costs and Benefits

Below, the cost-benefit table from Section 2.2 is repeated with some examples of countries that could fit into each ideal-type quadrant. For example, Mongolia and Switzerland are both cold and landlocked. Each is therefore relatively invulnerable to climate change compared to much of the rest of the world. Bangladesh and Singapore, on the other hand, are very near the equator and have high population densities near low-lying coastlines, making them highly vulnerable to the worst effects of climate change. Meanwhile, Mongolia and Bangladesh are relatively poor countries that are heavily dependent on fossil fuels. Switzerland and Singapore are wealthy tech-driven economies and would find it cheap to decarbonize by comparison. Thus, while Mongolia may be relatively uninterested in climate change mitigation, Singapore should be extremely interested, while Switzerland and Bangladesh may have cross-cutting preferences.

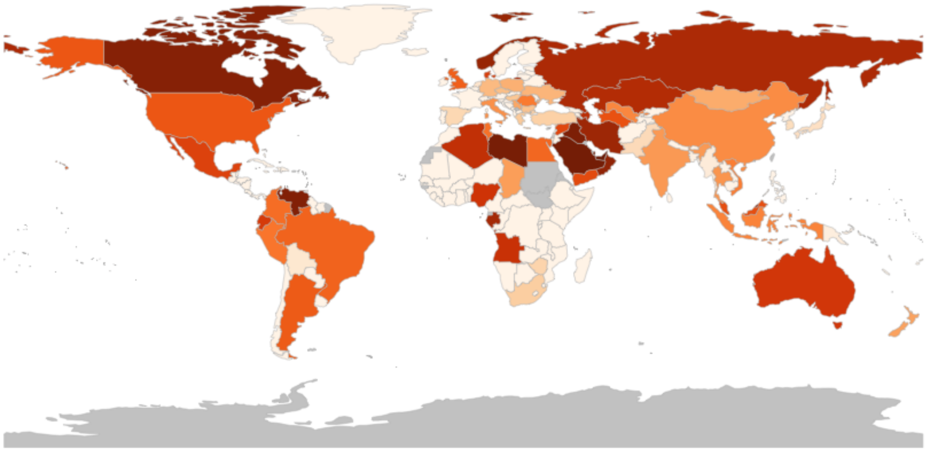
Table 2: Costs and Benefits of Climate Change Mitigation

		Climate Change Vulnerability	
		Low	High
Mitigation Cost	High	Mongolia	Bangladesh
	Low	Switzerland	Singapore

How should these costs and benefits be operationalized specifically? The two ways in which states can lower emissions are each economically costly. First, states may lower emissions by limiting production or consumption. This form of mitigation is a direct tradeoff with economic gain. Second, states may lower emissions by lowering their carbon intensity of GDP, or the amount emitted per unit of production or consumption. Lowering carbon intensity can be achieved through capital substitution, in which cleaner capital is developed through research or in which existing cleaner capital technology is purchased. Ability to use either mechanism could be proxied by GDP per capita, which could reflect both the willingness to forgo further economic gain due to diminishing returns and the ability to develop or purchase green technology. But GDP per capita is also indicative of ability to adapt to instead of mitigate climate change (Tol, 2019), and will be controlled for in the main analysis below. Instead, I use the log of proved fossil fuel reserves (measured in British Thermal Units) per capita as a proxy for higher costs to mitigating. This measure reflects the direct opportunity cost of decarbonizing through the amount of dirty energy left in the ground.

$$Costs = log\left(\frac{Coal + Oil + Gas}{Population}\right)$$

Figure 4: Logged Fossil Fuel Reserves per Capita (average, 1992-2016)



mean	sd	min	1st quartile	median	3rd quartile	max
3.46	6.00	0.00	0.00	0.00	2.94	18.65

Figure 4 shows the distribution of logged fossil fuel reserves per capita. High reserves are largely concentrated among known energy producers, while a large portion of the world have little to none.

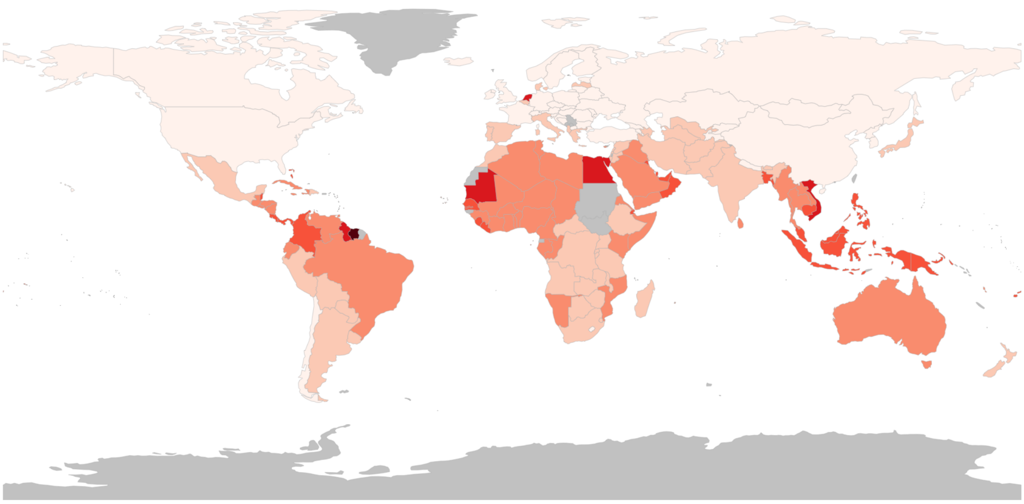
The benefits of mitigation, on the other hand, are the inverse of an actor's vulnerability to the effects of climate change. Like costs, vulnerability is multifaceted. Climate change has a wide range of deleterious effects, including extreme storms, droughts, heat waves, sea level rise, and other damaging outcomes from altered natural systems. Numerous estimates exist for the aggregate projected costs of climate change for the world, for regions, or for particular states of political significance (Hsiang et al., 2017). But in order to compare all states individually, scholars tend to reduce climate vulnerability to a few key variables.

Vulnerability can be divided into economic and geographic vulnerability. Economically vulnerable areas are those with "unmanaged systems", or those with production or consumption patterns that are highly vulnerable to changing environments and weather patterns (Nordhaus, 2013*b*; Schelling, 1992). Economies that are heavily dependent on farming or fishing are one example. Reliance on unmanaged systems, and therefore economic vulnerability to climate change, is closely related to low GDP per capita. Such vulnerability is also related to ability to adapt. As noted above, GDP per capita will be controlled for in the main analysis.

Geographic vulnerability, on the other hand, varies by location. Though complex, climate scientists consider geographic vulnerability to be broadly correlated with high temperatures, low-lying coastlines, and areas that are especially wet or dry (Emanuel, 2007). To measure geographic vulnerability, I average the standardized national average temperature, the standardized percent of population less than five meters above sea level, and the absolute value of standardized average rainfall per year (thus giving very wet and very dry areas a high value).

$$Vulnerability = \left(\frac{temp - \overline{temp}}{sd(temp)} + \frac{sealevel - \overline{sealevel}}{sd(sea)} + \left| \frac{rainfall - \overline{rainfall}}{sd(rainfall)} \right| \right) /3$$

Figure 5: Index for National Vulnerability to Climate Change



mean	sd	min	1st quartile	median	3rd quartile	max
0.00	0.29	-.47	-0.24	-0.03	0.16	1.13

Figure 5 depicts countries by this vulnerability index. A descriptive fact made clear by the map is the high correlation between vulnerability and national income, given the equatorial location of much of the developing world. Some exceptions are Singapore and Australia, which are relatively vulnerable but very wealthy, or Mongolia and North Korea, which are relatively invulnerable but very poor.

Unlike the costs of mitigation, which are paid as states cut emissions each year, the benefits of mitigation are future goods. Thus, when testing the effect of vulnerability to climate change on mitigation over time, vulnerability should be discounted. Following standard approaches, I use Ramsay variable discounting to allow different states to discount at different rates. States with higher GDP growth rates will discount the future at a higher rate, because sacrificing for the future entails greater opportunity cost in the present. I use a pure time preference discount rate (δ) of 1%.

$$\text{Discount Factor} = \frac{1}{(1 + \delta + \Delta\%GDP)^t}$$

3.2 Size

I argue for a simple operationalization of size. Larger actors are less tempted to free-ride because they feel a greater share of benefit of their action; larger actors lose less of the benefit of their actions as an externality because their actions result in greater provision of the public good for themselves. Thus, I define size as share of global emissions:[4]

$$S_{i,t} = \frac{E_{i,t-1}}{\sum_{j=1}^{J} E_{j,t-1}}$$

where $E_{i,t}$ is state i's emissions in year t, and J is the total number of states.

[4]Other research on international collective goods defines size as share of global population, meaning share of benefits of the global public good felt by the actor (Vicary, 2009), or as share of global population weighted by GDP, following the structure of the UN contribution share scheme (Barrett, 2007).

3.3 Emissions Changes as Mitigation Outcomes

The above operationalizations of costs, benefits, and size should predict climate change mitigation levels according to the theory sketched in Section 2. But how can mitigation itself be operationalized? Much research on climate politics attempts to measure state preferences or behavior as a proxy for mitigation. Below, I outline the significant problems with this strategy of focusing on mitigation preferences or mitigation behavior alone, and argue for the relative usefulness of focusing on the ultimate outcomes of mitigation: yearly changes in emissions.

State-level preferences are opaque on both a conceptual and practical level. On a conceptual level, it is unclear whose preferences should be considered state preferences: should researchers treat national public opinion, elite opinion, or policymaker opinion as the valid preference of the state? If elite opinion, what form of capital constitutes the elite? If policymaker opinion, is the executive, the legislature, the judiciary, or the bureaucracy more important? The correct answer clearly depends on the country in question, but also on the researcher's theory of politics. There is little agreement on what constitutes the preferences of the United States, much less the preferences of less exhaustively studied countries.

Preferences are also difficult to study on a practical level. Although great advances have been made in estimation of representative public opinion, elite or policymaker opinion is obscured both by lack of access and by strategic incentives. Talk is cheap, especially in international relations, and strategic actors may have incentives to misrepresent their preferences.

Given the difficulties of studying preferences directly, some research focuses on studying state behavior as revealed state preferences. But this strategy has limitations in the case of climate change mitigation. Greenhouse gases are emitted by nearly every human activity, and nearly every transaction in the economy has a carbon footprint, either directly or indirectly. Any policy with implications for consumption, production, technology, mobility, or trade has implications for emissions levels. States may therefore act on climate change in too many ways to count. States may cut emissions through regulation, subsidies, taxes, appropriations, or even the lack of one of these actions in particular circumstances. Many government actions that are not explicitly or directly dealing with climate change will have a large effect on emissions, which may have factored into the reasoning for the ultimate policy decision. In the case of recent United States politics, was the Inflation Reduction Act of 2022 or the Infrastructure Investment and Jobs Act of 2021 a larger case of climate change mitigation policy? Neither act was explicitly or primarily about climate change mitigation, but both had large climate-relevant policy changes. How does each act compare to the dozens of climate-related executive actions that the Biden administration has taken? Any attempt to catalogue and weigh climate mitigation policies into a usable index will grapple with these significant dilemmas.[5]

Just as the study of international collective action does not preclude the study of domestic politics, this paper's focus on real changes in emissions is not contrary to research on climate change mitigation preferences or behavior. In fact, these alternative dependent variables can be directly related to one another through the theoretical framework laid out in Section 2.1. But using emissions changes as a dependent variable is a novel contribution to the climate change mitigation literature that serves to ground discussions of preferences or policy in measurements of real and final outcomes. Studying emissions themselves is also worthwhile given their intrinsic importance. Ultimately, climate change is driven by real changes in emissions levels.

3.4 Supply, Demand, and Technology Shocks

The use of yearly changes in emissions as an outcome variable is rare in previous research because of two related methodological problems. First, yearly national emissions experience large degrees of fluctuation, making it difficult to separate the signal from the noise. Second, much of the variation in yearly national emissions is outside of the direct control of the state. Nearly every economic transaction emits greenhouse gases, but even

[5] There are several examples of relevant indices which provide differing weighted sums of climate-focused policies. General environmentalism could be measured by the Environmental Performance Index (or its predecessor the Environmental Sustainability Index). Climate-environmentalism specifically is summarized by the Climate Change Laws of the World Index (Nachmany et al., 2017). Alternatively, international climate mitigation commitment levels are operationalized by Baettig, Brander and Imboden (2008).

highly capable states have only partial control over the economic activities within their own borders. Many of the shocks driving economic fluctuations will transcend national borders, either from a cause in one country having effects in others, or from causes in multiple countries being correlated.

Supply or demand shocks affect prices and therefore consumption and production. An example of a demand shock is the growth in Chinese commodity imports in the first two decades of the 21st century, which led to global booms in commodities markets, especially for exporters in Asia and Latin America. An example of a recent supply shock is the 2022 Russian invasion of Ukraine, which has contributed to dramatic increases in the prices of oil, wheat, and other goods worldwide and especially in Europe and the Middle East.

Technological shocks occur when technology development or adoption changes modes of production, thereby affecting the carbon intensity of GDP. An example of a climate-relevant technological shock is the development of hydraulic fracturing, or "fracking." The development of large-scale commercial fracking technology surprised many observers in government and industry alike, leading to a scramble of economic adjustment, including a shift away from coal and towards natural gas, made cheaper by the new method. This transition dramatically lowered the carbon intensity of the electricity mix in relevant markets, especially the United States and Canada (Yergin, 2012).

Thus, supply, demand, and technology shocks are changes to the economic or technological conditions of greenhouse gas emitting activities, exogenous to any particular state's climate policy. They are widespread due to global interconnectivity, but often vary in direction or magnitude by industry and region. They can also have varying effects by level of economic development. Shocks affect emissions because they affect production and consumption levels and methods. These in turn determine emissions, as illustrated by the partial Kaya decomposition below.[6]

[6]The full Kaya decomposition includes terms for population and energy as well as GDP and emissions: $Emit = Pop * \frac{GDP}{Pop} * \frac{Energy}{GDP} * \frac{Emit}{Energy}$

$$Emit^{\Delta} = GDP^{\Delta} + \left(\frac{Emit}{GDP}\right)^{\Delta}$$

In the next section I estimate these exogenous shocks empirically. After adjusting for these shocks, the remaining change in emissions can be thought of as the policy-induced emissions change for a given country-year.

4 Empirics

In this section I test the consistency of observed mitigation outcomes with the theoretical framework presented above. Mitigation costs and climate vulnerability, mediated by state size, should predict climate change mitigation levels once supply, demand, and technology shocks are adjusted for.

4.1 Design

As discussed in Section 3.4, I conceptualize exogenous supply and demand shocks as the effect of global GDP changes on domestic GDP, and exogenous technology shocks as the effect of global technology changes on domestic carbon intensity of GDP. I estimate each relationship for individual industries rather than the whole economy, meaning that I use the term "value" or "value-added" below as the industry-level version of GDP. Thus, I run two separate regressions (one for value-added and one for carbon intensity), predicting industry-country-year growth with industry-year growth (that is, global growth in that industry in that year, excluding the growth from the industry-country-year being predicted). I use a linear multi-level regression structure with industry-region-year levels. For each level, I allow varying intercepts and varying slope for the global growth variable. This means that, for example, I am estimating value growth in the Chilean mining and quarrying industry in 2005 with global value growth in the mining and quarrying industry in 2005, but with a flexible estimation strategy that allows a greater effect of global growth on the mining and quarrying industry in Latin America for that year, given the geographic concentration of the Chinese-demand-driven commodities boom. I also adjust for each country-year's GDP per capita, acknowledging that supply, demand, and technological shocks may have heterogeneous effects on economies at different stages of development.

I use these first stage regression results to generate predicted values for industry value growth and industry carbon intensity growth for each industry-country-year. I then estimate each country-year's total expected emissions growth as a weighted sum of these predicted values. Thus, yearly national shifts in industry value and carbon intensity are combined by industry economic share for each domestic economy. The resulting estimate for expected emissions change represents each country-year's expected growth in emissions given supply, demand, and technology shocks in the global economy.

I plug estimated emissions changes into a second stage linear regression with the theoretical variables of interest from Sections 3.1 and 3.2. Real emissions changes minus predicted emissions changes are predicted by mitigation costs, time-discounted vulnerability to climate change, state size, and the interaction of state size with mitigation costs and vulnerability. I also adjust for GDP per capita and polity score, given that economic development and political institutions may each effect emissions changes as well as cost and vulnerability measures. If these variables are highly predictive of the outcome, then domestic politics may explain much of the residual variation. Finally, I adjust for potential international strategic factors that may affect domestic emissions choices, including membership in OPEC and treaty obligations under the Kyoto Protocol. If these variables are significant, then that would indicate that other international strategic factors besides collective action are affecting state emissions. I also use a multi-level regression model for the second stage, allowing varying intercepts by level. I use states and years as levels. This provides much of the benefit of two-way fixed effects by ruling out confounders associated with particular countries or years, while using partial-pooling between levels in order to allow estimation of coefficients for covariates that sometimes have low variation within level, (such as fossil fuel reserves).

The complete empirical design is outlined below, in which the Δ superscript indicates growth rate, the i-series subscripts indicate states, the a-series subscripts indicate industries, the t-series subscripts indicate years, and $\sigma_{i,a,t-1}$ indicates industry a's share of i's national emissions in year $t-1$. The variable $Industry.Region.Year_{i,t}$ in the first stage regressions represents the random effect level for each unique industry, region, and year combination. I allow the regression intercept and the slope of the global change variable to vary by level in the first stage model. The variables $State_i$ and $Year_t$ in the second stage represent the random effect levels for each unique state and year. I allow the regression intercept to vary for each level in the second stage model.

Empirical Design:

1st Stage:

$$Value^{\Delta}_{i,a,t} = Value^{\Delta}_{a,t} + \left(\frac{GDP}{Pop}\right)_{i,t-1} + Industry.Region.Year_{i,t}$$

$$\left(\frac{Emit}{Value}\right)^{\Delta}_{i,a,t} = \left(\frac{Emit}{Value}\right)^{\Delta}_{a,t} + \left(\frac{GDP}{Pop}\right)_{i,t-1} + Industry.Region.Year_{i,t}$$

$$\widehat{Emit}^{\Delta}_{i,t} = \sigma_{i,a,t-1} * \left[\widehat{Value}^{\Delta}_{i,a,t} + \widehat{\left(\frac{Emit}{Value}\right)}^{\Delta}_{i,a,t}\right]$$

2nd Stage:

$$\begin{aligned} Emit^{\Delta}_{i,t} - \widehat{Emit}^{\Delta}_{i,t} = {} & Cost_{i,t-1} + Vulnerability_{i,t-1} + Size_{i,t-1} + \\ & Cost_{i,t-1} * Size_{i,t-1} + Vulnerability_{i,t-1} * Size_{i,t-1} + \\ & \left(\frac{GDP}{Pop}\right)_{i,t-1} + Polity_{i,t-1} + OPEC_{i,t} + Kyoto_{i,t} + \\ & State_i + Year_t \end{aligned}$$

This methodology bears some resemblance to the shift-share approach common in the literature on the effects of trade, immigration, or labor shocks (Barff and Iii, 1988). I am using global *shifts* weighted by local industry *shares* in order to account for variation in the dependent variable. However, the crucial distinction is that a shift-share instrumental variable is used to identify exogenous variation, while I am using a similar tool to cancel out the exogenous variation. In practice, this means that rather than estimating a coefficient for the fitted values in the second stage, I subtract them from the dependent variable. Another difference is that the first stage has two regressions with separate independent variables (global value growth and global carbon intensity growth). The fitted values from these two regressions are combined as well as weighted by share in order to get expected emissions. This difference allows me to estimate shifts in industry value independently of shifts in industry carbon intensity, which could allow more precision in cases where these two variables diverge. As in a shift-share design, bias could arise from endogeneity of the industry shares. Endogeneity is especially threatening due to the probable correlation between industry shares and the key explanatory variables, namely fossil fuel reserves and vulnerability (i.e. local geography). However, the level of bias is dependent on the degree to which correlated shares are driving the variation in estimates (Goldsmith-Pinkham, Sorkin and Swift, 2020), and should be evident in the correlation between the first stage's predicted values and the second stage's explanatory variables. In Section 4.3 below I demonstrate the lack of concerning patterns in this relationship.

There are numerous possible alternative strategies to estimating counterfactual pollution trajectories. Simple solutions include aggregating structured expert scoring of counterfactual scenarios (Helm and Sprinz, 2000; Miles et al., 2001) or using a status quo ante as a baseline (Young, 2001). A more common and sophisticated approach is formally modeling emissions, either by solving for actors' non-cooperative Nash Equilibria (Sprinz and Helm, 1999) or by simulation.

Integrated assessment models (IAMs) are complex formal models of emissions decisions that are theory-based but may be empirically tuned. These models are the most popular method of counterfactual emissions projection, but often rely on hundreds of assumptions and tuning parameters (Nordhaus, 2013*a*).

My approach is empirical, predicting expected emissions changes with real changes in corresponding industries, countries, and time periods. My model therefore offers simplicity and clarity. My model also errors conservatively, by potentially attributing widespread policy-induced mitigation to exogenous economic change, rather than the other way around. Another approach to empirically estimating counterfactual emissions changes is to create a synthetic control via matching on previous emissions pathways (Bayer and Aklin, 2020; Lépissier and Mildenberger, 2021) or on relevant covariate values. My approach, however, offers greater granularity and flexibility in estimation, through the use of multi-level modeling and the ability to disaggregate emissions changes into industries and between value growth and carbon intensity growth.

Crucially, while many of the counterfactual derivation strategies outlined above have been used to estimate non-cooperative counterfactuals (i.e. the Nash Equilibria of collective action games), this paper's counterfactual is a scenario without climate policy, in which each domestic economy bobs along the current of global economic and technological trends, with perturbations allowed for region or development level, etc.

4.2 Data

For industry-level economic and emissions data used in the first-stage regression to estimate a counterfactual for the second stage, I use private data gathered by EORA (Lenzen et al., 2012, 2013). This data is commonly used for calculations of cross border emissions flows, including in reports by the World Bank, the IMF, and various UN agencies. The dataset covers 184 countries across 27 years (1991-2016). EORA data uses the 26-industry disaggregation listed below.

I supplement this data with measures of population, national average temperatures, and percentages of national population less than five meters above sea level from the World Bank (World Bank, 2024). I take estimates of proven fossil fuel reserves from the Statistical Review of World Energy, published by the energy institute (Energy Institute, 2023). Finally, I use Polity 2 measure of political institutions from the Polity 5 dataset as a control variable in the second stage regression (Center for Systemic Peace, 2020).

Table 3: Industries

Agriculture
Fishing
Mining and Quarrying
Food and Beverages
Textiles and Wearing Apparel
Wood and Paper
Petroleum, Chemical and Non-Metallic Mineral Products
Metal Products
Electrical and Machinery
Transport Equipment
Other Manufacturing
Recycling
Electricity, Gas and Water
Construction
Maintenance and Repair
Wholesale Trade
Retail Trade
Hotels and Restraurants
Transport
Post and Telecommunications
Finacial Intermediation and Business Activities
Public Administration
Education, Health and Other Services
Private Households
Others
Re-export and Re-import

4.3 Estimating the Counterfactual

The first stage of the analysis is estimating the counterfactual BAU change in emissions for each state-year, or the emissions changes to be expected solely due to global supply, demand, and technological shocks. Tables 1 and 2 show the results of the first stage regressions, which I have estimated with a multi-level model, using levels for unique industry-region-years and allowing varying intercepts and varying slopes for the global growth variable. The log likelihoods of each fit are negative and of large magnitude, indicating a highly noisy fit, although such extreme log likelihoods are to be expected in any multi-level model with such a large N.

A tighter fit could likely be achieved through machine learning or another non-parametric estimation strategy. But over-fitting the data would prove problematic in the second stage analysis, for which the first stage residual is the dependent variable. Relatedly, these models cannot be compared to others by their fits, such as in a cross-validation exercise, because the optimal residual is unknown but not zero. This strengthens the case for using a parametric estimator, as I have. A parametric model's fit is theoretically intelligible even if not empirically testable.

Although the coefficient values in this stage are not substantively important given that the purpose is generation of predicted values rather than causal interpretation, it is reassuring that the global log change predictor in each regression is near 1 and statistically significant to the level of $p < 0.01$. According to these results, a difference of 1 in the log change of a global industry's value added corresponds with a difference of 0.718 in the log change of a national industry's value added. Similarly, a difference of 1 in the log change of a global industry's carbon intensity corresponds with a difference of 0.709 in the log change of a national industry's carbon intensity.

Table 4: First Stage: Value Growth

	Log Change in Value
Global Log Change in Value	0.718***
	(0.014)
Lagged GDP Per Capita	−0.323***
	(0.021)
Constant	5.467***
	(0.185)
Observations	64,604
Log Likelihood	−212,928.500
Akaike Inf. Crit.	425,873.000
Bayesian Inf. Crit.	425,945.700
Note:	*p<0.1; **p<0.05; ***p<0.01

Table 5: First Stage: Intensity Growth

	Log Change in Intensity
Global Log Change in Intensity	0.709***
	(0.017)
Lagged GDP Per Capita	−0.087***
	(0.027)
Constant	−0.650***
	(0.225)
Observations	65,133
Log Likelihood	−236,375.400
Akaike Inf. Crit.	472,766.800
Bayesian Inf. Crit.	472,839.500
Note:	*p<0.1; **p<0.05; ***p<0.01

As outlined in Section 4.1, I calculate expected changes in yearly national emissions with a weighted sum of the fitted values from the first stage regressions above. These expected emissions changes constitute the counterfactual BAU baseline to which I will compare observed yearly national emissions changes in Section 4.4. As discussed above, one potential source of bias exists if the shares used to weight predicted emissions are correlated with the main explanatory variables in the second stage. To address this concern, I plot the share-weighted estimates (predicted emissions changes) against vulnerability, logged fossil fuel reserves per capita, and size in Figure 6. These plots show no concerning pattern, as the distribution of predicted emissions changes is roughly similar at different values of each explanatory variable.

Next, I subtract these predicted values from real values to create the dependent variable. This difference is equivalent to an industry-weighted sum of the the residuals of the first stage. To test robustness of this counterfactual, I plot my dependent variable against a variety of possible confounders. Figure 7 demonstrates no concerning patterns in real minus predicted emissions when compared across years or the logged values of population, GDP, GDP per capita, emissions, or emissions per capita.

Next, I illustrate the usefulness of using this counterfactual comparison. I plot real and predicted emissions for two individual country cases below.

The UK's predicted yearly emissions changes closely track its real values. Moreover,

Figure 6: Predicted Emissions Changes Compared to Stage Two Explanatory Variables

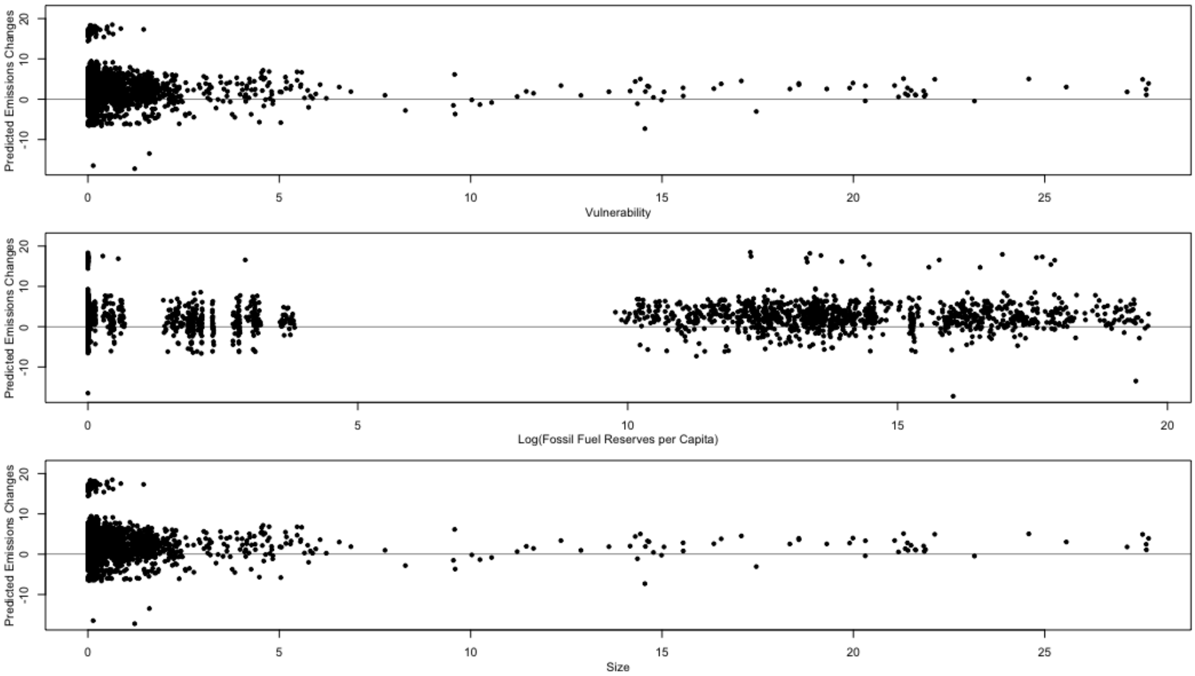


Figure 7: Real - Predicted Emissions Changes Compared to Potential Confounders

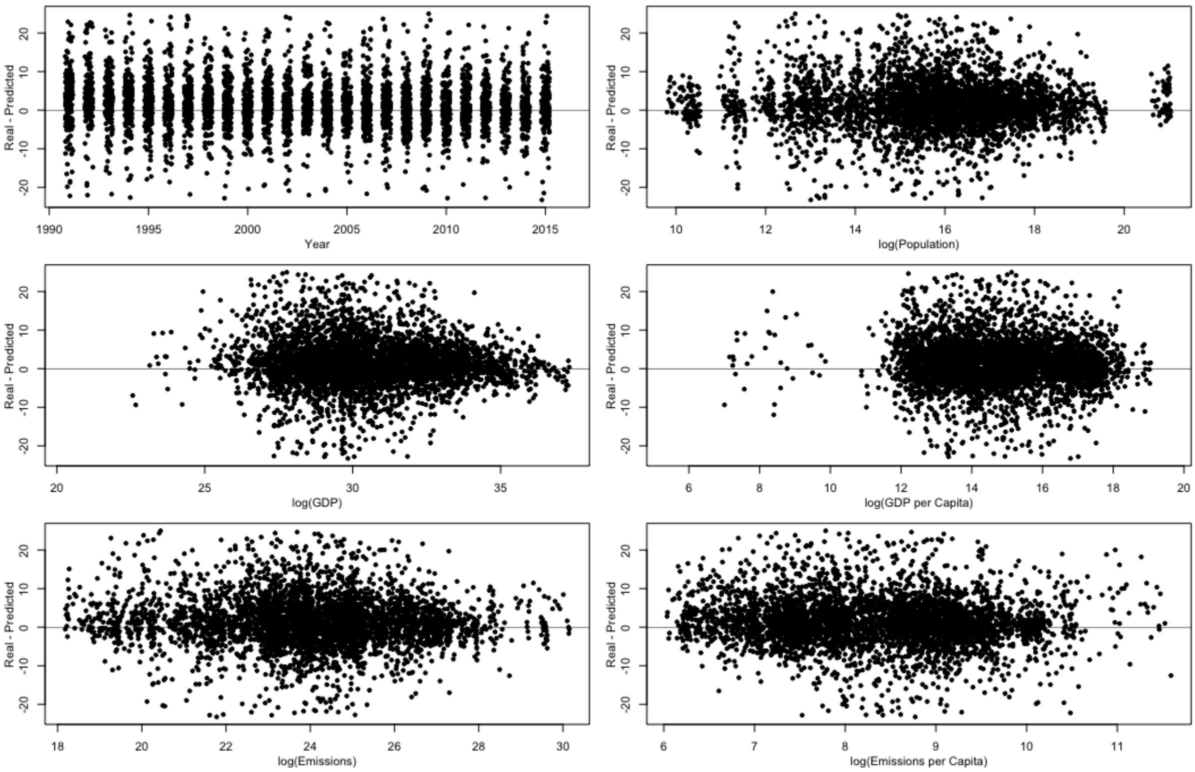
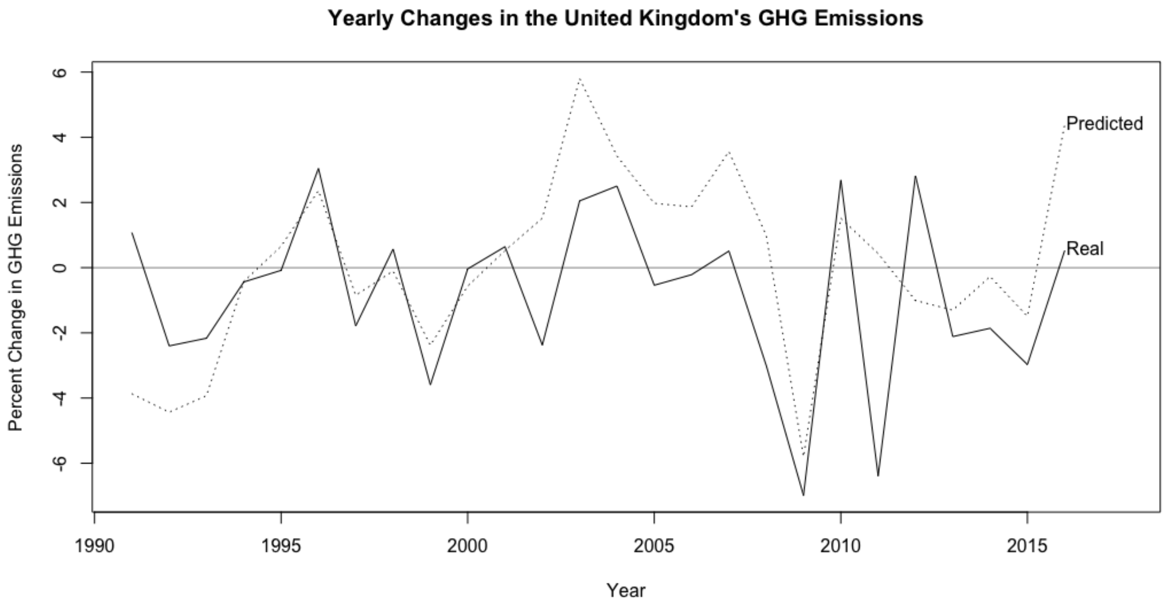


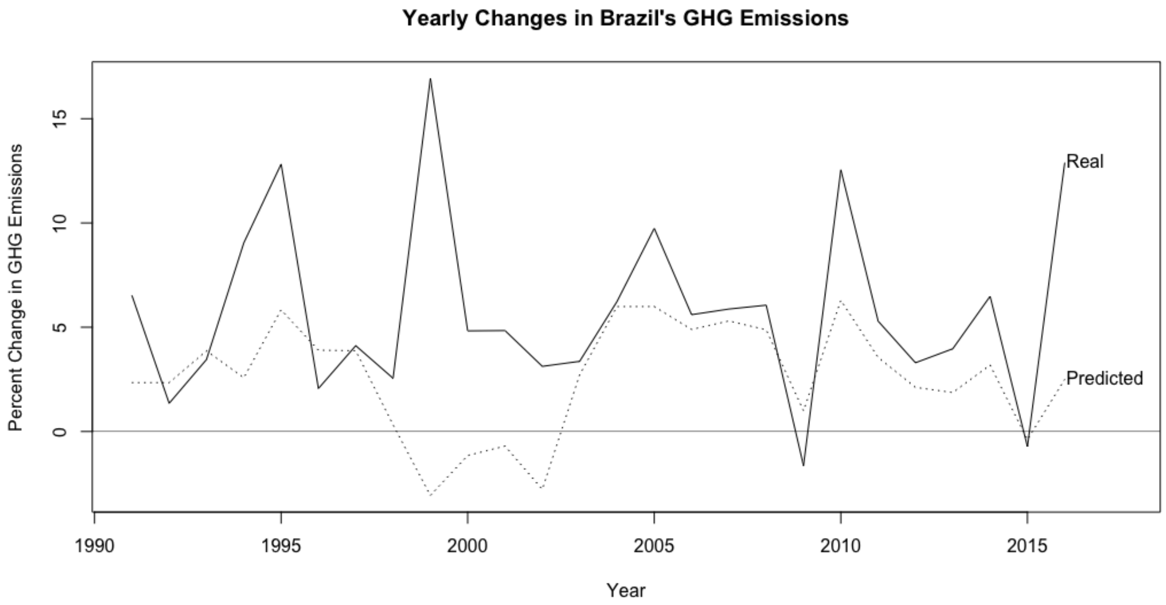
Figure 8:



the divergence of the predicted and real values makes sense given an understanding of UK policy and the international environment. The beginning of a divergence is evident after 2001, following the 2000 passage of major emissions legislation called the Climate Change Programme. The effect of this policy is evident from the slump in real yearly emissions changes below their predicted values. Later, the UK's predicted and real values converge again during the Great Recession, during which decreases in production and consumption caused emissions to plummet worldwide. During this period, the UK's green policies were no longer the binding constraint on emissions.

Brazil's predicted values also closely track its real values for much of the relevant period. But a distinct and large gap emerges between them for much of the 1994 through 2003 period. During this time, Brazilian emissions were rising much faster than predicted. This largely corresponds to the presidency of Fernando Henrique Cardoso, during which rapid economic growth was fueled by heightened natural resource extraction and other heavily polluting activities. Amazon deforestation, for example, also experienced a local maximum during this period. The end of this period corresponds with the 2003 beginning of Luiz Inácio Lula da Silva's presidency, which was noted for significantly heightened environmental protection.

Figure 9:



4.4 Main Results

Using real minus predicted emissions as a dependent variable, the main analysis confirms this paper's hypothesis, as shown in the second stage regression table below. The coefficient for GDP per capita is negative but not statistically significant, although its interpretation is ambiguous given income's relationships to multiple variables of interest discussed above. The coefficient for Polity score is positive and not statistically significant, contrasting previous claims in the literature that more democratic states will provide more environmental public goods (Bättig and Bernauer, 2009).

The important coefficients for validating the theory outlined above are those of the interaction terms, each of which is in the expected direction and statistically significant. The interaction of state size and climate vulnerability is negative, meaning that larger and more vulnerable states will mitigate more. A one unit difference in the vulnerability index corresponds to about 1.7% less yearly emissions for a country that represents 1% of global emissions but about 4.3% less yearly emissions for a country that comprises 10% of global emissions. Thus, states that are more vulnerable to climate change seem to be mitigating more, but especially so if they can reduce the free-rider problem through size.

The interaction of state size and fossil fuel rents is positive and statistically significant, meaning that larger and more fossil fuel dependent states will mitigate less. An approximately one hundred percent difference in fossil fuels reserves per capita corresponds to about 0.18% more yearly emissions for a state that emits 10% of global emissions but only about 0.01% more yearly emissions for a state that emits 1% of the global total. In other words, the cost of mitigating is not the binding constraint for small states, who will not find it rational to mitigate even at low cost.

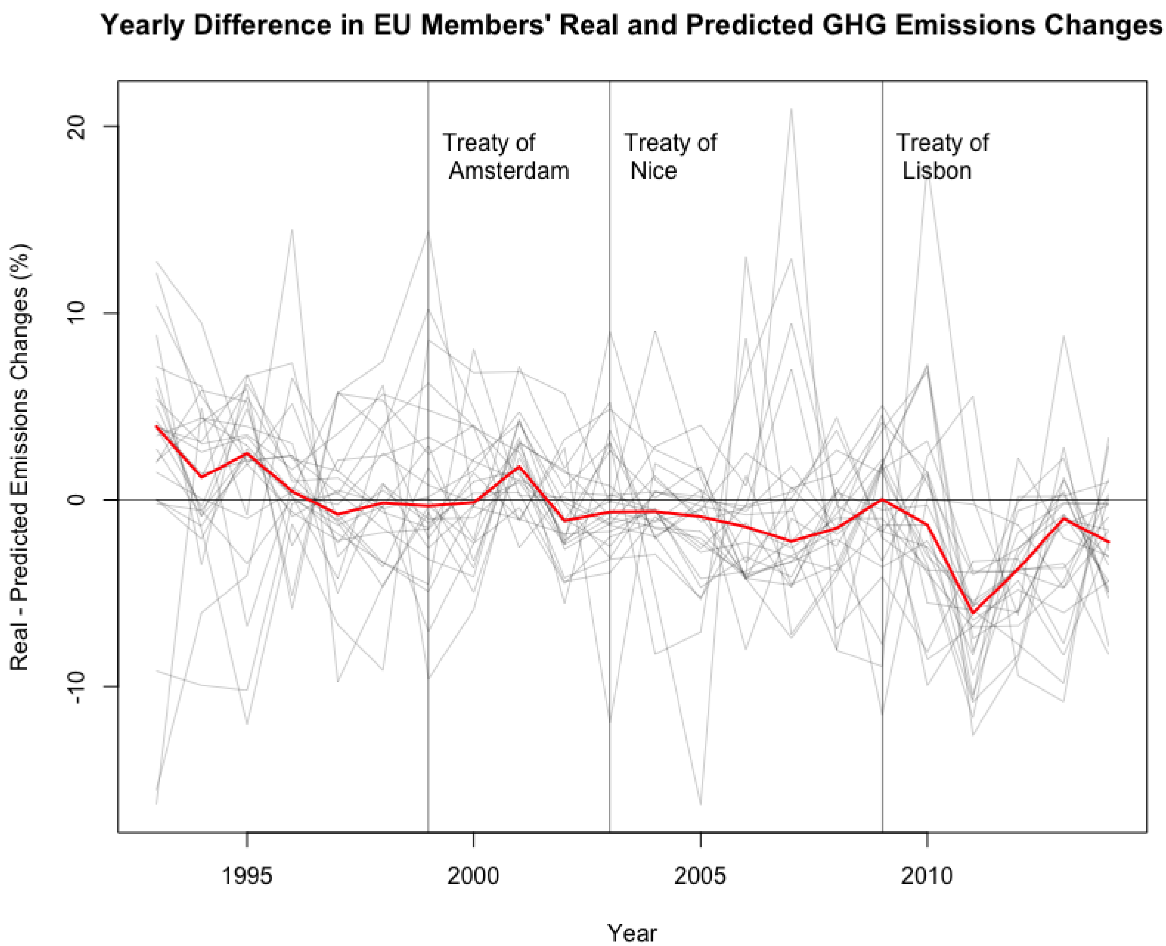
Meanwhile, international strategic effects beyond the collective action problem are only weakly supported by the analysis. The coefficient for OPEC is positive and statistically significant, indicating that OPEC membership may induce states to mitigate less. The coefficient for binding treaty obligations under the Kyoto Protocol, on the other hand, is negative but statistically insignificant. Both the Kyoto and OPEC coefficients are also extremely weak tests of the effects of those international organizations because membership in each is voluntary. This means that these variables suffer from selection bias in a way that state size does not. This fact makes it especially noteworthy that there is no effect of Kyoto commitments statistically distinguishable from zero.

Table 6: Second Stage

	Real - Predicted Emissions Changes (%)
Log GDP per Capita	−0.116
	(0.086)
Polity	0.005
	(0.021)
Size	0.003
	(0.088)
Vulnerability	−1.405***
	(0.320)
Log Fossil Fuel Reserves per Capita	−0.007
	(0.025)
OPEC	1.048**
	(0.500)
Kyoto	−0.332
	(0.557)
Size * Vulnerability	−0.294**
	(0.147)
Size * Log Fossil Fuel Reserves per Capita	0.019**
	(0.009)
Constant	3.318***
	(1.215)
Observations	2,887
Log Likelihood	−8,487.512
Akaike Inf. Crit.	17,001.020
Bayesian Inf. Crit.	17,078.610
Note:	*p<0.1; **p<0.05; ***p<0.01

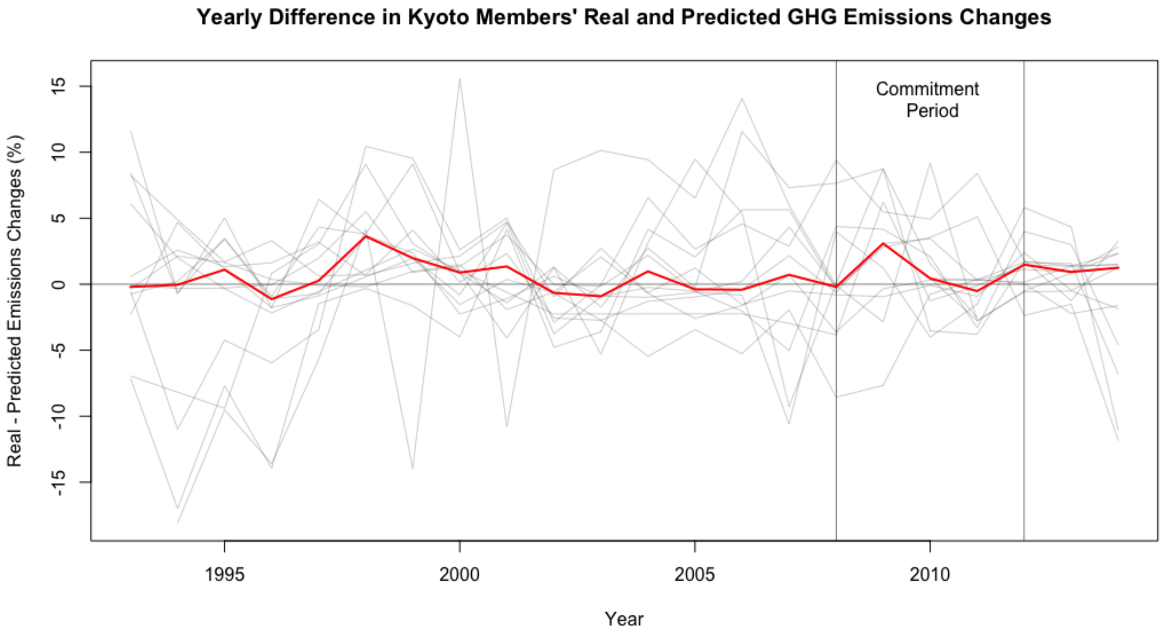
In order to illustrate the logic of the effects above, I plot real minus predicted emissions changes for each member of the EU across time. I also highlight the median member's outcome in red. Given the ongoing centralization of EU decision-making, especially in the Treaties of Amsterdam (1999), Nice (2003), and Lisbon (2009), EU members should be acting less like individual small actors and more like one large actor over time. In other words, the collective action problem for EU members should be declining over time. Despite the EU's relatively low vulnerability to the effects of climate change, its scarcity of fossil fuel reserves and growing centralization should mean increasing mitigation. This is evident in the plot below, as median EU mitigation has grown after successive rounds of political integration.

Figure 10:



Similarly, I plot real minus predicted emissions changes for each member of the Kyoto Protocol with a binding treaty commitment in the first commitment period (2008-2012), and highlight the median member's outcome in red. Despite the fact that states select themselves into participating in the Kyoto Protocol, thereby indicating that they at least have green preferences, no evident mitigation is visible from Kyoto members. This illustrative example demonstrates the weakness of international commitment devices relative to other strategic considerations, such as collective action.

Figure 11:



5 Implications

In the analysis above I have demonstrated consistency between observed state-level climate change mitigation outcomes and basic state environmental and economic interests interacted with the collective action constraint. Observed behavior in international relations is roughly consistent with states being as-if rationalist and as-if unitary actors in a manner attenuated by the free-rider problem. More specifically, states' climate change mitigation actions are correlated with their climate costs and benefits, and the correlation is stronger for larger states.

5.1 Theoretical Implications

The validation of state-level environmental and economic interests buttresses the usefulness of analyzing climate politics from an international relations perspective. Further, the validation of the free-rider phenomenon demonstrates the power of the collective action framework. But there are four major ways in which the theoretical framework from Section 2.1 is unsatisfying and could be expanded upon in future work.

First, the limitations of assuming rational unitary actors are obvious, not only due to the importance of state institutions in determining state preferences and of state capacity in determining outcomes, but because the nature of climate change exacerbates many well-studied sources of bias at both the individual and organizational level. Climate change mitigation's benefits are delayed over a long time horizon, are subject to high uncertainty and limited information, and often seem to be contested more through ideological movements than by rational cost-benefit calculation. States are clearly not rational or unitary, but modeling them as as-if-rational and as-if-unitary proves useful for a combination of descriptive power and parsimony (Friedman, 1953). Future work could weaken this assumption by incorporating state capacity or institutions variables or by modeling the individual and organizational pathologies unique to climate change.

Second, this paper focuses on mitigation over adaptation. These two actions are likely substitutes, but only mitigation is a collective good. This problem was partially addressed by adjusting for GDP per capita in the main analysis (i.e. comparing the mitigation outcomes for states that have equal abilities to adapt to climate change). But future work could directly incorporate adaptation as an alternative to mitigation in a state's modeled choices.

Third, while this paper acknowledges that states face a collective action problem, states are simultaneously confronting a bargaining problem. In classic collective action games, actors may vary by size and by marginal cost of goods provision (i.e. of mitigation), but in the climate change dilemma, actors also vary in their vulnerability, as discussed in Section 3.1. This means that climate change is not an ideal-type collective action problem, but rather exists somewhere on a spectrum between collective action and upstream/downstream problems (Mitchell, 2010). Equivalently, greenhouse gas emissions are not a perfectly symmetric negative externality, but are not strongly asymmetric either (Mitchell, 2010) In so far as climate change is an upstream/downstream issue, then it is a global bargaining problem between the polluters and the vulnerable, rather than a collective action problem (Schelling, 1992). While bargaining is left out of the explicit model, future work on side payments or coercion could enrich its predictions.

Fourth, this framework assumes non-interference/no spillovers between states. In other words, state A's interests are not affected by B's costs and benefits, and state C's outcomes are not modified by D's capabilities, etc. Moreover, the exogenous shocks are exogenous to the behavior and capabilities of all states. Clearly, states are not independent of one another, but this simplifying assumption is necessary for a tractable first-cut analysis and can be loosened in future research exploring the nature of system effects in interstate climate politics (Jervis, 1997).

5.2 Methodological and Practical Implications

Testing alternative formulations of this paper's variable choices or model design could improve robustness. This may include using alternative proxies for state cost or vulnerability. It could also include the use of alternative regression models or alternative specifications, such as allowing the effect of size to be non-linear.

This paper develops a novel empirical method for estimating a counterfactual emissions trajectory. An empirical approach yields a conservative estimate that forgoes the large number of assumed parameters necessary for any theoretically-derived alternative, such as an Integrated Assessment Model. Future work can benefit from this new method by applying it to program evaluation. The true effects of purported green policies can be determined through comparisons to the BAU estimate. Such a counterfactual can be used to evaluate climate treaty design and efficacy, for example. A comparable BAU counterfactual could also be estimated for other environmental goods, such as the ozone or acid rain dilemmas.

5.3 Avenues for Future Research

This paper provides two avenues for future research. First, theoretical or methodological extensions rectifying the current limitations discussed in Sections 5.1 or 5.2 would add greatly to the model's robustness.

Second, this model can be useful as a first cut rationalist baseline prediction to which other work can be compared. The contribution of this paper in predicting state-level outcomes is all the more important for cases where the model's predictions do not hold. The significance of the control variables and the generally large residuals in the regressions above indicate idiosyncrasies among and within states that complicate this paper's simple story of as-if rationalist and as-if unitary states. But defining said interests and constraints provides a baseline expectation against which more complicated theories can be compared. Researchers can bolster an argument that a government is not abating due to industrial state-capture if the model in this paper would strongly predict the state's interest in greater carbon abatement, for example. Such baseline predictions are crucial for the methodologically and theoretically pluralist approach to the study of climate politics that is necessary for such a complex and important phenomenon. Promising approaches to the study of climate politics that could benefit from a more direct baseline comparison against a rationalist interstate collective action model include international approaches emphasizing greater strategic interaction such as catalytic cooperation (Hale, 2020) or signaling games, domestic distributive politics approaches emphasizing firm-level competition (Kennard, 2020) or interest group cleavages Colgan, Green and Hale (2021), ideological politics approaches, psychological approaches, and others.

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